STUDY GUIDE

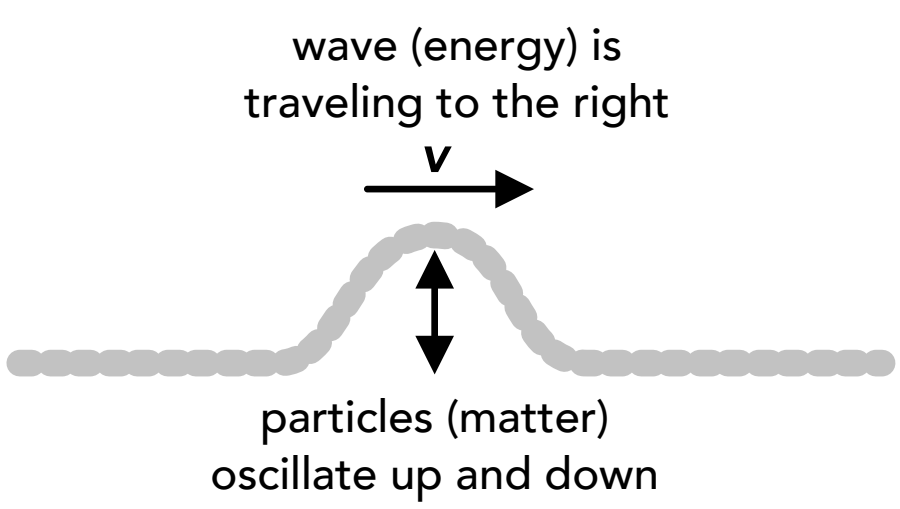
WAVES

Waves

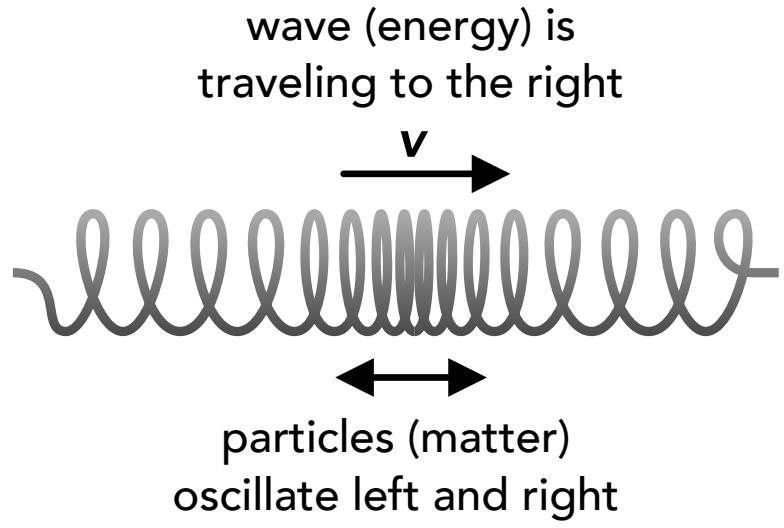
- There are many different types of waves which behave in different ways, but they all share similar characteristics.
- All waves carry or transport energy, and some waves also carry matter.
- **Transverse waves** are waves where the physical material moves **perpendicular** to the direction of the wave. If the wave is traveling to the right, the particles in the medium move up and down. Examples include water waves and waves traveling in a string.
- **Longitudinal waves** are waves where the physical material moves **parallel** to the direction of the wave. The particles in the medium do not travel with the wave, they just oscillate back and forth within a small distance. Examples include sound waves and longitudinal waves traveling in a spring.

Variables		SI Unit
λ	wavelength	m
T	period	s
f	frequency	$\text{Hz} = \frac{\text{cycles}}{\text{s}}$
A	amplitude	m, ...
v	velocity	$\frac{\text{m}}{\text{s}}$

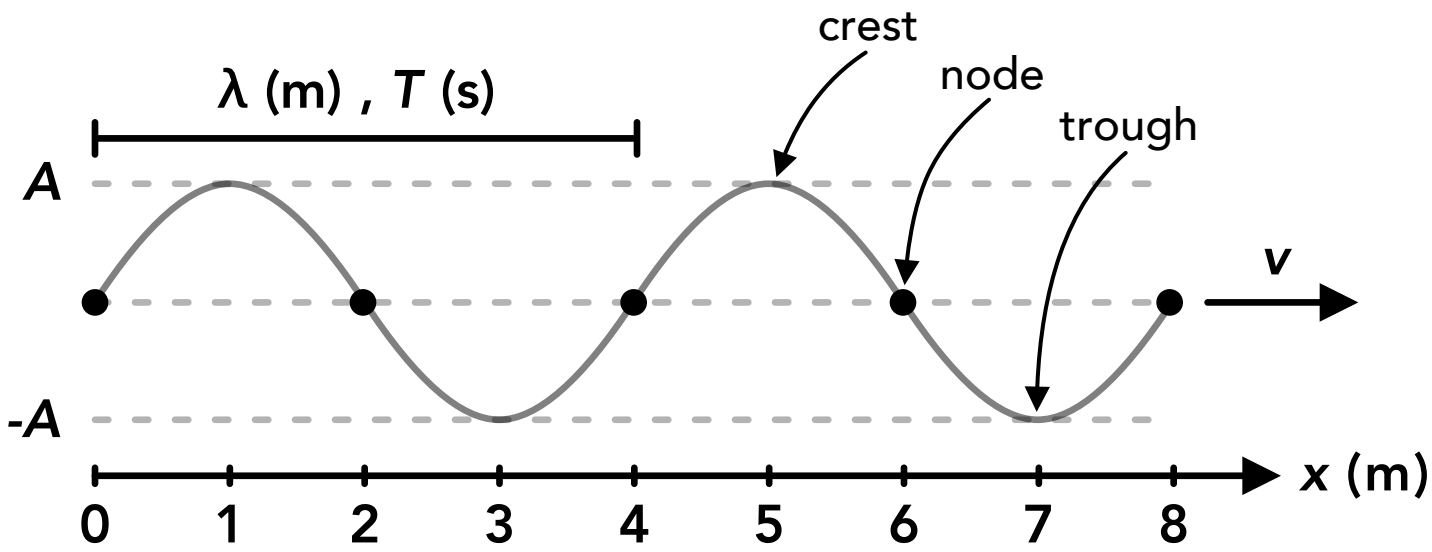
Transverse wave



Longitudinal wave

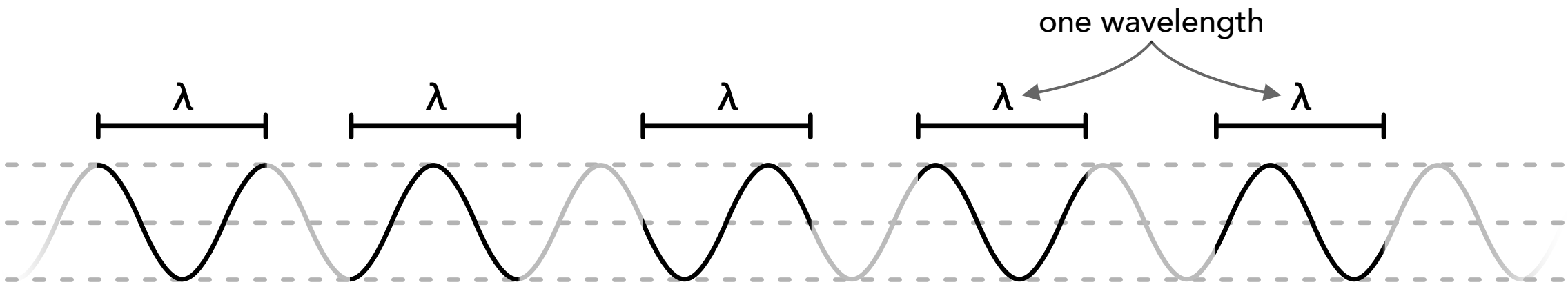


- A **crest** is the upper amplitude of a visual wave or graph of a wave. This is also an antinode.
- A **trough** is the lower amplitude of a visual wave or graph of a wave. This is also an antinode.
- A **node** is a point where the wave is at the center or equilibrium position.
- The **wavelength** is the length of a section that repeats and is easiest to measure as the distance between crests, the distance between troughs, or 3 nodes across.
- The **period** is the amount of time it takes the wave to travel one wavelength.
- The **wave speed** is the speed that the wave (energy) travels and is equal to the wavelength divided by the period.

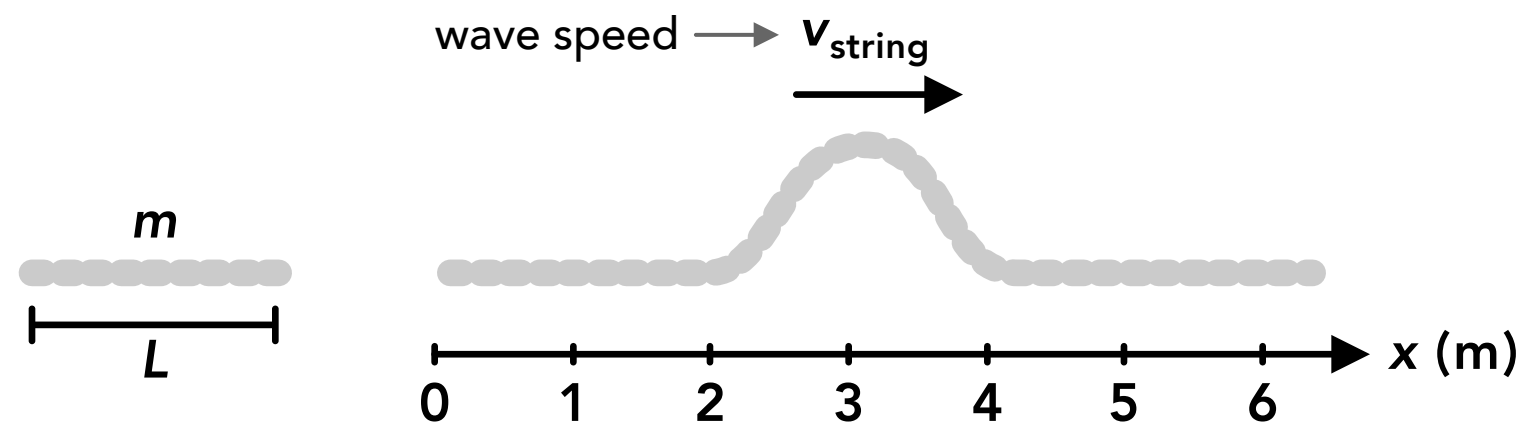


Wave speed

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



- If a wave is traveling on a string, the wave speed depends on the tension in the string and the linear mass density of the string (the mass per unit length).



Variables		SI Unit
μ	linear density	$\frac{kg}{m}$
m	mass	kg
L	length	m
T_s	string tension	N
v	velocity	$\frac{m}{s}$

Linear density

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

Speed of a wave in a string

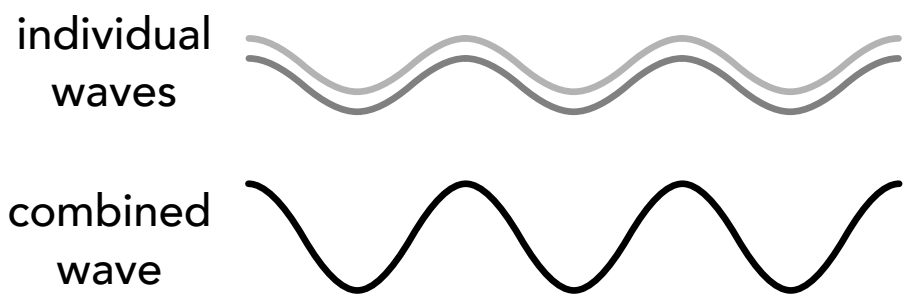
$$v_{string} = \sqrt{\frac{T_s}{\mu}}$$

Standing Waves

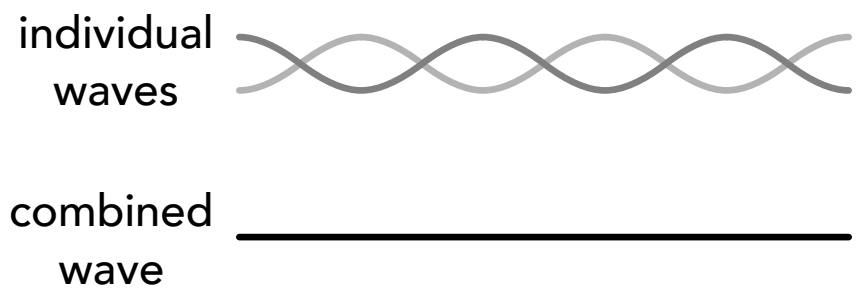
Variables		SI Unit
λ	wavelength	m
f	frequency	Hz
L	length	m
v	velocity	$\frac{m}{s}$
m	mode	

- When two waves overlap or interfere (they occupy the same space in the medium), their values at every position are added together, resulting in a new wave. At every point:
  - If the values of each wave have the same sign (positive or negative) the result is **constructive interference** and the waves "build" on each other, creating a larger wave.
  - If the values of each wave have opposite signs, the result is **destructive interference** and the waves "subtract" from each other, creating a smaller wave (or no wave if they completely cancel out).

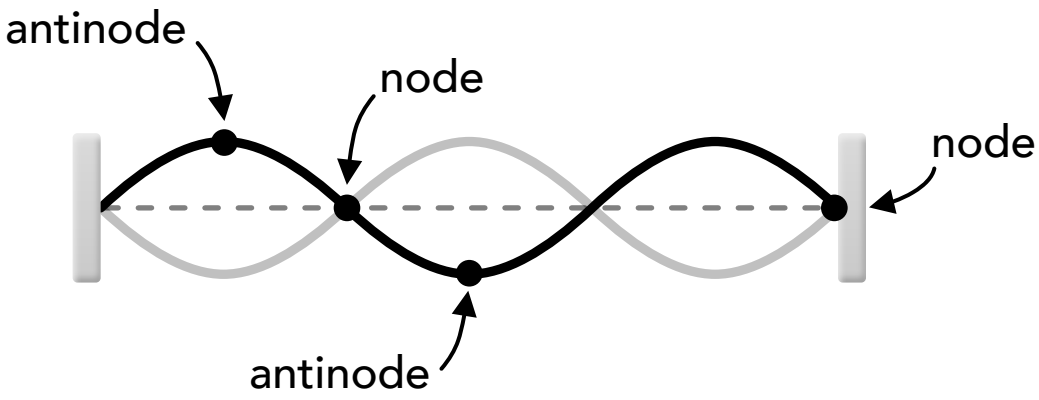
Constructive wave interference

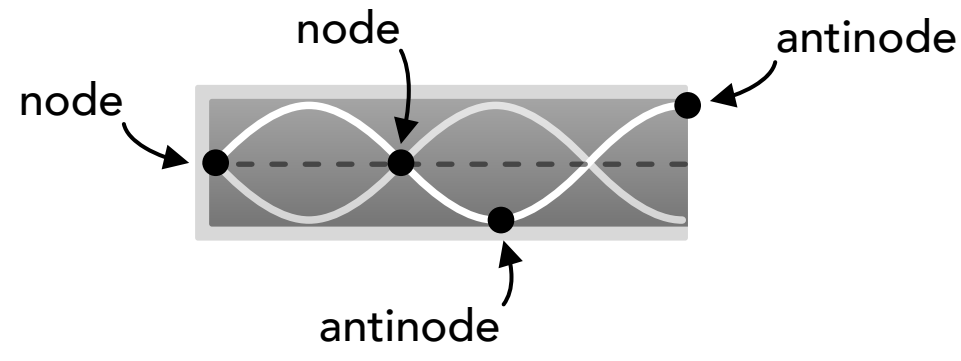


Destructive wave interference



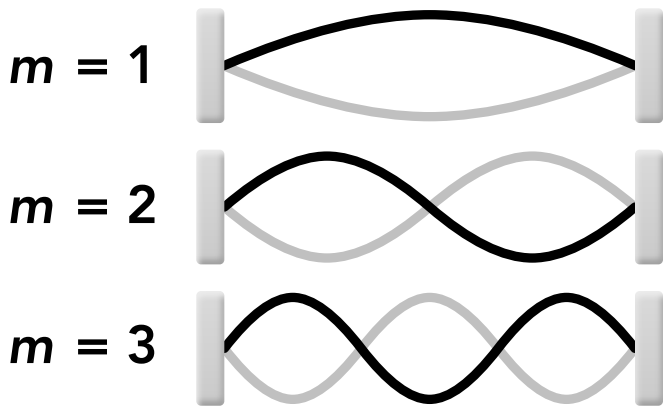
- When a wave is traveling in a medium (like air or a string) and it's **reflected** at one end, it travels back in the opposite direction. A wave may be reflected at both ends (of a tube or a string), moving back and forth.
- If multiple reflecting waves overlap we get standing waves.
- A **standing wave** is just the superposition of two waves reflecting back and forth, which results in the amplitudes of the waves appearing to switch between positive and negative but the wave doesn't travel anywhere.
- A **node** is a point on a standing wave that does not move (zero amplitude).
- An **antinode** is a point on a standing wave that moves the maximum amount (maximum amplitude).
- The wavelength of a standing wave, like any other wave, is the length of a section that repeats: the distance between two crests, the distance between two troughs, or the distance of 3 nodes across.
- A **mode** is the wave shape or the fractions of a wavelength that fit into the length of the medium. As the wavelength changes and more wavelengths fit into the length of the medium, new wave shapes are formed.





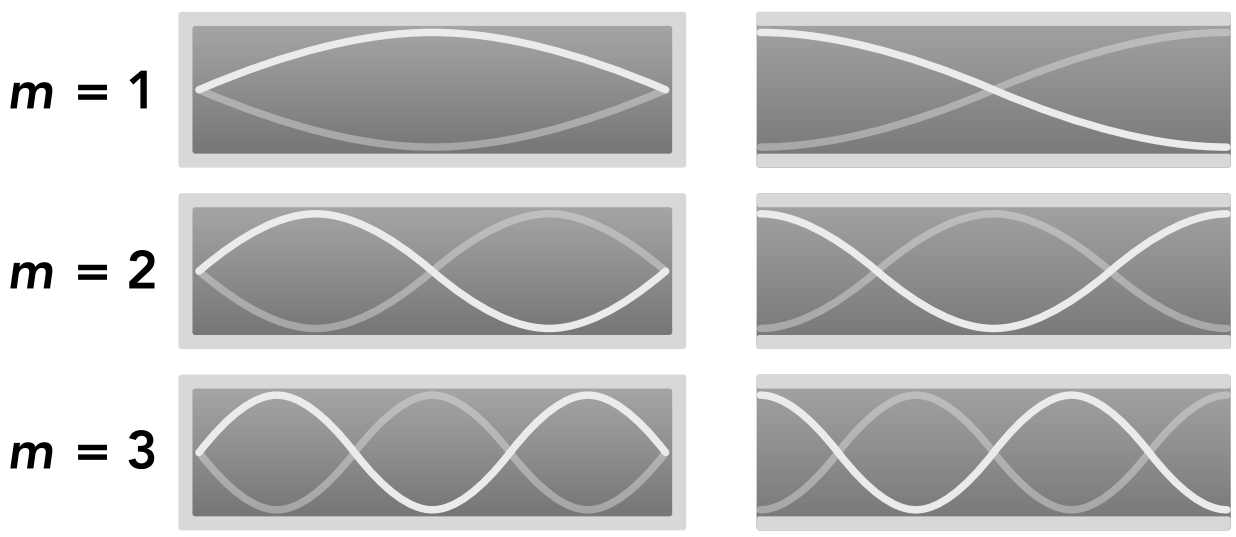
Both ends are either nodes or antinodes

String
(fixed at both ends)



Tube
(closed at both ends)

Tube
(open at both ends)



Wavelengths

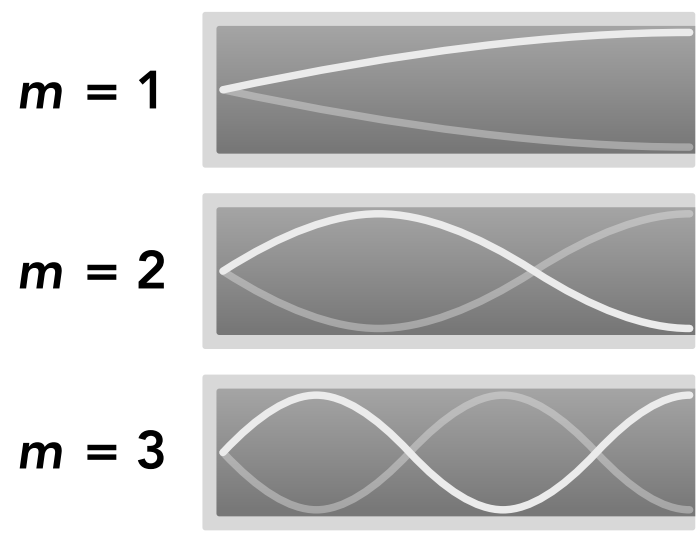
$$\lambda_m = \frac{2L}{m} \qquad m = 1, 2, 3, \ldots$$

Frequencies

$$f_m = \frac{v}{\lambda_m} = m\left(\frac{v}{2L}\right) \qquad m = 1, 2, 3, \ldots$$

One end is a node, one end is an antinode

Tube
(open/closed ends)



Wavelengths

$$\lambda_m = \frac{4L}{m} \qquad m = 1, 3, 5, \ldots$$

Frequencies

$$f_m = \frac{v}{\lambda_m} = m\left(\frac{v}{4L}\right) \qquad m = 1, 3, 5, \ldots$$