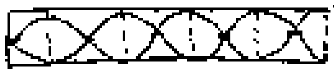
Ch. 18

Answer to Questions ①

3. (a) 2λ (b) 1.5λ
(c) fully constructive, fully destructive

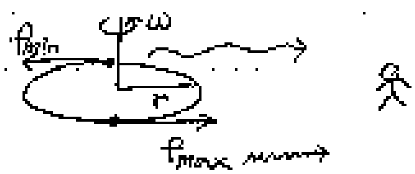
8. (a) one. 
(b) $(2+\frac{1}{2})\lambda$ in the pipe.

For pipe w/ one open end, $n\lambda = 4L$ $(n=1,3,5,\cdots)$
9λ's in $4L$. $\therefore n = 9$

11. For pipe w/ two open ends : $f = \frac{nv}{2L}$ $(n=1,2,3,\cdots)$
For pipe w/ one open end : $f = \frac{nv}{4L}$ $(n=1,3,5,\cdots)$

Pipe A has length of $2L$ w/ two open ends
$\Rightarrow f_A = \frac{nv}{4L}$ $(n=1,2,3,\cdots)$
$f_B = \frac{nv}{4L}$ $(n=1,3,5,\cdots)$
$\therefore$ all odd harmonics have same freq. for A & B.

14. (a) $3 > 1 = 2$
(b) $1 > 2 = 3$
(c) $3 > 2 > 1$ $(\because v = \omega r)$



· The greater the angular velocity ω, the faster the oscillation of f between f_{max} and f_{min}. $(\Rightarrow \omega_2 = \omega_3)$

· 1 & 2 have the same linear speed v because their amplitudes in the figure are the same.
18-30

(2)

Exercise & Problems

3E. In the concert, $t_1 = \frac{300\,m}{343\,m/s} = 0.87\,s$

Through the satellite, $t_2 = \frac{5000\,km}{3\times10^5\,km/s} = 0.02\,s$

$\Delta t = t_1 - t_2 = 0.87\,s - 0.02\,s = 0.85\,s$

10P. d : distance from the location of the earthquake to the seismograph.

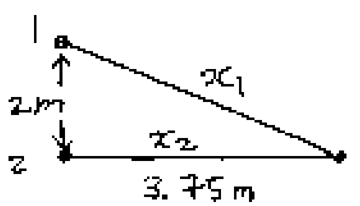
$t_p = \frac{d}{v_p}$, $t_s = \frac{d}{v_s}$

$\Delta t = \frac{d}{v_s} - \frac{d}{v_p} = \frac{d(v_p - v_s)}{v_s v_p}$

$d = \frac{v_s v_p \Delta t}{v_p - v_s} = 1900\,km$

12E. $\lambda = \frac{v}{f}$ ..... $17\,m \sim 1.7\times10^{-2}\,m$

21P.



$x_1 = \sqrt{2^2 + 3.75^2} = 4.25\,m$

$x_2 = 3.75\,m$

$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda} \Rightarrow \Delta\phi = \frac{2\pi}{\lambda}(x_1 - x_2)$

For minimum signals,

$\Delta\phi = (2m+1)\pi \quad (m = 0, 1, 2, \cdots)$

$\therefore \frac{2\pi}{\lambda}(x_1 - x_2) = (2m+1)\pi$

$\frac{2\pi f}{v}(x_1 - x_2) = (2m+1)\pi$

$\therefore f = \frac{(2m+1)v}{2(x_1 - x_2)} = (2m+1)\frac{343\,m/s}{2(4.25-3.75)m} = (2m+1)\,343\,Hz$

In the audible range, the frequencies which satisfy this equation correspond to $m = 0, 1, 2, \cdots, m_{max}$

where,

$$m_{max} \leq \frac{20{,}000\,Hz - 343\,Hz}{2 \cdot 343\,Hz} = 28.1$$

$\therefore\ m_{max} = 28.$

(b) maxmum signal $\Rightarrow \Delta\phi = 2m\pi \quad (m = 0, 1, 2, \cdots)$

we get

$$f = m \cdot 686\,Hz$$

where $m = 0, 1, 2, \cdots, m'_{max}$

$$m'_{max} \leq \frac{20{,}000\,Hz}{686\,Hz} = 29.1$$

$\therefore\ m'_{max} = 29.$

42P. (a) $I = \frac{P}{4\pi r^2} = \frac{30\,W}{4\pi \cdot (200)^2} = 5.97 \times 10^{-5}\,W/m^2$

(b) $P' = IA = (6.0 \times 10^{-5}\,W/m^2) \cdot (0.75 \times 10^{-4}\,m^2)$

$= 4.48 \times 10^{-9}\,W$

46E. (a) $\lambda = \frac{v}{f} = \frac{343\,m/s}{1000\,Hz} = 0.343\,m$

(b) $\Delta P_m = v\rho\omega s_m = 2\pi v\rho f s_m \quad (\because \omega = 2\pi f)$

$$\therefore s_m = \frac{\Delta P_m}{2\pi v\rho f} = \frac{10\,Pa}{2\pi \cdot (343\,m/s) \cdot (1.21\,kg/m^3)\,(1000\,Hz)} = 3.83 \times 10^{-6}\,m$$

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

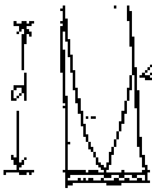
$$\frac{\partial s}{\partial t} = \omega s_m \sin(kx - \omega t)$$

$$v_{max} = \left(\frac{\partial s}{\partial t}\right)_{max} = \omega s_m = 2\pi f s_m = 2.41 \times 10^{-2}\,m/s$$

(d) fundamental harmonic $\Rightarrow n = 1$.

For a pipe w/ two open ends

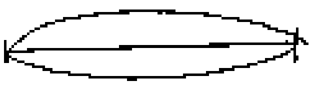
$$f = \frac{nv}{2L} \Rightarrow L = \frac{nv}{2f} = \frac{1 \cdot \lambda}{2} = 0.172\,m$$

56P. 

$\leftarrow \frac{1}{4}\lambda = d$ $\qquad \therefore \lambda = 4d$

$$v = \lambda f \Rightarrow f = \frac{v}{\lambda} = \frac{v}{4d} = \frac{1}{4d}\sqrt{\frac{B}{\rho}}$$

$$\therefore d = \frac{1}{4f}\sqrt{\frac{B}{\rho}} = \frac{1}{4(7\,Hz)}\sqrt{\frac{1.33\times10^5\,Pa}{1.10\,kg/m^3}} \doteq 12.4\,m$$

63P.  $\Rightarrow \lambda = 2L$

$$f = \frac{v}{\lambda} = \frac{1}{2L}\sqrt{\frac{\tau}{\mu}}$$

τ : tension
μ : linear mass density of the wire

Increase τ to $\tau + \Delta\tau$ for the second wire.
Then $f_1 = \frac{1}{2L}\sqrt{\frac{\tau}{\mu}}$, $f_2 = \frac{1}{2L}\sqrt{\frac{\tau+\Delta\tau}{\mu}}$

$$\therefore \frac{f_2}{f_1} = \sqrt{\frac{\tau+\Delta\tau}{\tau}} = \sqrt{1+\frac{\Delta\tau}{\tau}}$$

$$\Rightarrow \frac{\Delta\tau}{\tau} = \left(\frac{f_2}{f_1}\right)^2 - 1$$

We want $f_1 = 600\,Hz$ & $f_2 = 606\,Hz$.

$$\therefore \frac{\Delta\tau}{\tau} = \left(\frac{606}{600}\right)^2 - 1 = 0.02$$

72E. $\theta = \sin^{-1}\left(\frac{v}{v_s}\right) = \sin^{-1}\left(\frac{1125\,ft/s}{2200\,ft/s}\right) \approx 31^\circ$

77P. (a) Imagine having a sound detector installed on the target. The frequency f_d that it registers would be $f_d = f\,\frac{u+v}{v}$, since the detector is moving toward the source at speed u.

Now, as the target reflects a wave with this frequency, it also acts as a moving source, approaching the receiver at speed u.

Thus,
$$f_r = f_d\,\frac{v}{v-u}$$

Combining the above two eqn's yields
$$f_r = f_s\left(\frac{v+u}{v-u}\right)$$

(b) $u \ll v$

$$f_r = f_s\left(\frac{1+u/v}{1-u/v}\right) \qquad \left(\because \frac{1}{1-x} = 1+x+x^2+\cdots\right)$$

$$\simeq f_s\left(1+\frac{u}{v}\right)\cdot\left(1+\frac{u}{v}\right) \leftarrow \text{discard higher order terms}$$

$$= f_s\left(1+\frac{2u}{v}+\cancel{\frac{u^2}{v^2}}\right)$$

discard

$$\therefore \frac{f_r - f_s}{f_s} = \frac{2u}{v}$$

90E. (a) The speed of the galaxy is given by eqn. 18-57.

$$u = \frac{c\Delta\lambda}{\lambda} = (3.00\times10^5\ \text{km/s})\cdot\left(\frac{525\,\text{nm}-513\,\text{nm}}{513\,\text{nm}}\right)$$
$$= 7\times10^3\ \text{km/s}$$

(b) Since the light from the galaxy is red-shifted, the galaxy must be receding from us.