Chapter 11

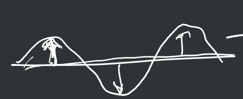
After this you can

- discuss the properties of a waves and distiguish wave motion from particle motion
- discuss what causes waves to propogate and what effects the speed of propogation

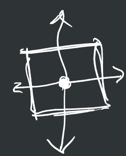
wave - a travelling 'disturbance'

carries and delivers energy, but no large scale movement of matter

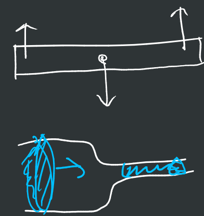
waves vs. particles

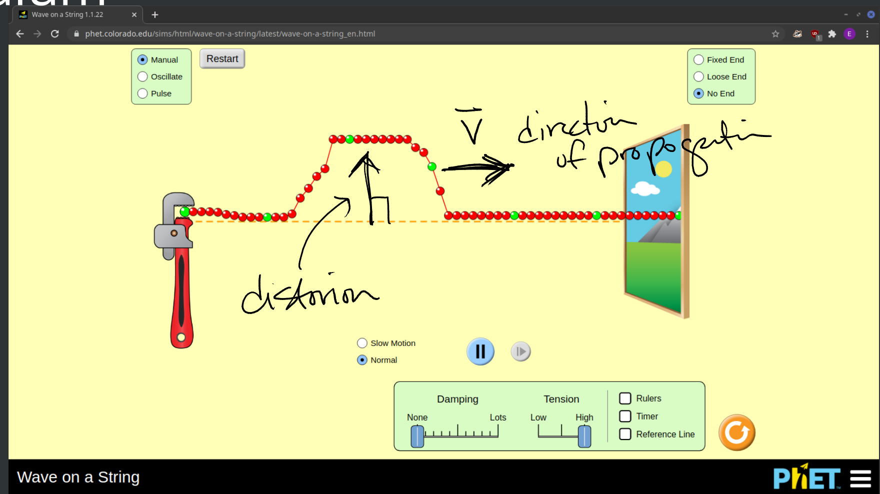


$\rightarrow v$



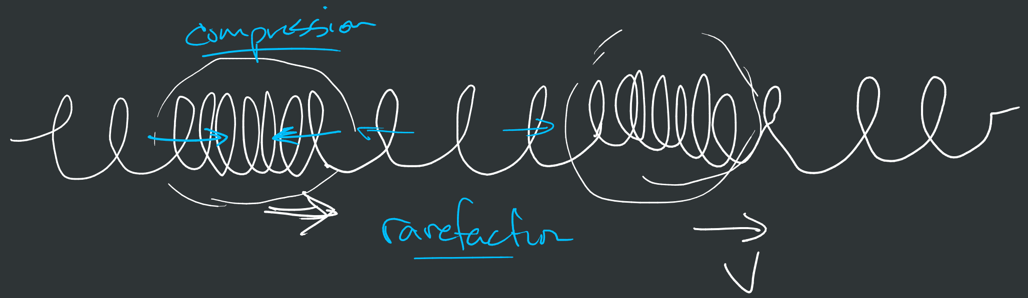
mechanical waves - distortions of a medium that travel through the medium





- transverse waves - distortion is ⊥ to the direction of travel
(string, ripple)

- longitudinal wave - distortion is ∥ to the direction of travel
(sound)



wave speed depends on the medium

↳ waves on a string

$$v \propto F^{1/2} L^{1/2} m^{-1/2}$$

tension

$$\boxed{v = \sqrt{\frac{F \cdot L}{m}}}$$

$\frac{m}{L}$ } like a density but not volume

$\mu = \frac{m}{L}$ } linear mass density

"mu"

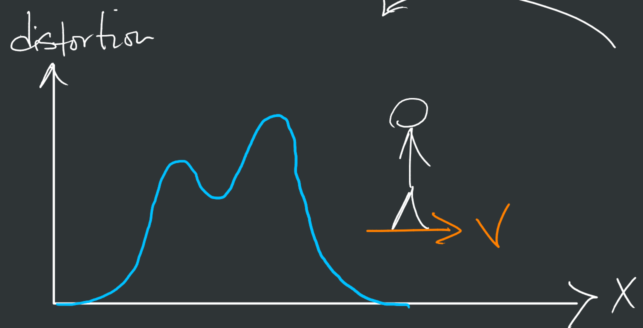
$$\boxed{v = \sqrt{\frac{F}{\mu}}}$$

– or –

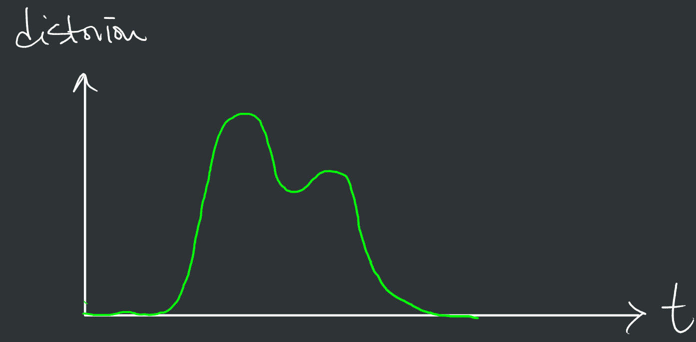
$$v \propto F^{1/2} \mu^{-1/2}$$

After this you can

- discuss properties of periodic waves unique from aperiodic waves
- discuss the special case of harmonic travelling waves
- identify key quantities from the mathematical description of a harmonic wave

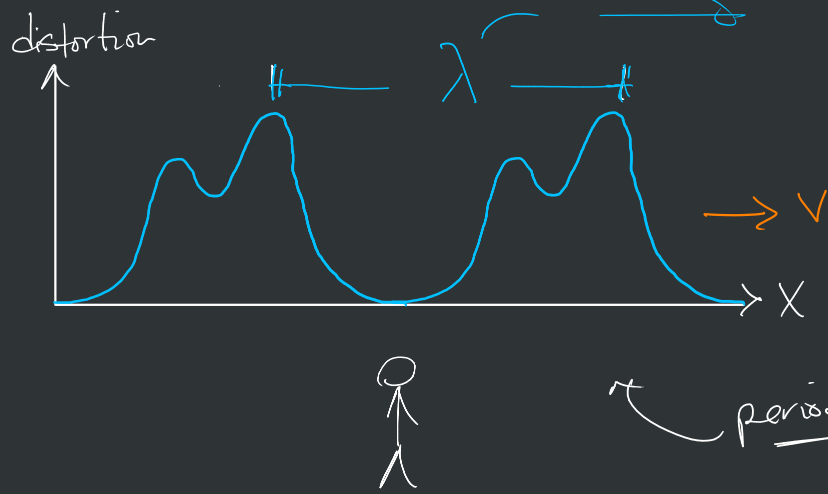


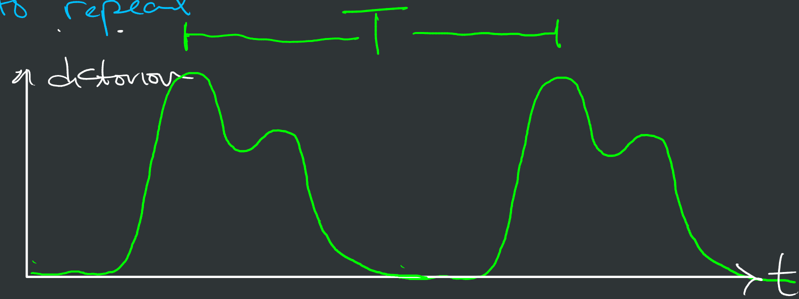
aperiodic (not periodic)



wavelength – distance for wave pattern to repeat

period





periodic

$$\boxed{v = \frac{\lambda}{T}} \longleftarrow \lambda = vT$$

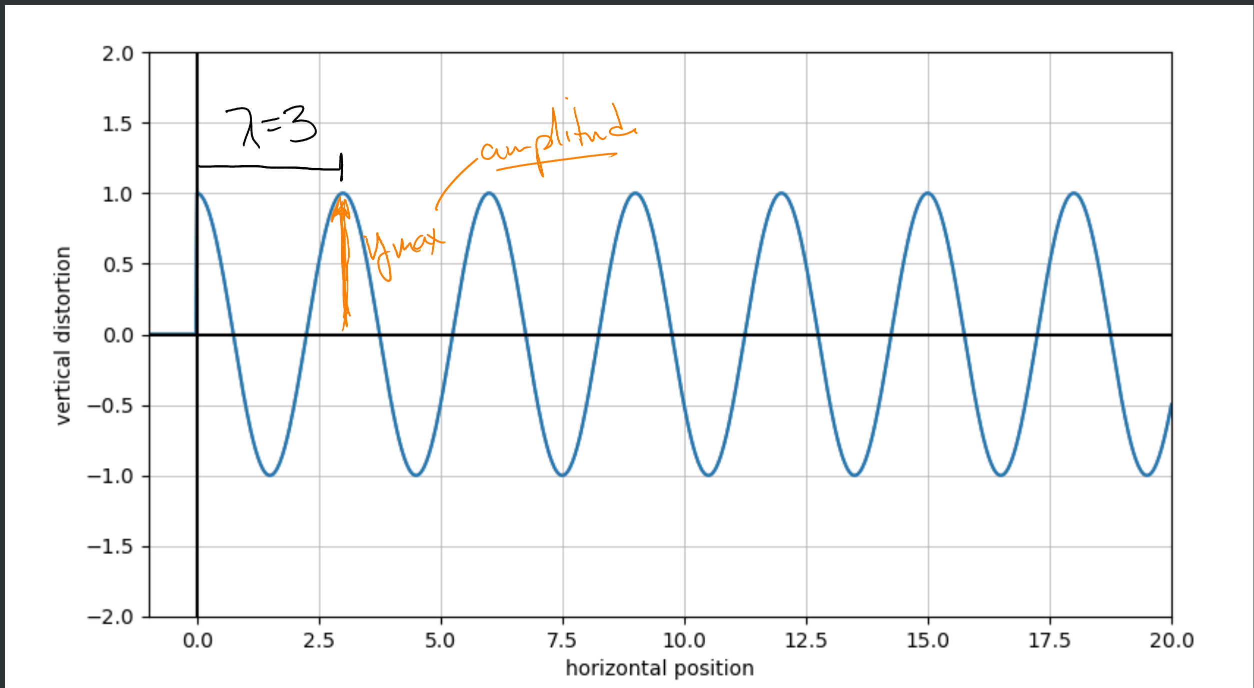
$$\text{frequency} = \frac{1}{T} \longrightarrow \boxed{v = \lambda \cdot f}$$

For waves on a string:

$$V = \sqrt{\frac{FL}{m}}$$ ← physical attributes that cause the velocity

$$v = \lambda \cdot f$$ ← relationship between wavelength and frequency

Harmonic Travelling Wave



$$y(x,t) = y_{max} \cdot \cos\left(\omega\left(\frac{x}{v} - t\right)\right)$$

$$\omega = \frac{2\pi}{T} = 2\pi f$$

$$y = y_{max} \cdot \cos\left(\frac{2\pi}{T}\left(\frac{x}{v} - t\right)\right)$$

$$y = y_{max} \cdot \cos\left(2\pi\left(\frac{x}{v \cdot T} - \frac{t}{T}\right)\right)$$

$$v = \frac{\lambda}{T} \Rightarrow \lambda = v \cdot T$$

$$y = y_{max} \cdot \cos\left(2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right)$$

$$y = y_{max} \cos\left(\underbrace{\frac{2\pi}{\lambda}}_{k} x - \underbrace{\frac{2\pi}{T}}_{\omega} \cdot t\right)$$

wavenumber (not spring constant) ← k

ω angular freq

$$\boxed{y(x,t) = y_{max} \cos(kx - \omega t)}$$

$$k = \frac{2\pi}{\lambda} \qquad \omega = \frac{2\pi}{T}$$

$$\lambda = \frac{2\pi}{k} \qquad T = \frac{2\pi}{\omega}$$

$$v = \frac{\lambda}{T}$$

$$v = \left(\frac{\cancel{2\pi}}{k}\right)\left(\frac{\omega}{\cancel{2\pi}}\right)$$

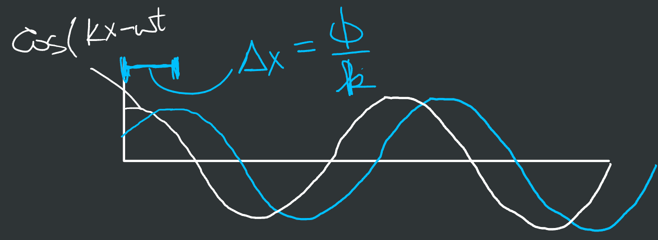
$$\boxed{v = \frac{\omega}{k}}$$

$$y(x,t) = y_{max}\cos(kx - \omega t + \phi)$$

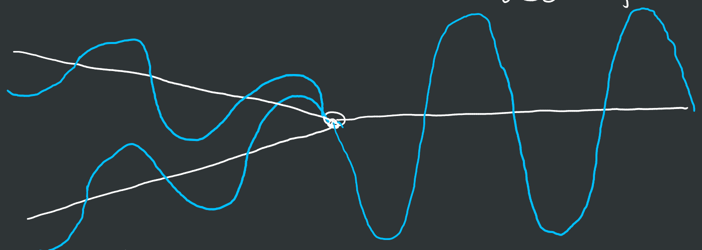
phase shift

$\phi = k\Delta x$

$\Delta x = \frac{\phi}{k}$



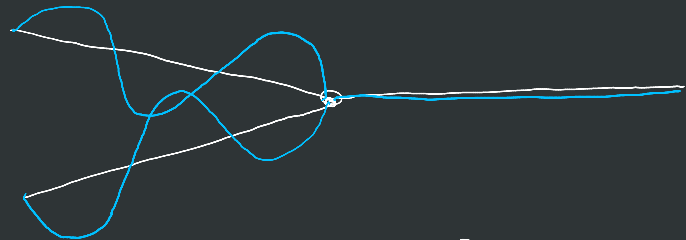
Multiple Waves → principle of superposition - at any time the resultant waveform is the sum of the individual waveforms



Constructive Interference

phase difference = 0 radians

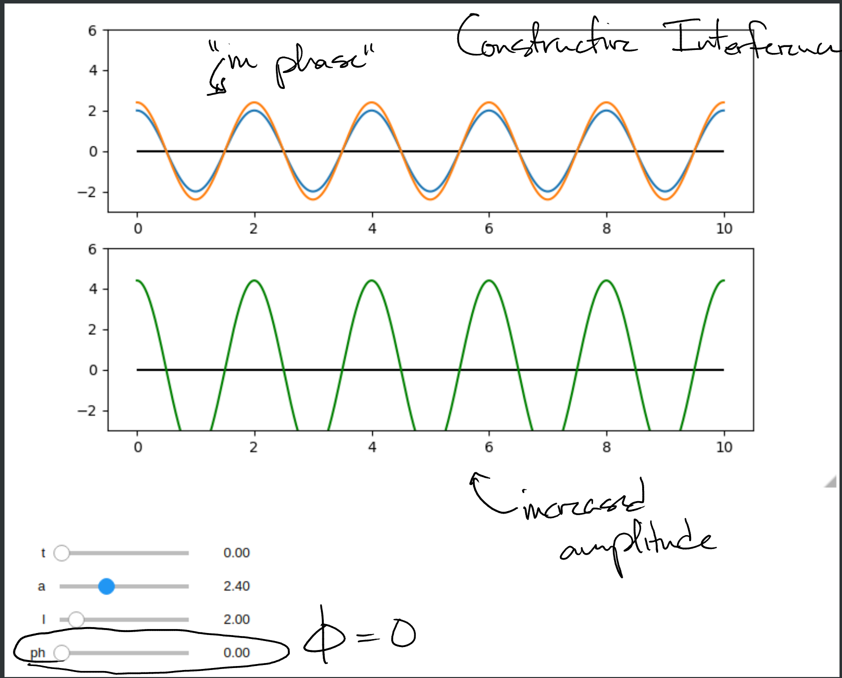
increased amplitude results

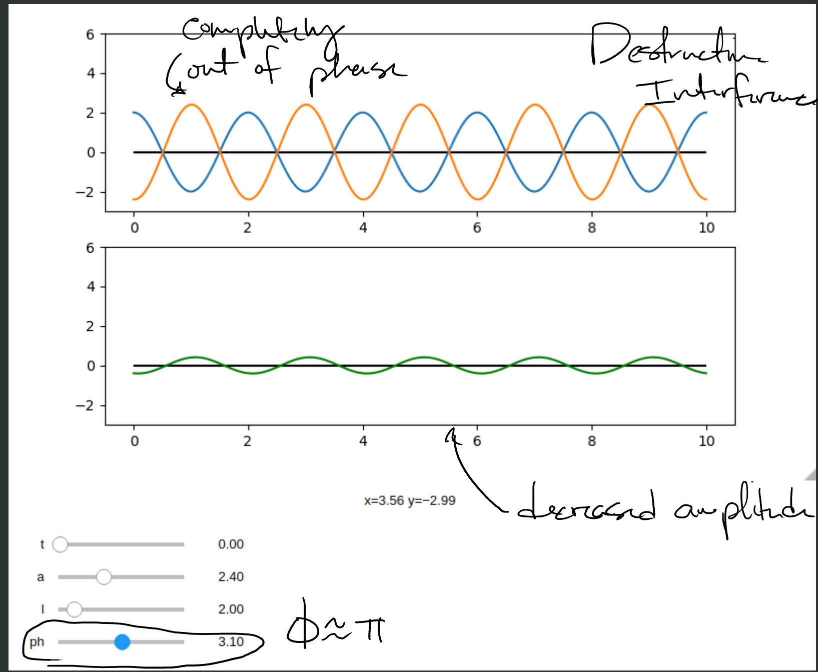


Destructive Interference

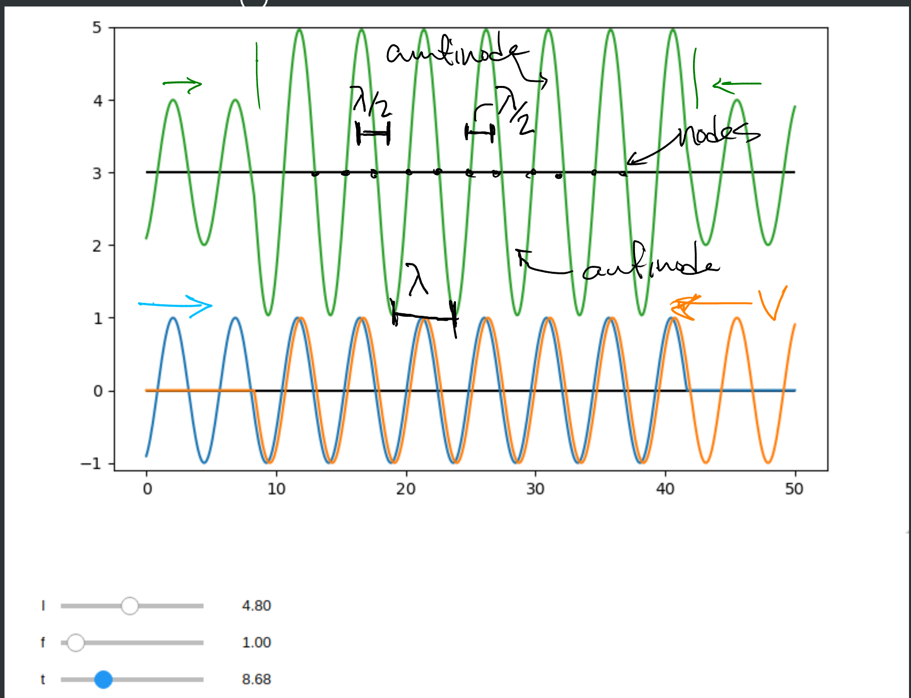
phase difference = π radians

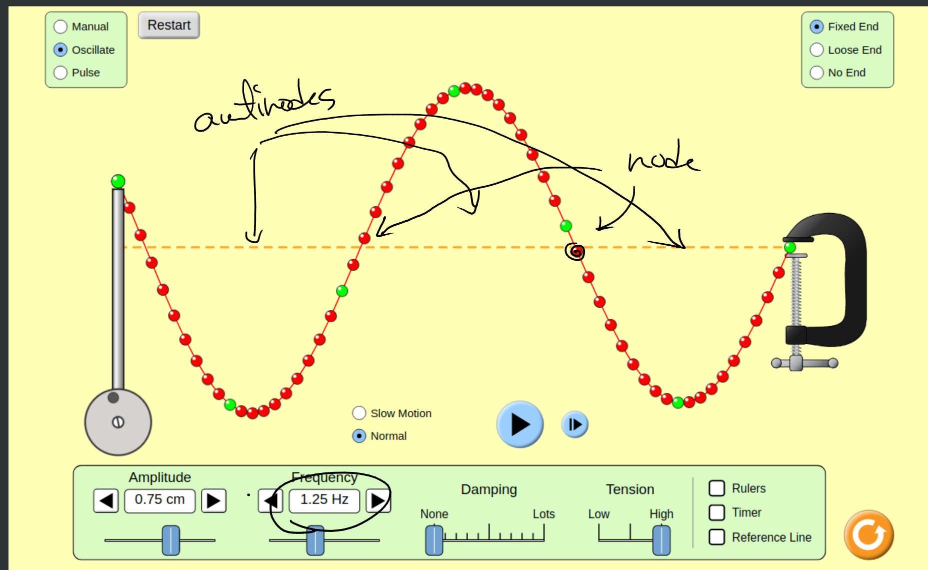
decreased amplitude results





Standing Waves

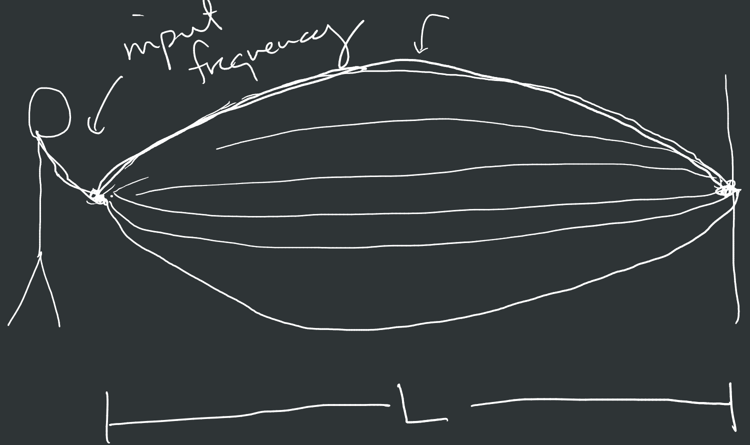


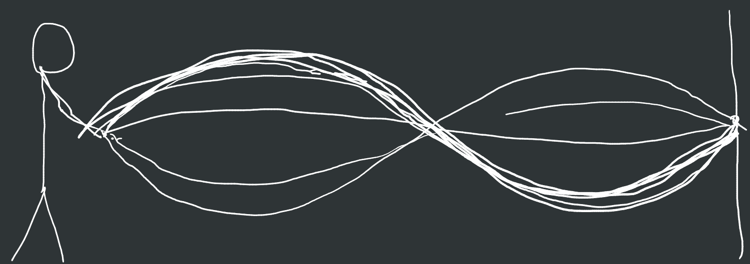


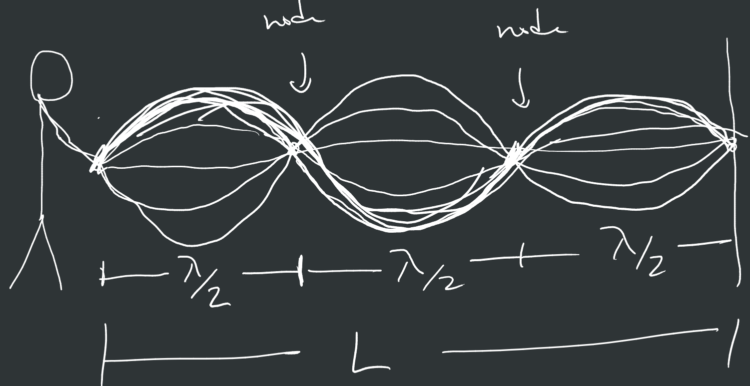
$V = \lambda \cdot f \rightarrow \lambda$ must have certain values with respect to the length of the string

↳ only be integer numbers of antinodes

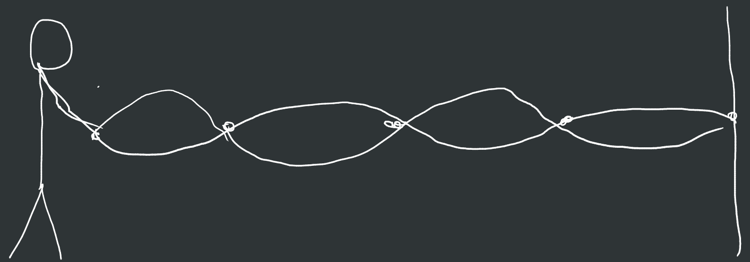
↑ caused by tension, mass density







antinodes	wavelength	frequency	
1	$\lambda_1 = \frac{2L}{1}$	$V = f_1 \lambda_1$ $f_1 = \frac{V}{\lambda_1}$ $\boxed{\frac{1V}{2L} = f_1}$	$f_1 = 1\frac{V}{2L}$ ↑ fundamental frequency (1st harmonic) (1st mode)
2	$\lambda_2 = \frac{2L}{2}$	$V = f_2 \lambda_2$ $\boxed{f_2 = \frac{2v}{2L}}$	$f_2 = 2 f_1$ (2nd harmonic) (1st overtone) (2nd modes)
3	$\lambda_3 = \frac{2L}{3}$	$V = f_3 \lambda_3$ $f_3 = \frac{3v}{2L}$	$f_3 = 3 f_1$ (3rd harmonic 2nd overtone 3rd mode)



	4	$\lambda_4 = \frac{2L}{4}$	$f_4 = \frac{4v}{2L}$
in general	n	$\lambda_n = \frac{2L}{n}$	$f_n = \frac{nv}{2L}$