Acoustics - Chapter 3

(2) $f = 300\ Hz$ In a steel bar. $\rho_{steel} = 7700\ kg/m^3$

<u>Find wavelength</u> $E_{steel} = 195\ GPa$

$c_{steel} = 5050\ m/s$

$\lambda \cdot f = c$

$$\lambda = \frac{c}{f} = \frac{5050\ m/s}{300\ Hz} = \boxed{16.8\ m}$$

$$k = \frac{2\pi}{\lambda} = \boxed{0.374\ rad/m}$$

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(3) $f = 30\ Hz$

$T = 20°C$

$= 293.2K$

$$c = \sqrt{\gamma R T}$$

$$c = \sqrt{(1.4)\left(287\ \frac{Nm}{kgK}\right)(293.2K)}$$

$$c = 343\ m/s$$

<u>Find wavelength</u>

$$\lambda = \frac{c}{f} = \frac{343\ m/s}{30\ Hz} = \boxed{11.4\ m}$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{11.4\ m} = \boxed{0.55\ rad/m}$$

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(4) $f_1 = 135.3\ Hz$

$f_2 = 136.0\ Hz$

<u>Find The beat frequency.</u>

$$f_b = f_2 - f_1 = 136.0 - 135.3$$

$$f_b = \boxed{0.7\ Hz}$$

<u>Time Period of beats</u>

$$T_b = \frac{1}{f_b} = \frac{1}{0.7\ Hz} = \boxed{1.4\ s}$$

(6) $f = 400\text{ Hz}$ Where would quieter locations exist?

If a wall is located near the machine, a standing wave will exist at the wall. Nodes will be located at

$$X_n = \frac{(2n-1)\pi}{2k} \qquad n = 1, 2, 3, 4, \ldots$$

since $k = \frac{2\pi}{\lambda}$, then

$$X_n = \frac{(2n-1)\pi}{2(2\pi/\lambda)} = \frac{(2n-1)\lambda}{4}$$

for $f = 400\text{ Hz}$, $\lambda = \frac{c}{f} = \frac{343\text{ m/s}}{400\text{ Hz}} = 0.858\text{ m}$

$n=1 \quad X_1 = \frac{(2\cdot 1 - 1)(0.858\text{ m})}{4} = \boxed{0.215\text{ m}}$

$n=2 \quad X_2 = \frac{(2\cdot 2 - 1)(0.858\text{ m})}{4} = \boxed{0.644\text{ m}}$

$n=3 \quad X_3 = \frac{(2\cdot 3 - 1)(0.858\text{ m})}{4} = \boxed{1.073\text{ m}}$

$\vdots$

Loud spots will be half way between these nodes

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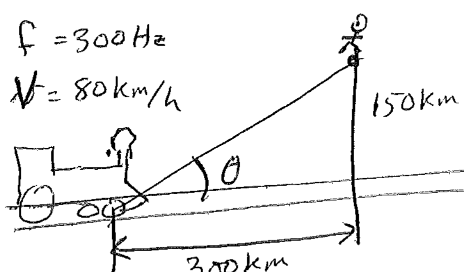
(9)



Actually at these distances, you probably won't hear anything.

What frequency is perceived by the observer?

$\cancel{v = V\cos\theta}$

$$V = 80\,\frac{\text{km}}{\text{h}}\left(\frac{1000\text{ m}}{1\text{ km}}\right)\left(\frac{1\text{ hr}}{3600}\right) = 22.2\text{ m/s}$$

$$\tan\theta = \frac{150\text{ km}}{300\text{ km}} = \frac{1}{2} \Rightarrow \theta = 26.6^\circ$$

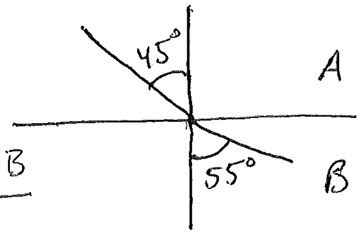
$$v = V\cos\theta = (22.2\text{ m/s})\cos(26.6^\circ) = 19.8\text{ m/s}$$

Doppler Effect

$$f_d = \frac{f}{1 - v/c} = \frac{300\text{ Hz}}{1 - \left(\frac{19.8\text{ m/s}}{343\text{ m/s}}\right)} = \boxed{318\text{ Hz}}$$

(11)

$v_A = 450\,m/s$



Find velocity in medium B

$$\frac{\sin\theta_A}{c_A} = \frac{\sin\theta_B}{c_B}$$

$$c_B = \frac{\sin\theta_B\, c_A}{\sin\theta_A} = \frac{\sin(55^\circ)(450\,m/s)}{\sin(45^\circ)} = \boxed{521\,m/s}$$

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(12) $p(x,t) = 35 \sin 2.5\,(x - 344t)$ $f = 150\,Hz$

Compare to

$p(x,t) = P_m \cos k\,(x - ct)$ or in this case ~~could also~~ $p(x,t) = P_m \sin k\,(x - ct)$

a) Find wave number. By Inspection $\boxed{k = 2.5\,rad/m}$

b) Find wavelength. $k = \frac{2\pi}{\lambda}$ Therefore $\lambda = \frac{2\pi}{k} = \frac{2\pi}{2.5\,rad/m} = \boxed{2.51\,m}$

c) Find P_{rms}. $P_{rms} = \frac{P_m}{\sqrt{2}} = \frac{35}{\sqrt{2}} = \boxed{24.7}$ No units given, probably pascals

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(13) Convert P_{rms} to dB $L_p = 20 \log\left(\frac{P_{rms}}{P_0}\right)$ $P_0 = 20\times10^{-6}\,P_a$

a) $P_{rms} = 20\,\mu Pa$ $L_p = 20 \log\left(\frac{20\times10^{-6}\,Pa}{20\times10^{-6}\,Pa}\right) = \boxed{0\,dB}$

b) $P_{rms} = 150\,\mu Pa$ $L_p = 20 \log\left(\frac{150\times10^{-6}\,Pa}{20\times10^{-6}\,Pa}\right) = \boxed{17.5\,dB}$

c) $P_{rms} = 1\,kPa$ $L_p = 20 \log\left(\frac{1\times10^{3}\,Pa}{20\times10^{-6}\,Pa}\right) = \boxed{154\,dB}$

d) $P_{rms} = 50\,kPa$ $L_p = 20 \log\left(\frac{50\times10^{3}\,Pa}{20\times10^{-6}\,Pa}\right) = \boxed{188\,dB}$

(14) Convert dB to P_{rms} $\quad P_{rms} = P_o \, 10^{\frac{L_p}{20}}$ $\quad P_o = 20 \times 10^{-6}\, Pa$

a) $L_p = 20\,dB$ $\quad P_{rms} = (20\times10^{-6})\,10^{20/20} = 20\times10^{-5}\,Pa = \boxed{200\,\mu Pa}$

b) $L_p = 60\,dB$ $\quad P_{rms} = (20\times10^{-6})\,10^{60/20} = 20\times10^{-3}\,Pa = \boxed{20\,m\,Pa}$

c) $L_p = 90\,dB$ $\quad P_{rms} = (20\times10^{-6})\,10^{90/20} = \boxed{0.632\,Pa}$

d) $L_p = 130\,dB$ $\quad P_{rms} = (20\times10^{-6})\,10^{130/20} = \boxed{63.2\,Pa}$

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(15) $L_{p_1} = 95\,dB$ $\quad$ Find the combined L_{pt}

$L_{p_2} = 98\,dB$

$$L_{pt} = 10\log\left(\sum_i 10^{L_{pi}/10}\right) = 10\log\left(10^{L_{p1}/10} + 10^{L_{p2}/10}\right)$$

$$= 10\log\left(10^{95/10} + 10^{98/10}\right) = \boxed{99.8\,dB}$$

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(16) $L_{p_t} = 115\,dB$ (3 machines) $\quad$ Find the noise output of these two machines.

$L_{p_t} = 110\,dB$ (2 identical machines)

Since the two machines are identical, then

$$L_{pt} = 10\log\left(10^{L_p/10} + 10^{L_p/10}\right)$$

$$\frac{L_{pt}}{10} = \log\left(10^{L_p/10} \times 2\right) \Rightarrow 2\times10^{L_p/10} = 10^{L_{pt}/10}$$

$$10^{L_p/10} = \frac{10^{L_{pt}/10}}{2}$$

$$L_p/10 = \log\left(\frac{10^{L_{pt}/10}}{2}\right)$$

$$L_p = 10\log\left(\tfrac{1}{2}\times10^{L_{pt}/10}\right) = 10\log\left(\tfrac{1}{2}\times10^{110/10}\right)$$

$$\boxed{L_p = 107\,dB}$$

you would expect the noise to be 3 dB lower and it is.

Now the third machine

$$L_{pt} = 10\log\left(10^{L_p/10} + 10^{L_p/10} + 10^{L_{p3}/10}\right)$$

$$10^{L_{pt}/10} = 10^{L_p/10} + 10^{L_p/10} + 10^{L_{p3}/10} \Rightarrow 10^{L_{p3}/10} = 10^{L_{pt}/10} - 10^{L_p/10} - 10^{L_p/10}$$

$$L_{p3} = 10\log\left(10^{L_{pt}/10} - 10^{L_p/10} - 10^{L_p/10}\right) = 10\log\left(10^{115/10} - 10^{107/10} - 10^{107/10}\right) = \boxed{113\,dB}$$

(17) Find L_{PTA}, L_{PTB}, + L_{PTC}

f	SPL	A	L_{PA}	B	L_{PB}	C	L_{PC}
31.5	72	-39.4	32.6	-17.1	54.9	-3.0	69
63	76	-26.2	49.8	-9.3	66.7	-0.8	75.2
125	77	-16.1	60.9	-4.2	72.8	-0.2	76.8
250	72	-8.6	63.4	-1.3	70.7	0	72
500	69	-3.2	65.8	-0.3	68.7	0	69
1000	84	0	84	0	84	0	84
2000	92	+1.2	93.2	-0.1	91.9	-0.2	91.8
4000	83	+1.0	84.0	-0.7	82.3	-0.8	82.2
8000	80	-1.1	78.9	-2.9	77.1	-3.0	77
16,000	78	-6.6	71.4	-8.4	69.6	-8.5	69.5

$$L_{PTA} = 10\log\left(\sum_i 10^{\frac{L_{PAi}}{10}}\right) = \boxed{94.3\ dB(A)}$$

$$L_{PTB} = 10\log\left(\sum_i 10^{\frac{L_{PBi}}{10}}\right) = \boxed{93.2\ dB\ (B)}$$

$$L_{PTC} = 10\log\left(\sum_i 10^{\frac{L_{PCi}}{10}}\right) = \boxed{93.2\ dB\ (C)}$$

(18) Find L_{eq}

t	SPL
15	73.4
22	79.4
20	88.9
12	91.9

$$L_{eq} = 10\log\left(\frac{1}{N}\sum_i 10^{L_i/10}\right)$$

$$L_{eq} = 10\log\left(\frac{1}{(15+22+20+12)}\left[15\cdot 10^{73.4/10} + 22\cdot 10^{79.4/10} + 20\cdot 10^{88.9/10} + 12\cdot 10^{91.9/10}\right]\right)$$

$$= 10\log\left(\frac{1}{69}\left[15\cdot 10^{7.34} + 22\cdot 10^{7.94} + 20\cdot 10^{8.89} + 12\cdot 10^{9.19}\right]\right)$$

$$L_{eq} = 10\log\left(\frac{1}{69}\left(3.636\times 10^{10}\right)\right) = \boxed{87.2\ dB}$$

(19) Find L_{eq} + L_{dn}

t	SPL
7AM - Noon	87.5
Noon - 4PM	84.6
4PM - 9PM	78.5
9PM - 3AM	76.5
3AM - 7AM	77.4

$$L_{eq} = 10\log\left(\frac{1}{24}\left[5\cdot 10^{87.5/10} + 4\cdot 10^{84.6/10} + 5\cdot 10^{78.5/10} + 6\cdot 10^{76.5/10} + 4\cdot 10^{77.4/10}\right]\right)$$

$$= 10\log\left(\frac{1}{24}\left(4.807\times 10^{9}\right)\right) = \boxed{83.0\ dB(A)}$$

$$L_{dn} = 10\log\left(\frac{1}{24}\left[5\cdot 10^{87.5/10} + 4\cdot 10^{84.6/10} + 5\cdot 10^{78.5/10} + 1\cdot 10^{76.5/10} + 5\cdot 10^{(76.5+10)/10} + 4\cdot 10^{(77.4+10)/10}\right]\right)$$

$$= 10\log\left(\frac{1}{24}\left(8.796\times 10^{9}\right)\right) = \boxed{85.6\ dB(A)}$$