EXERCIZES - 3

DOPPLER Effect

Detector Moves, Source at rest

$$f' = f\left[1 \pm \frac{V_D}{V_S}\right], \quad \begin{matrix} + \text{toward} \\ - \text{away} \end{matrix}$$

Source Moves, Detector at rest

$$f' = \frac{f}{1 \mp \frac{V_{sou}}{V_s}} \quad \begin{matrix} - \text{Toward} \\ + \text{away} \end{matrix}$$

Beat FREQUENCY

$$f_B = (f_1 - f_2)$$

INTERFERENCE

Maxima $(d_1 - d_2) = n\lambda \quad n = 0, 1, 2, \ldots$

Minima $(d_1 - d_2) = \left(n + \frac{1}{2}\right)\lambda, \quad n = 0, 1, 2 \ldots$

CHARGE

$$Q = (N_+ - N_-) \times 1.6 \times 10^{-19}\ C.$$

COULOMB FORCE

$$\vec{F}_E = \frac{k_e Q_1 Q_2}{r^2}\hat{r}$$

$$k_e = 9 \times 10^9 \frac{N\text{-}m^2}{C^2}$$

Compare $\vec{F}_G = -\frac{G M_1 M_2}{r^2}\hat{r} \quad G = 6.7 \times 10^{-11} \frac{N\text{-}m^2}{(kg)^2}$

E3-1 Two identical piano wires have a fundamental frequency of 440 Hz (Concert A). What fractional increase in tension of one wire will be needed to produce 6 beats/sec when both wires vibrate simultaneously?

In the fundamental mode

$$f_1 = \frac{1}{2L}\sqrt{\frac{T}{\mu}} \quad \text{so} \quad 440\,\text{Hz} = \frac{1}{2L}\sqrt{\frac{T_{440}}{\mu}}$$

To get 6 beats/sec we must increase frequency to 446 Hz. Corresponding Tension must satisfy

$$446\ \text{Hz} = \frac{1}{2L}\sqrt{\frac{T_{446}}{\mu}}$$

Hence $$\sqrt{\frac{T_{446}}{T_{440}}} = \frac{446}{440}$$

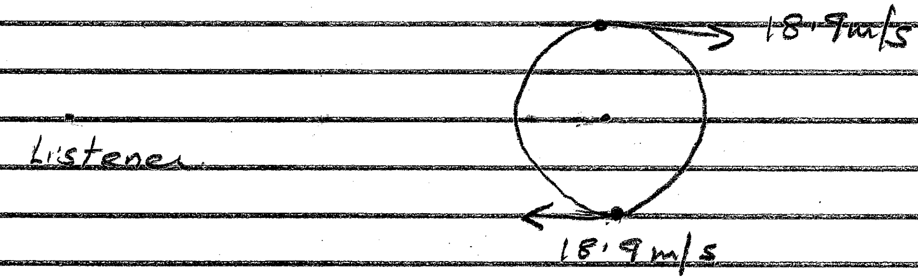
$$\frac{T_{446}}{T_{440}} = 1.027 \qquad T_{446} = 1.027 \times T_{440}$$

Hence Tension must be increased by 2.7 % of initial tension.

E3-2 (This is the Demo we did in class.) A whistle of frequency 500Hz moves in a circle of radius 1m at 3rev/sec. What are the maximum and minimum frequencies heard by a stationary listener in the plane of the circle and 5m away from the center. Take speed of sound to be 340m/s.

Period $T = \frac{1}{3}$ sec.

speed $S = \frac{2\pi R}{T} = 2\pi \times 1 \times 3 = 18.85\,m/s$



Max $f' = \dfrac{500}{1 - \frac{18.9}{340}} = 529\,Hz$

Min $f' = \dfrac{500}{1 + \frac{18.9}{340}} = 474\,Hz$

E3-3 The Ear Canal which is about 2.5cm long, roughly approximates a pipe which is open at one end and closed at the other. If the speed of sound is 340m/s what are first three harmonics of this "tube"?

$$(2n-1)\frac{\lambda_n}{4} = L \qquad n = 1, 2, 3, \ldots$$

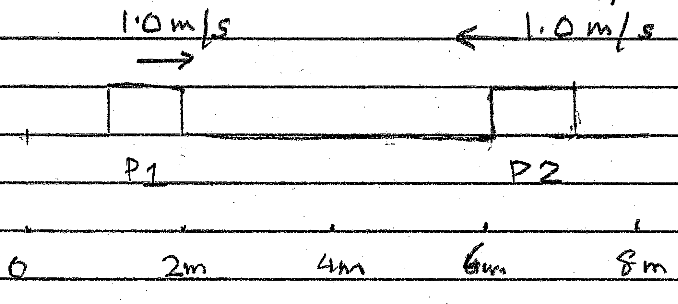
$n=1 \quad \frac{\lambda_1}{4} = L \qquad \lambda_1 = 4 \times 2.5 = 0.1m \quad f_1 = \frac{340}{0.1} = 3400Hz$

$n=2 \quad \frac{3\lambda_2}{4} = L \qquad \lambda_2 = \frac{4 \times 2.5}{3} = 0.033m, \quad f_2 = 10,200Hz$

$n=3 \quad \frac{5\lambda_2}{4} = L \qquad \lambda_3 = \frac{4 \times 2.5}{5} = 0.020m \quad f_3 = 17,000Hz$

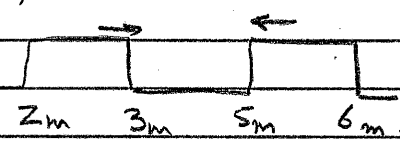
Consequently, your Ears have increased sensitivity at $f_1, f_2 \ldots$

E3-4 Two pulses approach Each other. At $t=0$, they are shown P1 between $1 \to 2m$ and P_2 between 6-7m.

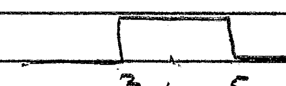


Make a careful sketch of the resultant wave at $t = 1.0s$, 2 sec, 2.5 s, 3.0 & 4 sec.

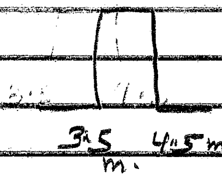
1 s



2 s

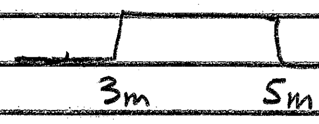


2.5s

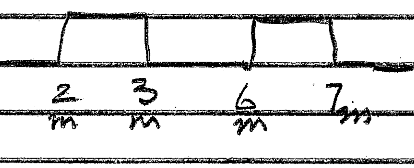


[amplitude Dbl]

3.0 s.

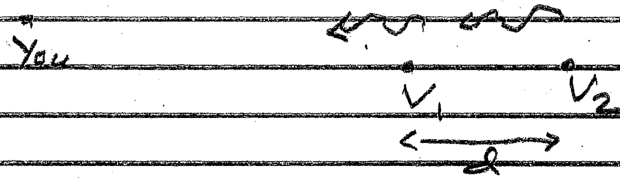


4.0s.



Note If one of the pulses was inverted (down rather than up) the total amplitude at 2.5s would be "ZERO"!

E3-5 Two Violinists both playing the Concert A (440 Hz) stand one behind the other. You are standing right in front of them. What must be the least separation between V_1 and V_2 so that you hear (i) Nothing (ii) Maximum sound (speed in air = 340 m/s)



Wavelength $\lambda = \frac{340}{440} = 0.772$ m

Minimum - Destructive Interference

$$d = \lambda/2 = 0.386\ m$$

Maximum Constructive Interference (Exclude zero).

$$d = \lambda = 0.772\ m.$$

E-6 Hearing loss - To determine the temporary hearing loss due to loud music, researchers exposed 20 young women to 110 dB music for 60 minutes. Eleven of them showed a 20 dB reduction in sensitivity. What is the threshold of hearing for these subjects if the normal threshold is $I_0 = 10^{-12}$ Watt/m^2

$$\beta = 10 \log \frac{I}{I_0}$$

$$20 = 10 \log \frac{I}{10^{-12}}$$

$$I = 10^{-10}\ \text{Watt}/m^2$$

A factor of 100!