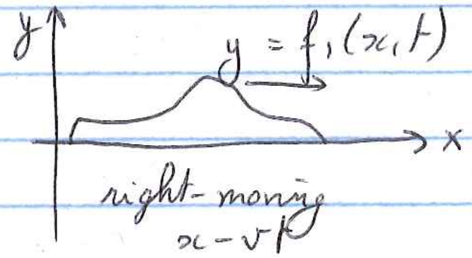
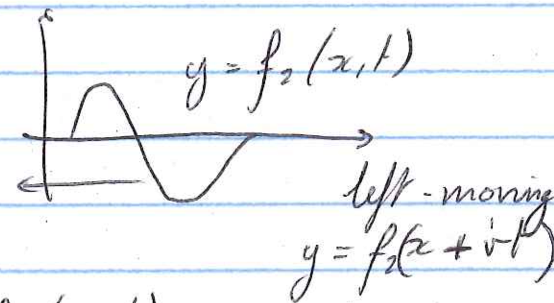
* <u>Superposition and interference</u>





$$y = f_1(x,t) + f_2(x,t)$$

* Beat ~~no~~ notes

$$f_1 \approx f_2 \quad \begin{cases} y_1 = A\cos(2\pi f_1 t) & (\underline{x=0}) \\ y_2 = A\cos(2\pi f_2 t) & (x=0) \end{cases}$$

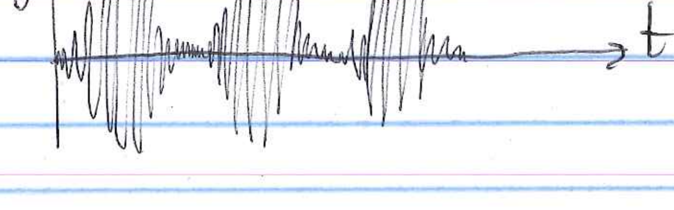
$$y = y_1 + y_2 = A\cos(2\pi f_1 t) + A\cos(2\pi f_2 t)$$

$$= 2A\cos(\pi f_B t)\cos(2\pi f_{avg} t)$$

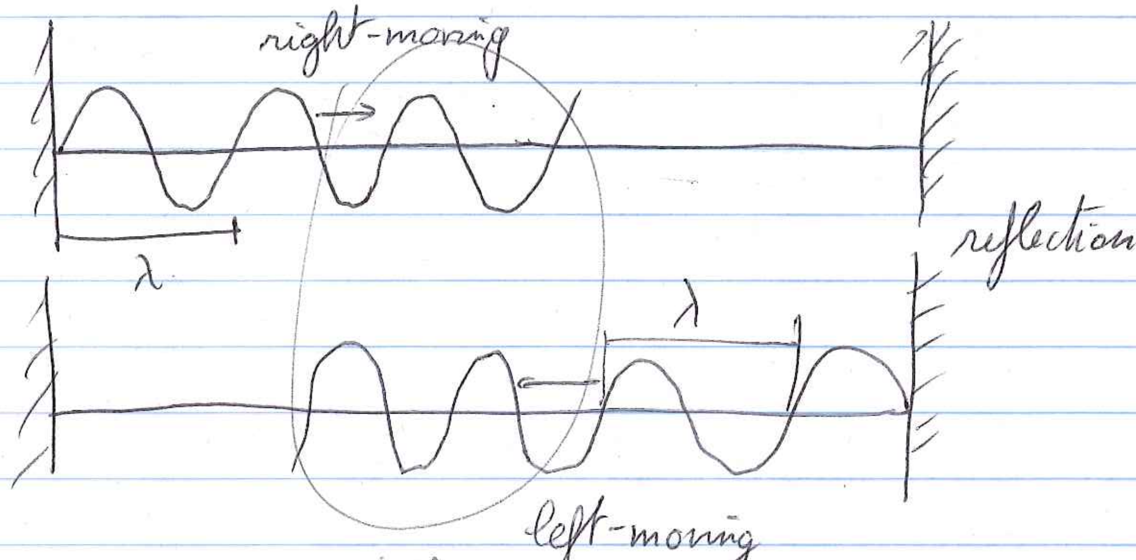
$$f_B = |f_1 - f_2| \ll f_1, f_2$$

$$f_{avg} = \frac{f_1 + f_2}{2}$$

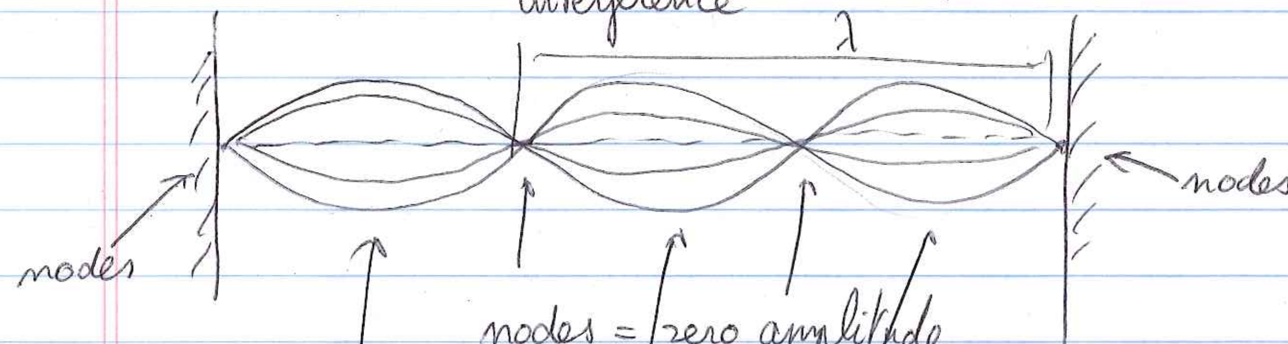
$$\left.\begin{matrix} f_1 = 440\,Hz \\ f_2 = 442\,Hz \end{matrix}\right\} \rightarrow f_B = |f_1 - f_2| = 2\,Hz \ll 440\,Hz$$



* Standing waves

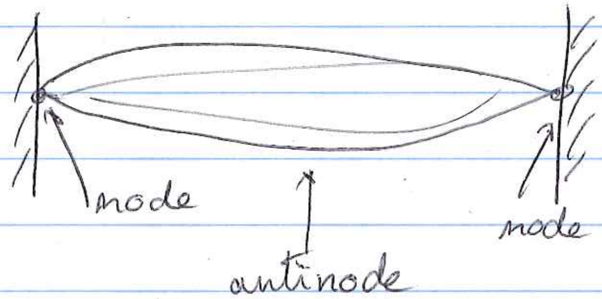


interference

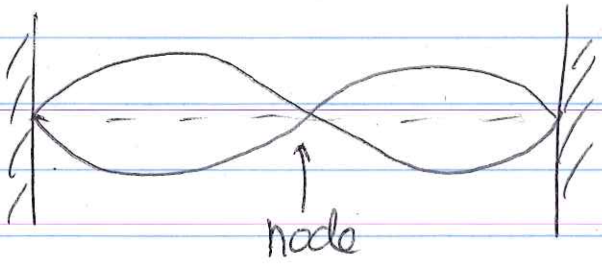


nodes = zero amplitude

antinodes = maximum amplitude

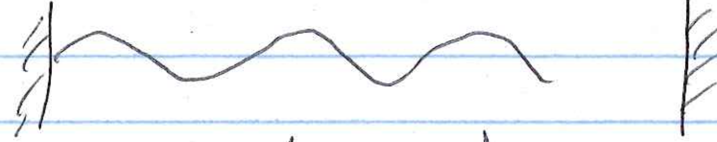


fundamental, $L = \frac{\lambda}{2}$



1^{st} harmonic, $L = 2\,\frac{\lambda}{2} = \lambda$
(2^{nd} order)

k^{th} harmonic
(n^{th} order)
$n = k+1$



$$L = n\frac{\lambda}{2}, \quad n = 1, 2, 3, \ldots$$

fundament (n = 1)

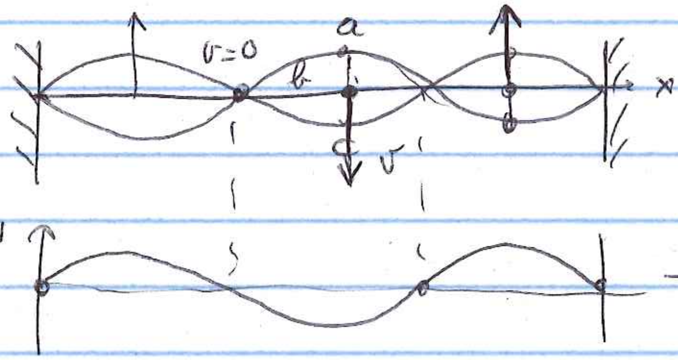
1st harm. (n = 2)

$$\lambda = \frac{2L}{n}$$

If v = constant: $v = \lambda f \rightarrow f = \frac{v}{\lambda} = \frac{nv}{2L}$, $n = 1, 2, 3, \ldots$

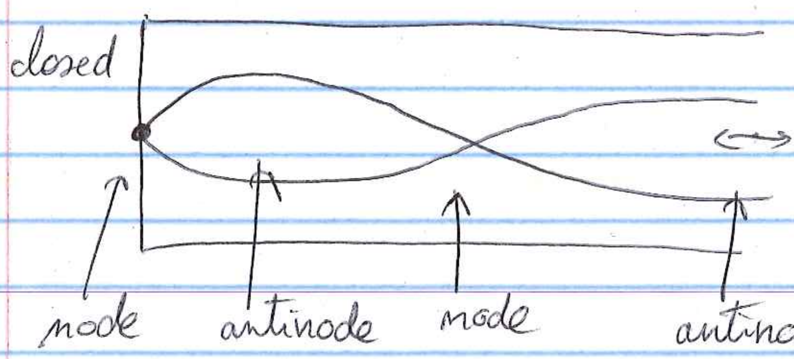
$$f_n = n\frac{v}{2L} = n f_1$$

f_1: fundamental frequency



→ v depends on the position

+ musical instruments



$$f_1 = \frac{v}{2L}$$

large L → low f

small L → high f

* Waves transport energy:

SHM: energy $\propto A^2$ = amplitude squared

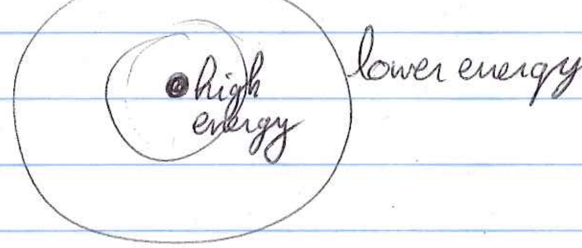
$$E = \frac{1}{2} k A^2$$

effects of waves, determined by energy ~~de~~ transported.

depend on : – $A \rightarrow E \propto A^2$

– duration : all energy arrives in a short time $\rightarrow$ Power $= \frac{\text{energy}}{\text{time}} = \frac{E}{\Delta t}$

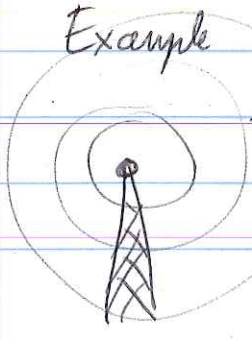
– spatial concentration :



I = intensity $= \dfrac{E/\Delta t}{A} = \dfrac{\text{power}}{\text{area}}$ ~~in~~ units $\dfrac{W}{m^2}$

$$\left.\begin{aligned} A_{circle} &= \pi r^2 \\ A_{sphere} &= 4\pi r^2 \end{aligned}\right\} A \propto r^2 \rightarrow I \propto \frac{1}{r^2}$$

Example : radio-transmitter emits a 10 kW power signal in all directions



$$A_{sphere} = 4\pi r^2$$

1) what is the ~~EA~~ intensity at 1 km distance?

$$I = \frac{P}{A} = \frac{10\,kW}{4\pi(1000\,m)^2} = 8 \times 10^{-4}\,\frac{W}{m^2}$$

2) what is the intensity at 10 km distance?

$$I = \frac{1}{100}\left(8 \times 10^{-4}\,\frac{W}{m^2}\right) = 8 \times 10^{-6}\,\frac{W}{m^2}$$

3) What is the power received by an 10 cm x 10 cm antenna at 10 km?

$$P = IA = I\,(0.1\,m)^2$$

$$P = 8 \times 10^{-8}\,W \approx 10^{-7}\,W$$

$$0.1\,\mu W$$