SOLUTIONS - 3

FORMULAE

Sound in Gases LONGITUDINAL WAVE $20\,Hz < f < 20\,kHz$

Displacement $s = s_m \sin(kx - \omega t)$

Pressure

$$P = P_0 + \gamma P_0 s_m k \cos(kx - \omega t)$$

speed

$$v = \sqrt{\frac{\gamma k_B T}{m}}$$

Intensity $I = \dfrac{P}{4\pi R^2}$, $\beta = (10\,dB) \log \dfrac{I}{10 I_0}$

$$I = \frac{1}{2} s_m^2 \omega^2 \frac{\gamma P_0}{v}$$

DOPPLER EFFECT

SOURCE MOVES $\dfrac{f'}{f} = \dfrac{1}{1 - \dfrac{V_{source}}{V}}$

Detector Moves $\dfrac{f'}{f} = 1 \pm \dfrac{V_{Det}}{V}$

Stretched wire

Transverse wave $V = \sqrt{\dfrac{T}{\mu}}$

Reflection at $x=0$ — Freq. does not change

Incident wave $y_i = A_i \sin(kx - \omega t)$

Reflected wave $y_r = A_r \sin(kx + \omega t)$

Transmitted wave $y_t = A_t \sin(k'x - \omega t)$

$$\frac{A_r}{A_i} = \frac{V - V'}{V + V'} \qquad \frac{A_t}{A_i} = \frac{2V'}{V + V'}$$

Reflection at fixed End: phase changes by π so both ends fixed, normal modes are

$$n\frac{\lambda_n}{2} = L \qquad n = 1, 2, 3$$

$$f_n = \frac{v}{\lambda_n} = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$$

Reflection at open end. - No change in phase. — One end open, one fixed

$$\frac{(2n-1)\lambda_n}{4} = L$$

$$f_n = \frac{v}{\lambda_n} = \frac{(2n-1)v}{4L}$$

In both cases you have standing waves.

Fixed end $y = 2A_i \sin kx \cos\omega t$,

Nodes at $x = 0$ and every $\frac{\lambda}{2}$

First antinode at $\frac{\lambda}{4}$ and then every $\frac{\lambda}{2}$.

Open end $y = 2A_i \cos kx \sin\omega t$.

Antinode at $x = 0$ and every $\frac{\lambda}{2}$.

First node at $\frac{\lambda}{4}$ an then every $\frac{\lambda}{2}$

Radiation Electromagnetic Waves:

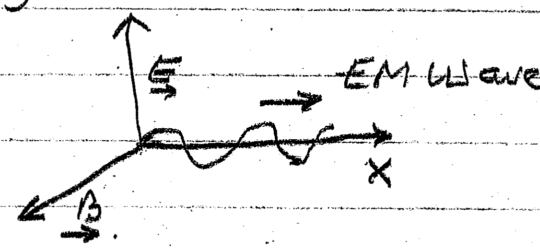
Radio waves, Heat waves, Light, UV, X-rays, γ-rays.

In vacuum EM waves are transverse

Wave travels along x

$$\vec{E} = E_m \sin(kx - \omega t)\,\hat{y}$$

$$\vec{B} = B_m \sin(kx - \omega t)\,\hat{z}$$



$$E_m = c B_m$$

Speed in Vac.

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \, m/s$$

$$\epsilon_0 = 9 \times 10^{-12} \, F/m$$

$$\mu_0 = 4\pi \times 10^{-7} \, H/m.$$

Intensity $I = \frac{1}{2} \epsilon_0 c E_m^2 = \frac{1}{2} \frac{c B_m^2}{\mu_0}$

CHAPTER 15

CHAPTER – 15.

15-35

(a) $f' = \dfrac{f}{1 - v_s/v}$ = Source moves Toward

$v_s = 90\ km/hr = 25\ m/s$

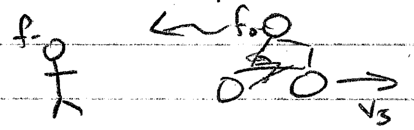
$v = 330\ m/s$

$f'_+ = \dfrac{600\ s^{-1}}{1 - \frac{25}{330}} = 649\ Hz$

(b) $f'_- = \dfrac{f_0}{1 + \frac{v_s}{v}} = 558\ Hz$ Source moves away

15-37 So, now take $f = 21\ kHz$ To hear you

must make $f' \leq 20\ kHz$ so you must travel away



$f' = \dfrac{f_0}{1 + \frac{v_s}{v}}$

$f'\left(1 + \frac{v_s}{v}\right) = f_0$

$\frac{v_s}{v} f_- = f - f$

$\frac{v_s}{v} = \dfrac{f - f'}{f'}$

$v_s = v\left(\frac{f}{f'} - 1\right)$

$= 330\ m/s\left(\frac{21\ kHz}{20\ kHz} - 1\right)$

$v_s = 16.5\ m/s$ AWAY!

you are the detector

$f' = f\left[1 - \frac{v_D}{v}\right]$

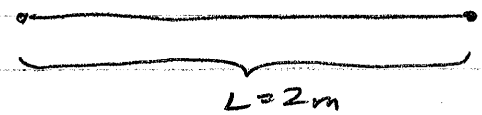
$20{,}000 = 21{,}000\left[1 - \frac{v_D}{v}\right]$

$\frac{20}{21} = 1 - \frac{v_D}{v} \qquad \frac{v_D}{v} = 1 - \frac{20}{21} = \frac{1}{21}$

$v_D = \frac{v}{21} = \frac{330}{21} = 15.7\ m/s\ (16\ m/s)$

CHAPTER 15

15-44 $T_s = 20N$



IF THE PULSE TRAVELS THE LENGTH OF THE STRING IN $\Delta\tau = 50ms$, THEN THE VELOCITY OF THE PULSE

$$V_{STRING} = \frac{L}{\Delta\tau}$$

FROM EQ. 15.2,

$$V_{STRING} = \sqrt{\frac{T_s}{\mu}} \Rightarrow \mu = \frac{T_s}{V^2_{STRING}}$$

But $\mu \neq \frac{m}{L}$

$$\mu = \frac{m}{L} \Rightarrow \mu L = m$$

OR,

$$m = L\frac{T_s}{V^2_{STRING}} = \frac{T_s \Delta\tau^2}{L} = .025 \text{ kg}$$
$$= 25 g$$

47 LIKE ABOVE, $V_1 = \sqrt{\frac{T_1}{\mu_1}}$, $V_2 = \sqrt{\frac{T_2}{\mu_2}}$

$$L_2 = 4m - L_1$$

$$t = \frac{L_1}{V_1} = \frac{L_2}{V_2}$$

SO THAT, $L_1\sqrt{\frac{\mu_1}{T_1}} = L_2\sqrt{\frac{\mu_2}{T_2}}$

BUT, $T_1 = T_2$

$$L_1\sqrt{\mu_1} = L_2\sqrt{\mu_2} \Rightarrow L_1(\sqrt{\mu_1}+\sqrt{\mu_2}) = 4\sqrt{\mu_2}$$
$$L_1 = 4\sqrt{\mu_2}(\sqrt{\mu_1}+\sqrt{\mu_2})^{-1}$$

$$L_2 = 1.66m \Longleftarrow L_1 = 2.34m$$

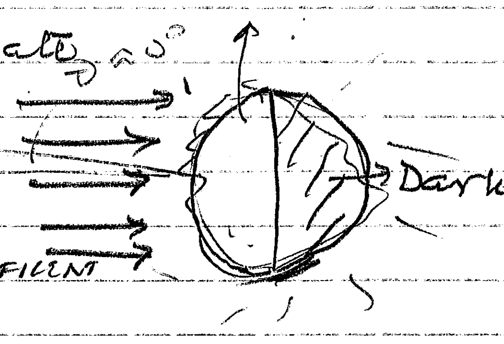
CHAPTER 15

(15-64) $r_s = 1.5 \times 10^{11}\ m$

$I = 1.38\ kW/m^2$

$R_e = 6.37 \times 10^6\ m$

We do not need r_s to calculate P but it ensures that radiation arriving on Earth is a parallel beam

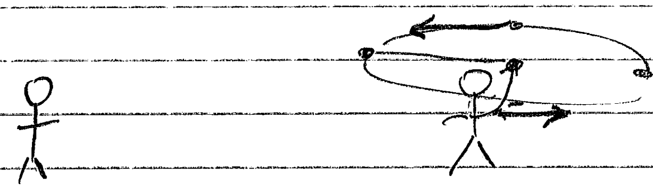


ASSUME 1/2 ~~the surface~~ AREA IS SUFFICIENT FOR APPROXIMATION...

$$I = \frac{P}{2\pi R_e^2} \Rightarrow 2\pi R_e^2 I = P$$

$$P = 3.52 \times 10^{14}\ kW$$

(15-71)



THE SPEED OF THE SOURCE IS GIVEN BY:

$$V_s = 2\pi\left(\frac{100}{60}\right) = 10.47\ m/s$$

AT 20°C, $V_{SOUND} = 343\ m/s$

FOR A STATIONARY OBSERVER, Source moves

$$f'_{\mp} = \frac{f_0}{1 \pm \frac{V_s}{V}}$$

$$= \frac{600\ s^{-1}}{1 \mp 2\pi \frac{10}{6(343)}}$$

$f'_- = 582\ Hz$ away

$f'_+ = 619\ Hz$ toward.

SUPPLEMENTARY

SUPPLEMENTARY PROBLEMS

(S-6)

$$I = \frac{1}{2} S_m^2 \omega^2 \frac{\gamma P_0}{V_s}$$

$$S_m^2 = \frac{2I}{\omega^2} \frac{V_s}{\gamma P_0}$$

OR, $$|S_m| = \frac{1}{\omega}\sqrt{\frac{2 I V_s}{\gamma P_0}}$$

$P_0 = 10^5 \; N/m^2$, $\gamma = 1.4$, $V_s = 330 \; m/s$, $I = 10^{-12} \; W/m^2$

SO THAT $|S_m| = \frac{1}{\omega}\left[6.87 \times 10^{-8} \; m/s\right]$

$\omega = 1000 \; rad/s$ $\qquad S_m = 7 \times 10^{-11} \; m$

(S-7) THINK OF THE WAY A PRESSURE WAVE IS CREATED. THERE IS SOME PRESSURE P_0 OF THE AIR. A PARTICLE THAT HAS NOT YET BEEN DISPLACED (OR IS RETURNING TO ITS ORIGINAL POSITION) EXPERIENCES A HIGH (LOW) PRESSURE BECAUSE THE DENSITY OF PARTICLES IS GREATER (LESS) THAN THAT OF THE UNDISTURBED AIR.

NEXT PAGE

(S-8) $V_s = 330 \; m/s$

$$\lambda = \frac{V_s}{f}$$

BUT FOR SOUND, f CAN RANGE FROM $20 \; Hz - 20 \; kHz$ SO THAT

$$\lambda_{MAX} = \frac{330 \; m/s}{20 \; s^{-1}} = 16.5 \; m$$

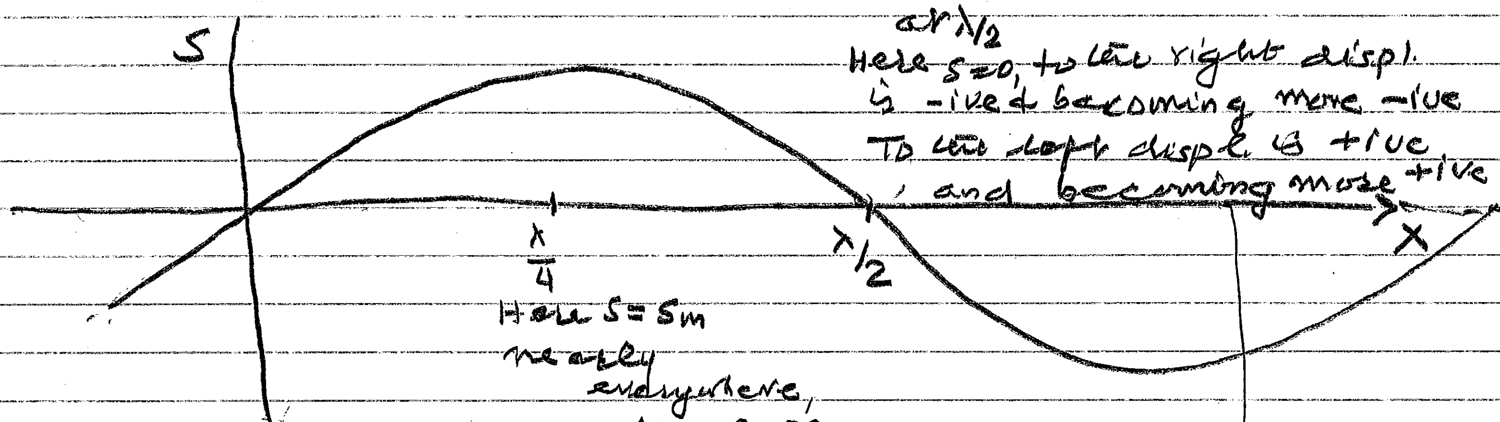
$$\lambda_{MIN} = \frac{330 \; m/s}{20 \times 10^3 \; s^{-1}} = .0165 \; m$$

WHICH MEANS AUDIBLE SOUND IS FROM ABOUT 1.7 cm TO 17 m

S-7 Consider the displacement wave

$$s = s_m \sin\left(\frac{2\pi x}{\lambda} - \frac{2\pi t}{T}\right).$$

Plot s as a function of x at t=0



at λ/2
Here s=0, to the right displ. is -ive & becoming more -ive
To the left displ. is +ive and becoming more +ive

Here S = Sm nearly everywhere, ΔV = 0, ΔP = 0
Pressure change is zero.

Here S=0

To the left S is -ive and becoming more negative. To the right S is +ive and increasing. Hence, gas is expanding so pressure reduces.
Where s=0, pressure is lowest.

Gas is contracting, Pressure is increasing so pressure is at a maximum.

where $s = 0$ $\quad P = P_0 \pm P_m$

Where $s = s_{max}$ $\quad P = P_0$

SUPPLEMENTARY

S-9

RADIATION IS ~~composed of~~ ~~Electromagnetic waves~~ TRANSMITS ENERGY VIA ELECTROMAGNETIC WAVES. WE DISTINGUISH DIFFERENT FORMS OF RADIATION BY FREQUENCY/ WAVELENGTH.

FROM THE TABLE ON PG. 497...

TYPE		λ
i) HEAT (IE. INFRARED)	$\sim$	$3\times10^{-4}\,m$ — $3\times10^{-6}\,m$
ii) FM RADIO	$\sim$	$3\,m$
iii) GAMMA	$\lesssim$	$1\times10^{-10}\,m$ ...

S-10

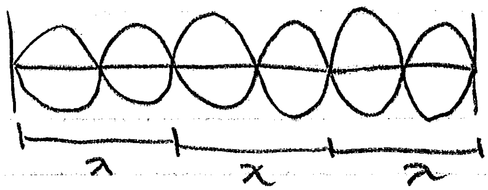
$$I = \frac{1}{2} c \epsilon_0 E_m^2 \qquad c \approx 3\times10^8\,m/s \quad \epsilon_0 \approx 8.85\times10^{-12}\,\frac{C^2}{Nm^2}$$

$$I = 1.4\times10^3\,W/m^2$$

$$\Rightarrow \sqrt{\frac{2I}{c\epsilon_0}} = E_0 \approx 1027\,N/C$$

CHAPTER 16

16-9



$3\lambda = 2m$

$V = 40\ m/s$

THUS $f = \frac{V}{\lambda} = \frac{40\ m/s}{\left(\frac{2m}{3}\right)} = 60\ Hz$

16-12 THE VELOCITY OF THE WAVE IS RELATED TO TENSION BY

$f_1 = \frac{1}{2L}\sqrt{\frac{T}{\mu}} = 384\ Hz$

$V = \sqrt{\frac{T}{\mu}}$

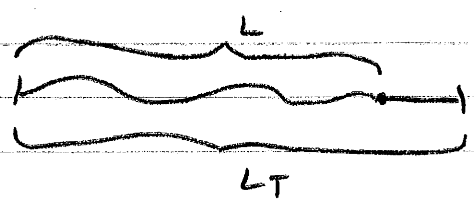
SINCE FREQUENCY IS SUCH THAT

$f_1 \propto V \qquad f_1 \propto \sqrt{T}$

IF $T' = \frac{1}{2}T \qquad f_1' = \frac{f_1}{\sqrt{2}} = 271.6\ Hz$

16-18 $f_0 = 27.5\ Hz$, $L_T = 2m$, $m = 400\ g = .4\ kg$

$L = 1.9m$



NOW, $\mu = \frac{m}{L_T}$

$V_s = \sqrt{\frac{T_s}{\mu}}$

$$f_1 = \frac{V}{2L} = \sqrt{\frac{T_s}{\mu}}\,\frac{1}{2L} = \sqrt{\frac{T_s L_T}{m}}\,\frac{1}{2L}$$

$$\frac{m(2Lf_1)^2}{L_T} = T_s = 2184\ N$$