Physics 101: Lecture 22

Waves

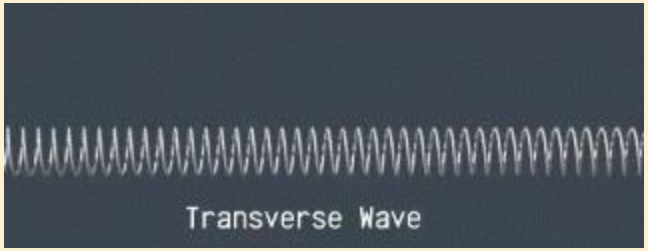
Waves Overview

- Types of waves
- Speed or a wave
- Harmonic waves
- Superposition and Interference
- Standing waves

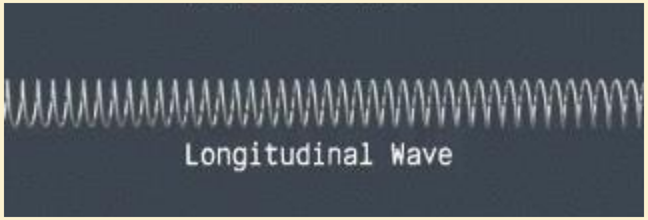
Bottom line for today: Lots of definitions to remember, and some algebra/trig to do, but material is not difficult

Types of Waves

- **Transverse:** The medium oscillates perpendicular to the direction the wave is moving.
  - ➔ Water (more or less)
  - ➔ Slinky demo



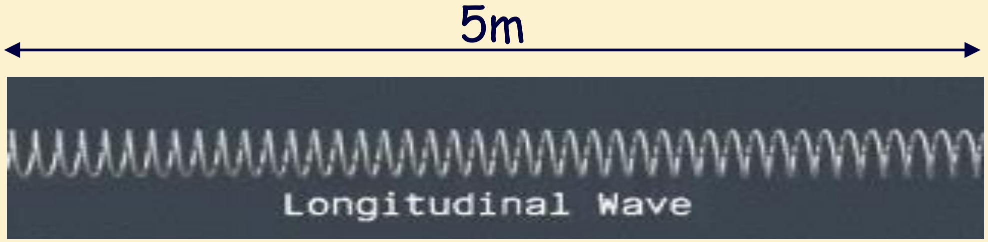
- **Longitudinal:** The medium oscillates in the same direction as the wave is moving
  - ➔ Sound
  - ➔ Slinky demo



Slinky Clicker Q

Suppose that a longitudinal wave moves along a Slinky at a speed of 5 m/s. Does one coil of the slinky move through a distance of five meters in one second?

1. Yes
2. No



Velocity of Waves Clicker Q

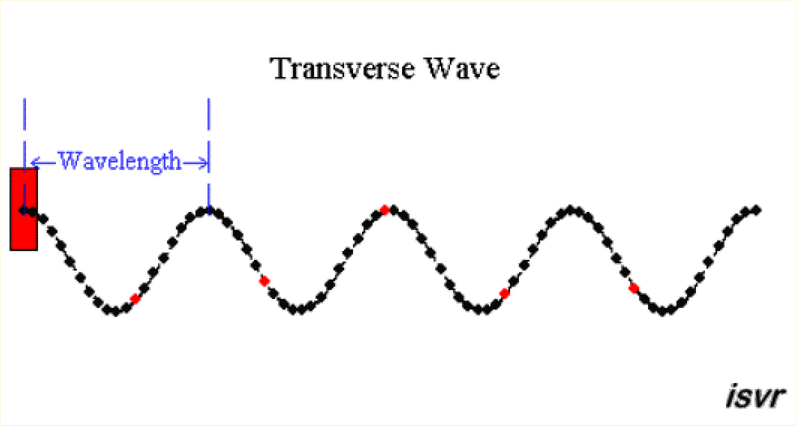
$$v = \sqrt{\frac{T_{tension}}{m/L}} = \sqrt{\frac{T_{tension}}{\mu}}$$

A spring and slinky are attached and stretched. Compare the speed of the wave pulse in the slinky with the speed of the wave pulse in the spring.

A) $v_{slinky} > v_{spring}$ B) $v_{slinky} = v_{spring}$ C) $v_{slinky} < v_{spring}$

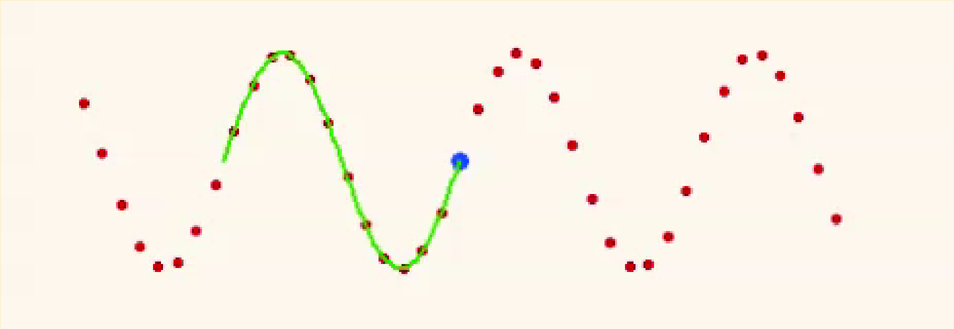
Period and Velocity

- Period: The time T for a point on the wave to undergo one complete oscillation.



- Speed: The wave moves one wavelength λ in one period T so its speed is $v = \lambda / T$.

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



Harmonic Waves

$$y(x,t) = A\cos(\omega t - kx) \quad \text{or} \quad A\cos(kx - \omega t)$$

Wavelength: The distance λ between identical points on the wave.

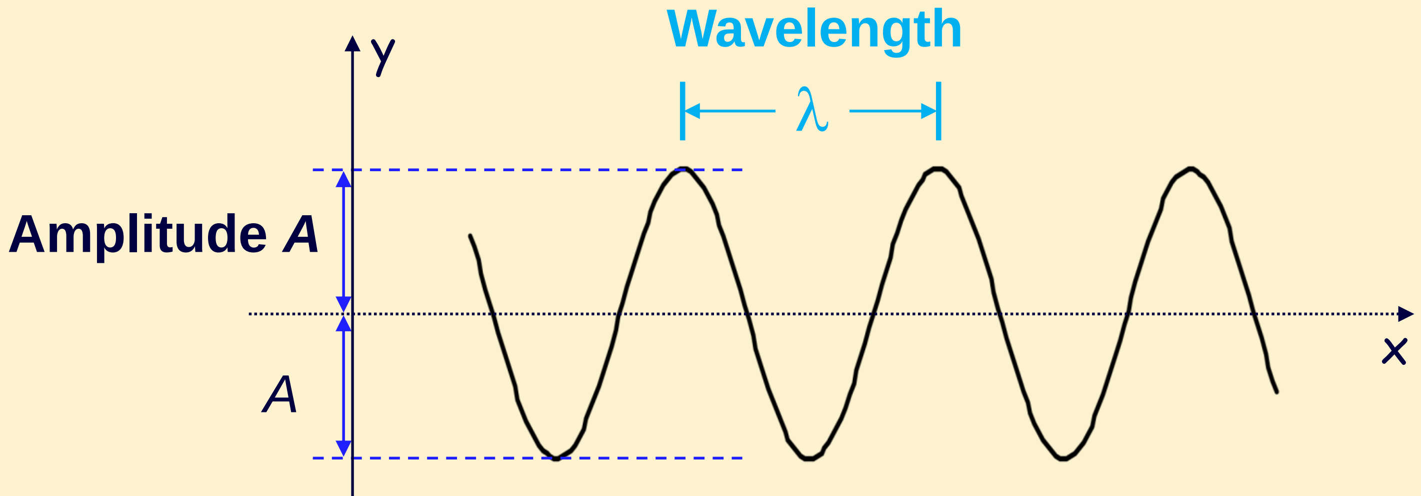
Amplitude: The maximum displacement *A* of a point on the wave.

Angular Frequency ω: $\omega = 2\pi f = 2\pi / T$

f is simply called the Frequency

Wave Number k: $k = 2\pi / \lambda$

Remember: $f = v / \lambda$ or $f\lambda = v$ OR $v = \omega / k$



Harmonic Waves Exercise

Plot wave at a fixed position as time passes

$y(x,t) = A \cos(\omega t - kx)$

Label axis and tic marks if the graph shows a snapshot of the wave

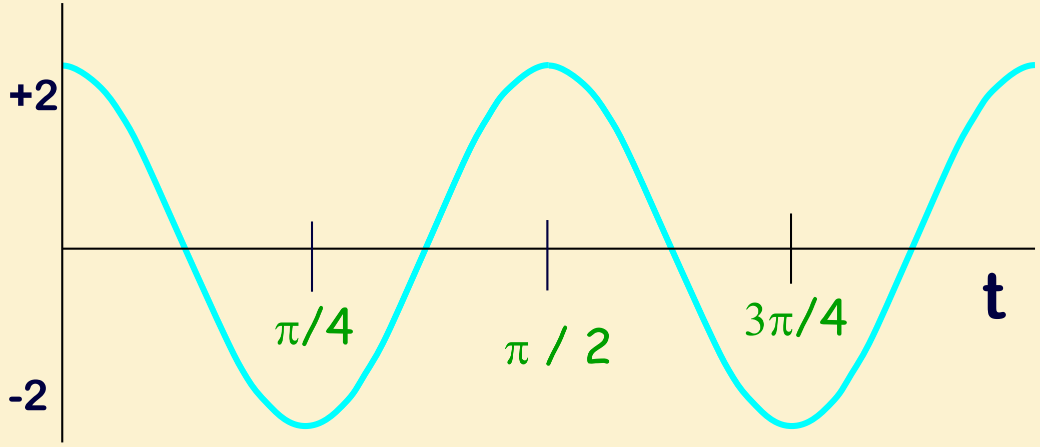
$y(x,t) = 2 \cos(4t - 2x)$ at $x=0$.

$T = 2\pi / \omega$

$= 2\pi / 4$

$= \pi / 2$

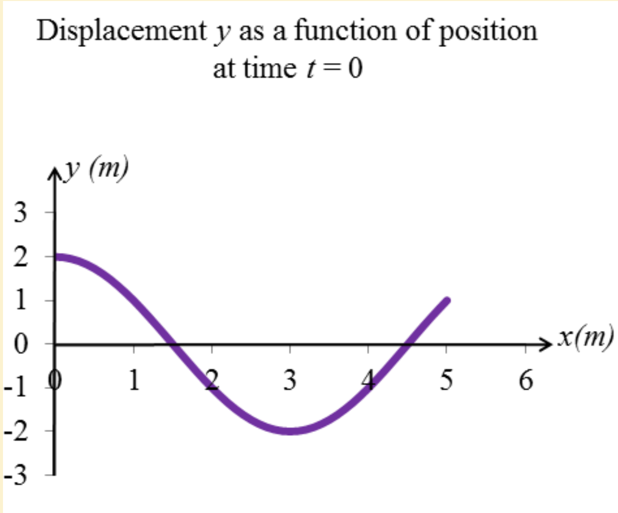
Recall: $T = 2\pi/\omega$

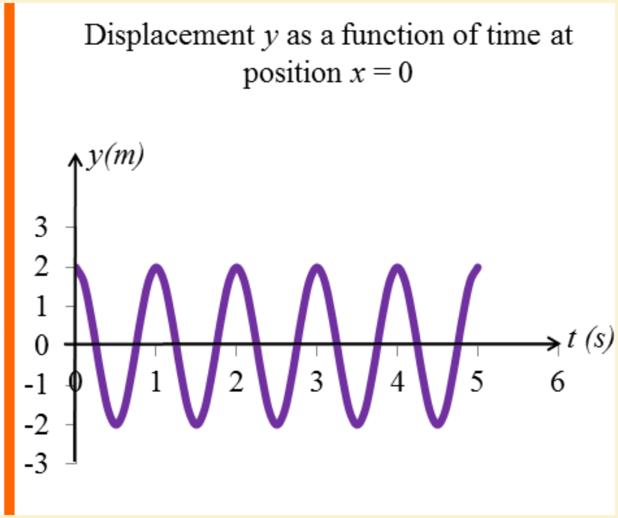


Checkpoint 2a

A student is sending pulses of a transverse sinusoidal wave to the right along a string by whipping it up and down. With the help of a high-speed camera, plots of the displacement, y, of the wave are produced as shown below. Which of the following wave functions describes best the wave?

A. y=(2 m)cos(2πx/(1 m)–2π(6 Hz)t)
B. y=(2 m)cos(2πx/(3 m)–2π(1 Hz)t)
C. y=(2 m)cos(2πx/(3 m)–2π(2 Hz)t)
D. y=(2 m)cos(2πx/(6 m)–2π(1 Hz)t)
E. None of the above





Checkpoint 2b

In the previous problem if the tension on the string is doubled while the student is whipping the string at a constant rate, which of the following will change as well?

A. Amplitude of the wave
B. Angular frequency
C. Wave number
D. None of the above

Checkpoint 1

In an experiment to illustrate the propagation of sound through fluids, identical sound sources emitting at 440 Hz are used to propagate sound waves through mercury and through ethanol. Which of the following statements is correct, assuming that the dampening effect in each medium is negligible?

A. In ethanol, the frequency of the wave is greater to compensate for the smaller wavelength.
B. In mercury, the frequency of the wave is the same as in ethanol, but the wavelength is greater.
C. In ethanol and mercury, the wavelength of the wave is the same, even if the speed of sound is different.?

Medium	Speed of sound (m/s)
Ethanol	1,160
Mercury	1,450

Clicker Q

Suppose a periodic wave moves through some medium. If the period of the wave is increased, what happens to the wavelength of the wave assuming the speed of the wave remains the same?

1. The wavelength increases
2. The wavelength remains the same
3. The wavelength decreases

Clicker Q

The wavelength of microwaves generated by a microwave oven is about *3 cm*. At what frequency do these waves cause the water molecules in your burrito to vibrate?

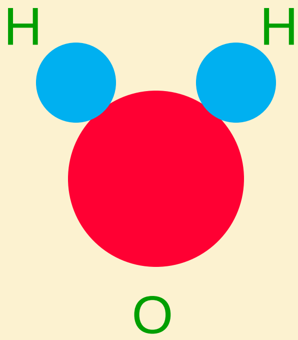
(a) *1 GHz* (b) *10 GHz* (c) *100 GHz*

1 GHz = 10^9 cycles/sec

The speed of light is $c = 3 \times 10^8$ m/s

Solution to Clicker Q

To be filled in during class



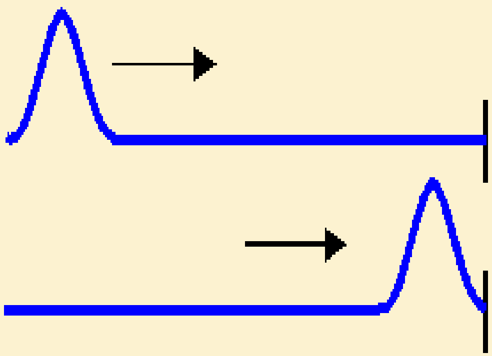
Makes water molecules wiggle

1 GHz = 10^9 cycles/sec

The speed of light is $c = 3x10^8\ m/s$

Reflection Clicker Q

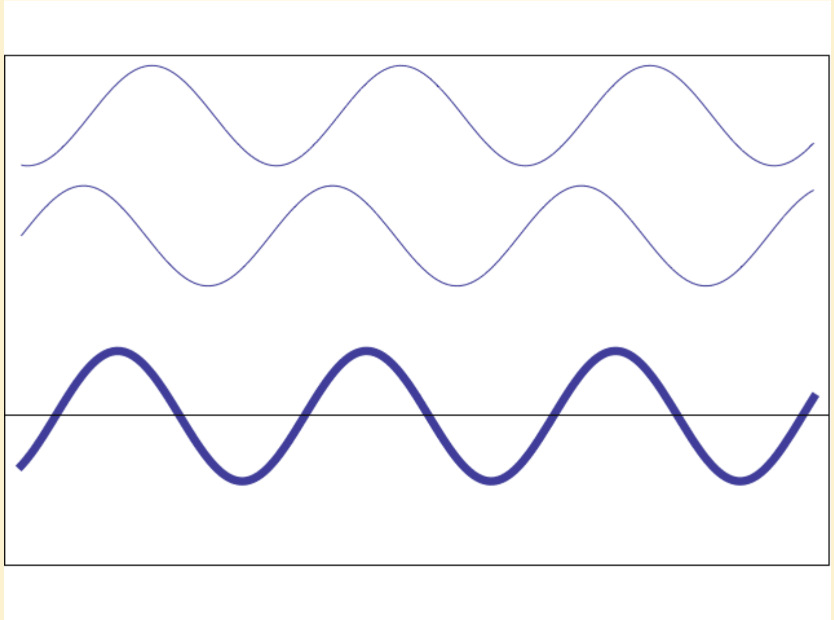
- A slinky is connected to a wall at one end. A pulse travels to the right, hits the wall and is reflected back to the left. The reflected wave is

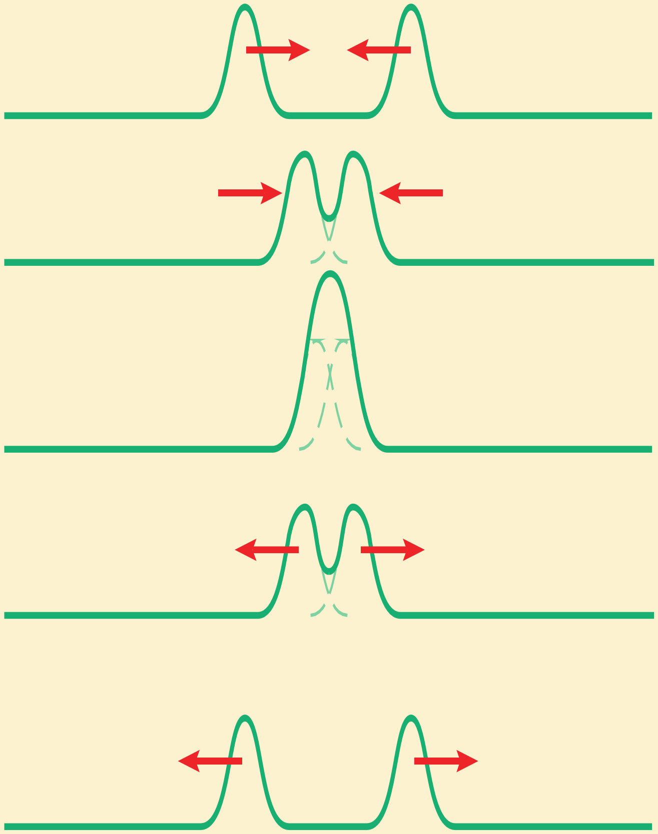


A) Inverted B) Upright

Interference and Superposition

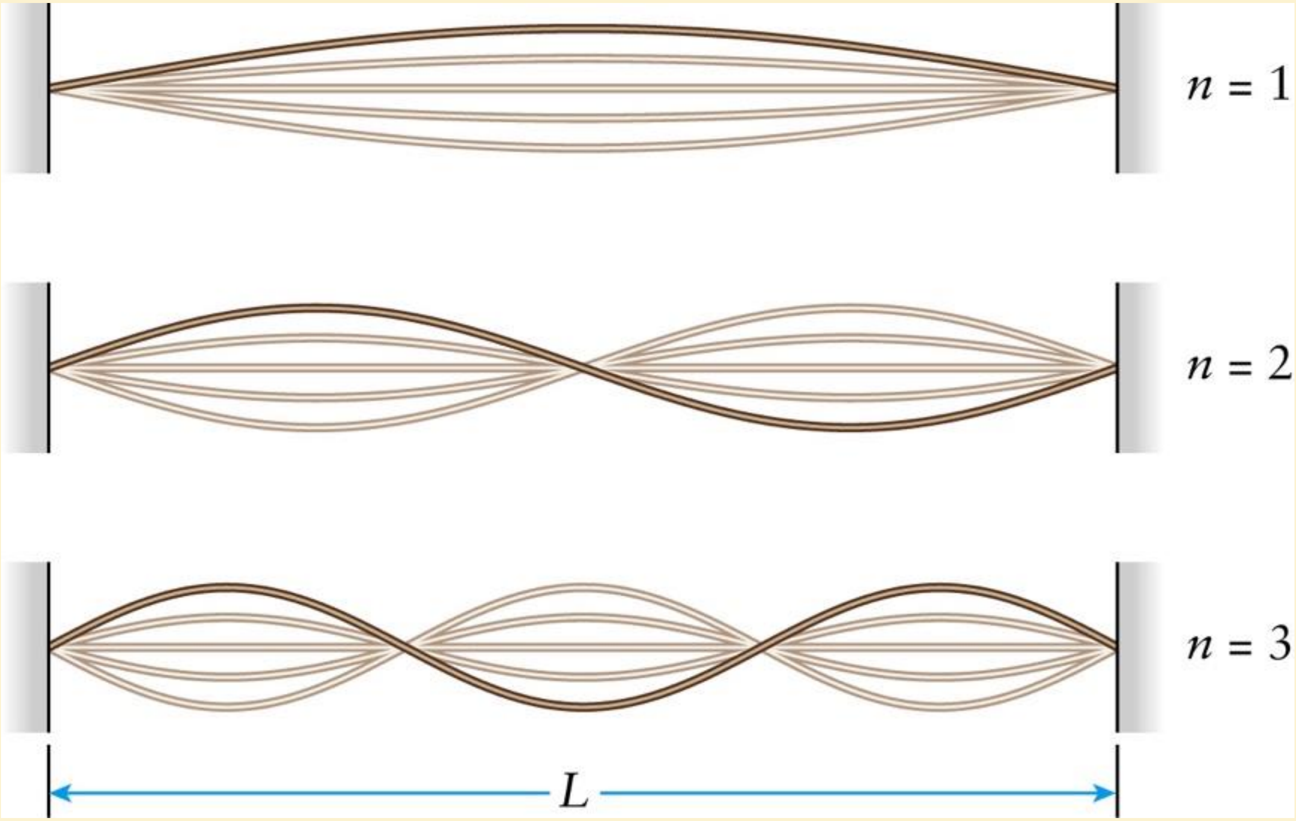
- When two waves overlap, the amplitudes add (sign important).
  - ➔Constructive interference: increases amplitude
  - ➔Destructive interference: decreases amplitude



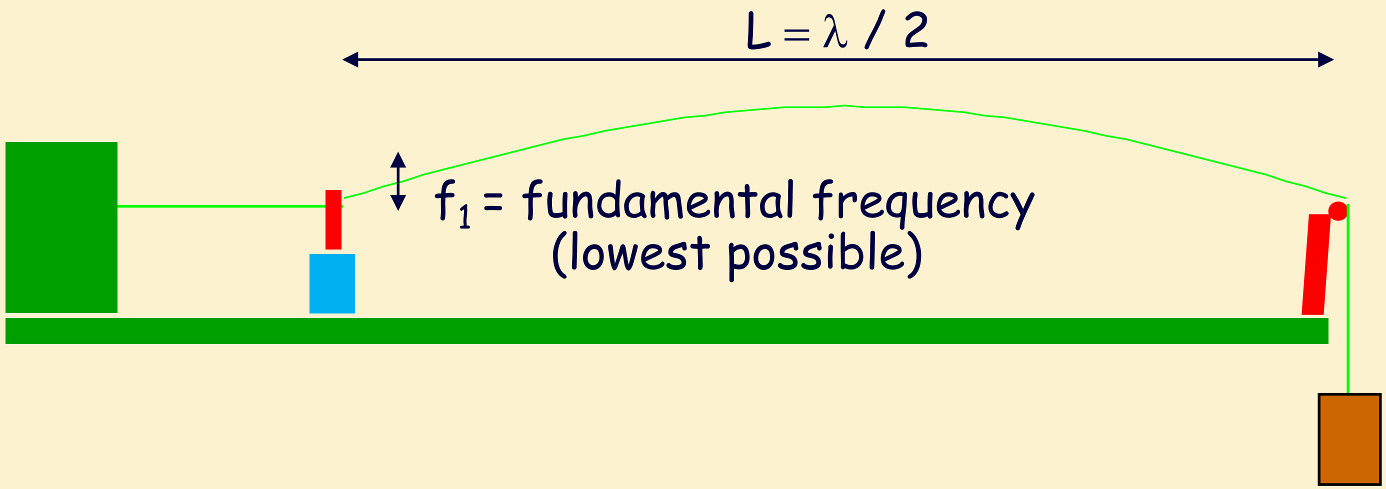


Standing Waves Fixed Endpoints

- Fundamental
  n=1 (2 nodes)
- $\lambda_n = 2L/n$
- $f_n = n\, v / (2L)$



Standing Waves Example



A guitar's E-string has a length of 65 cm and is stretched to a tension of 82N. If it vibrates with a fundamental frequency of 329.63 Hz, what is the mass of the string?

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

$f = v / \lambda$ tells us v if we know f (frequency) and λ (wavelength)

$v = \lambda f$
$= 2\,(0.65\text{ m})\,(329.63\text{ s}^{-1})$
$= 428.5\text{ m/s}$

$v^2 = T / \mu$
$\mu = T / v^2$
$m = T L / v^2$
$= 82\,(0.65) / (428.5)^2$
$= 2.9 \times 10^{-4}\text{ kg}$

Summary

- Wave Types
  - ➔ Transverse (e.g. pulse on string, water)
  - ➔ Longitudinal (sound, slinky)
- Harmonic
  - ➔ $y(x,t) = A\cos(\omega t - kx)$ or $A\sin(\omega t - kx)$
- Superposition
  - ➔ Just add amplitudes
- Reflection (fixed point inverts wave)
- Standing Waves (fixed ends)
  - ➔ $\lambda_n = 2L/n$
  - ➔ $f_n = n\,v / 2L$