

Lectures: Physics 3306

Provides an introduction to a wide variety of topics in classical (pre-quantum) physics as a bridge to prepare students for subsequent upper-level courses in physics. The topics covered include thermodynamics, fluid mechanics, mechanical waves, optics, radiation, electromagnetic phenomena, atoms, and laboratory techniques. Prerequisites: C- or better in PHYS 1106; and in PHYS 1304 or PHYS 1308.

Saptaparna Bhattacharya

February 9th, 2026

Based on Simon Dalley's lectures taught in Spring 2025

Labs

Lectures

Schedule

No class

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
January	19	20	21 ✓	22	23 ✓	24	25
	26 ❄️☁️❄️❄️❄️	27	28 ❄️☁️❄️❄️❄️	29	30 ✓	31	1
February	2 ✓	3	4 ✓	5	6 ✓	7	8
	9 ✓	10	11 HWB due	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	1
March	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
April	30	31	1	2	3	4	5

Labs

Lectures

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No class

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April	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
May	27	28	29	30	1	2	3
	4	5	6	7	8	9	10



Transverse Waves

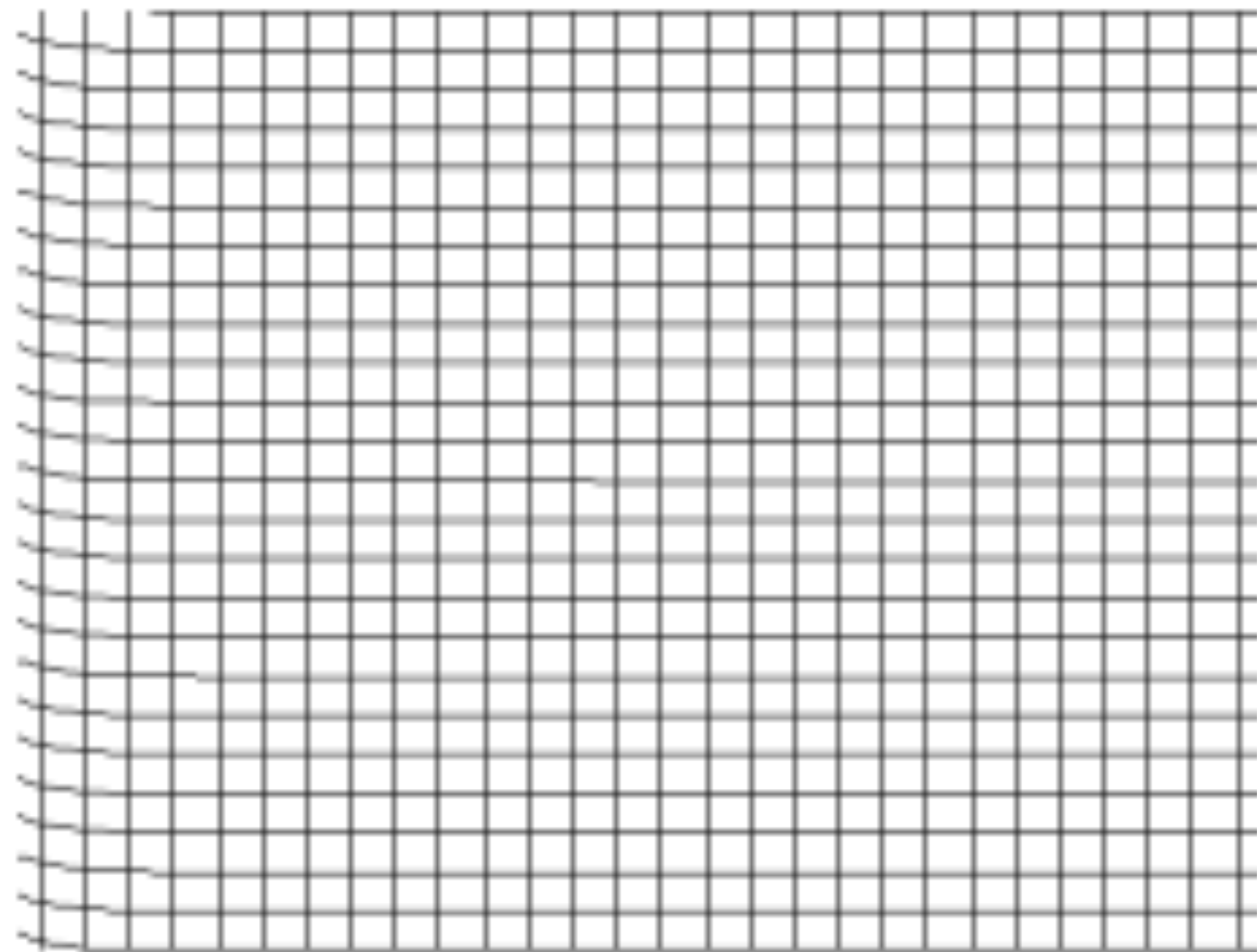
Book: 16.1-16.3

Key concepts

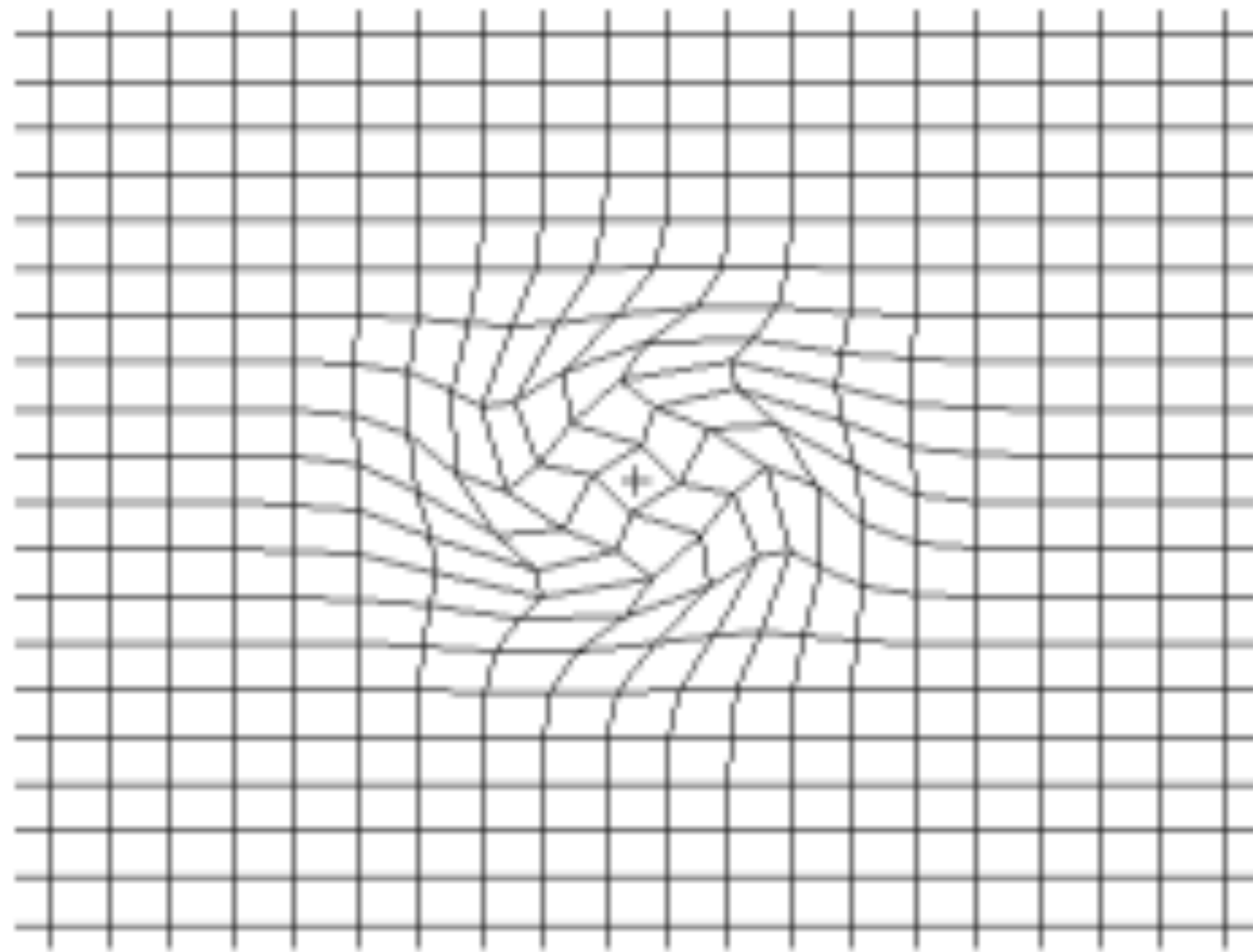
- Mechanical waves are governed by Newton's laws
- Transverse mechanical waves like those on a stretched string, are waves in which the particles of the medium oscillate perpendicular to the wave's direction of travel
- Waves in which the particles of the medium oscillate parallel to the wave's direction of travel are longitudinal waves



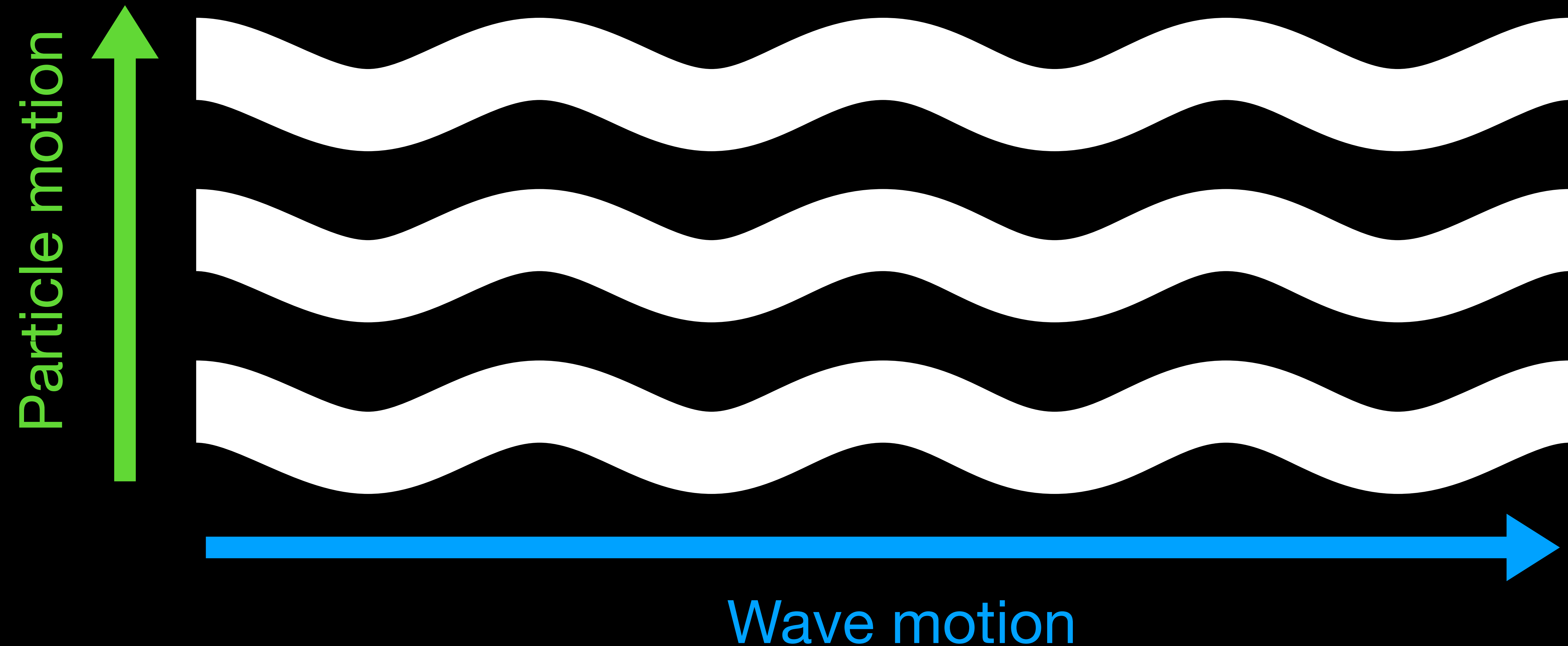
Key concepts



Key concepts: 2D waves



Key concepts: Transverse waves



Key concepts

- Types of waves:
 - Mechanical waves
 - Electromagnetic waves
 - Matter waves
- Can you give an example of each type of wave?

Key concepts

- Types of waves:
 - Mechanical waves
 - Commonly encountered: Water waves, sound waves
 - Electromagnetic waves
 - Visible and ultraviolet light
 - Travel through vacuum at the same speed c
 - Matter waves
 - Waves associated with electrons
- Most key concepts apply to all three kinds of waves

Key concepts: transverse waves

- First picture:
 - Pulse is sent
- Second picture:
 - Continuous simple harmonic motion (traveling to velocity \vec{v})
- Example of a transverse wave

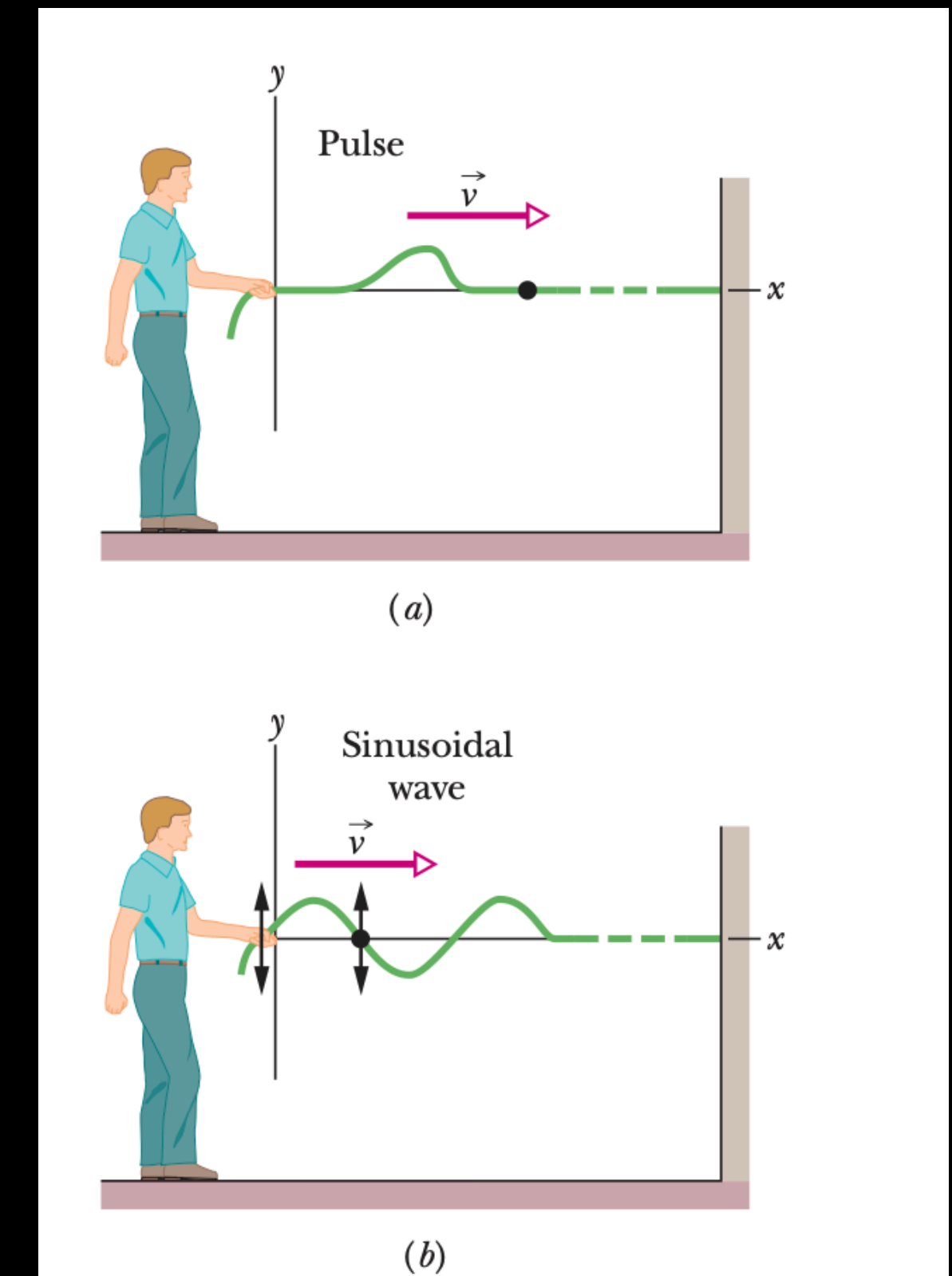


Figure 16-1 (a) A single pulse is sent along a stretched string. A typical string element (marked with a dot) moves up once and then down as the pulse passes. The element's motion is perpendicular to the wave's direction of travel, so the pulse is a *transverse wave*. (b) A sinusoidal wave is sent along the string. A typical string element moves up and down continuously as the wave passes. This too is a transverse wave.

Key concepts: longitudinal waves

- Produce a sound wave by moving the piston right to left
- Motion of the air and change in air pressure travel rightward along the pipe as a pulse

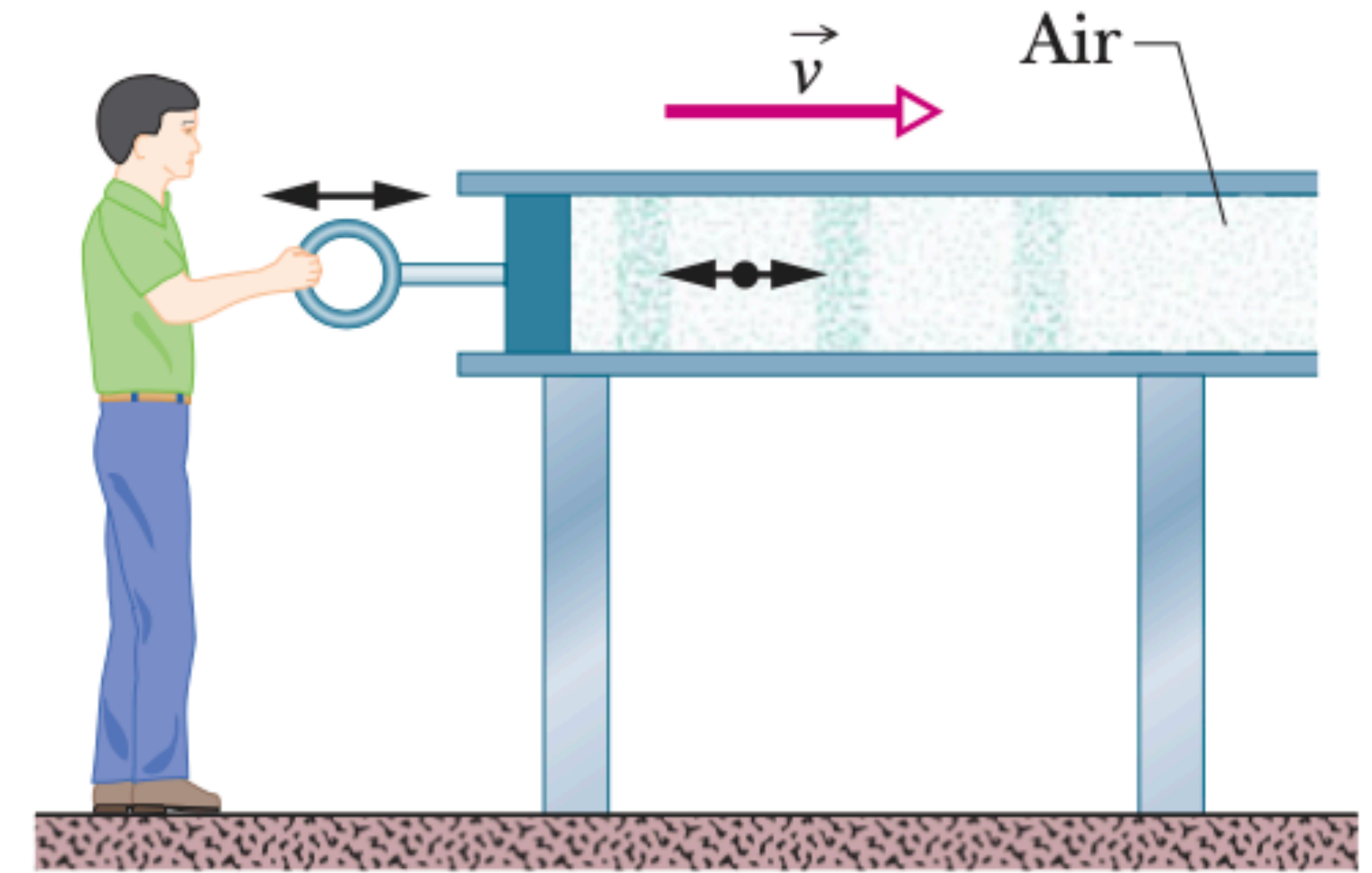
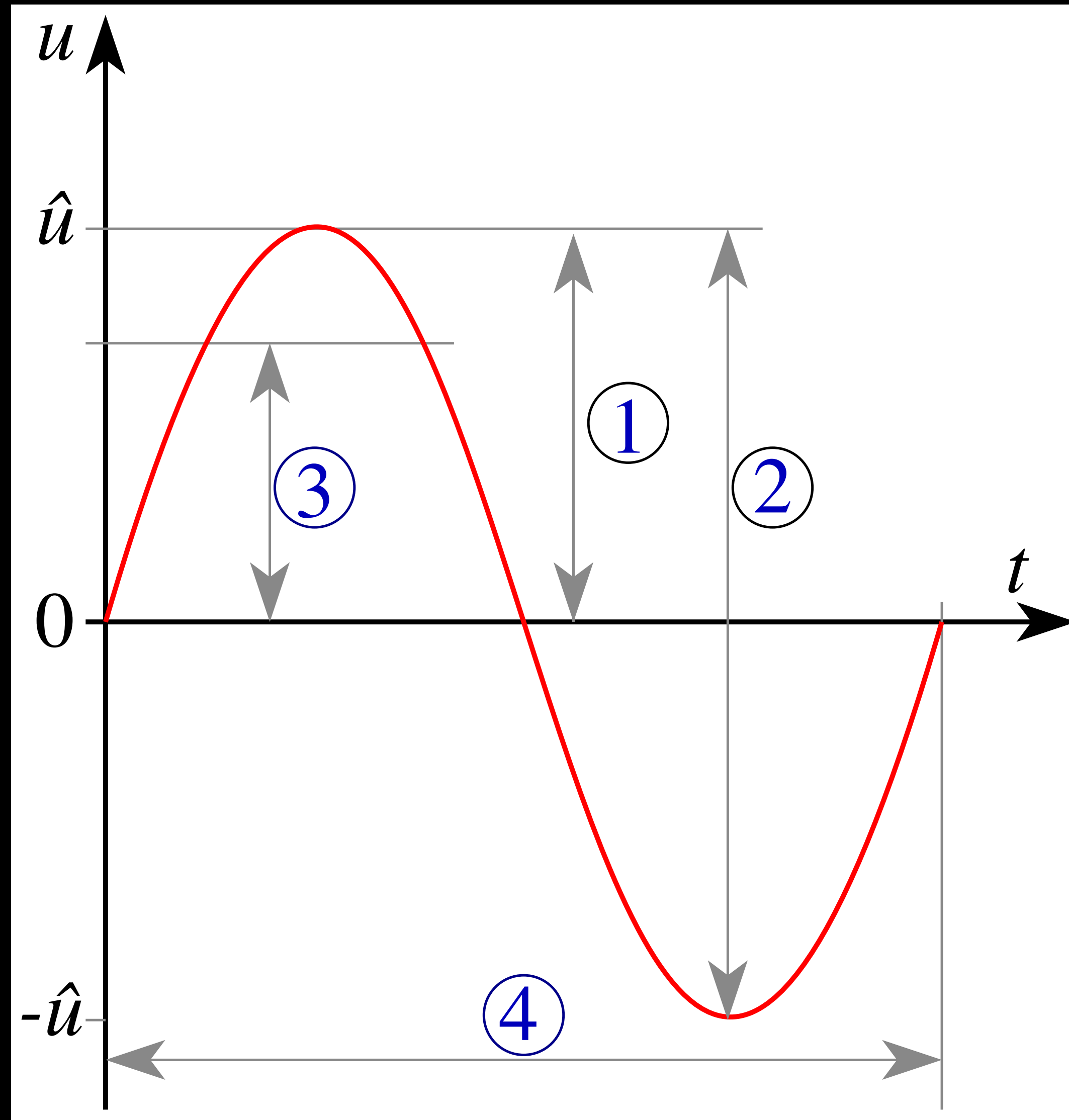


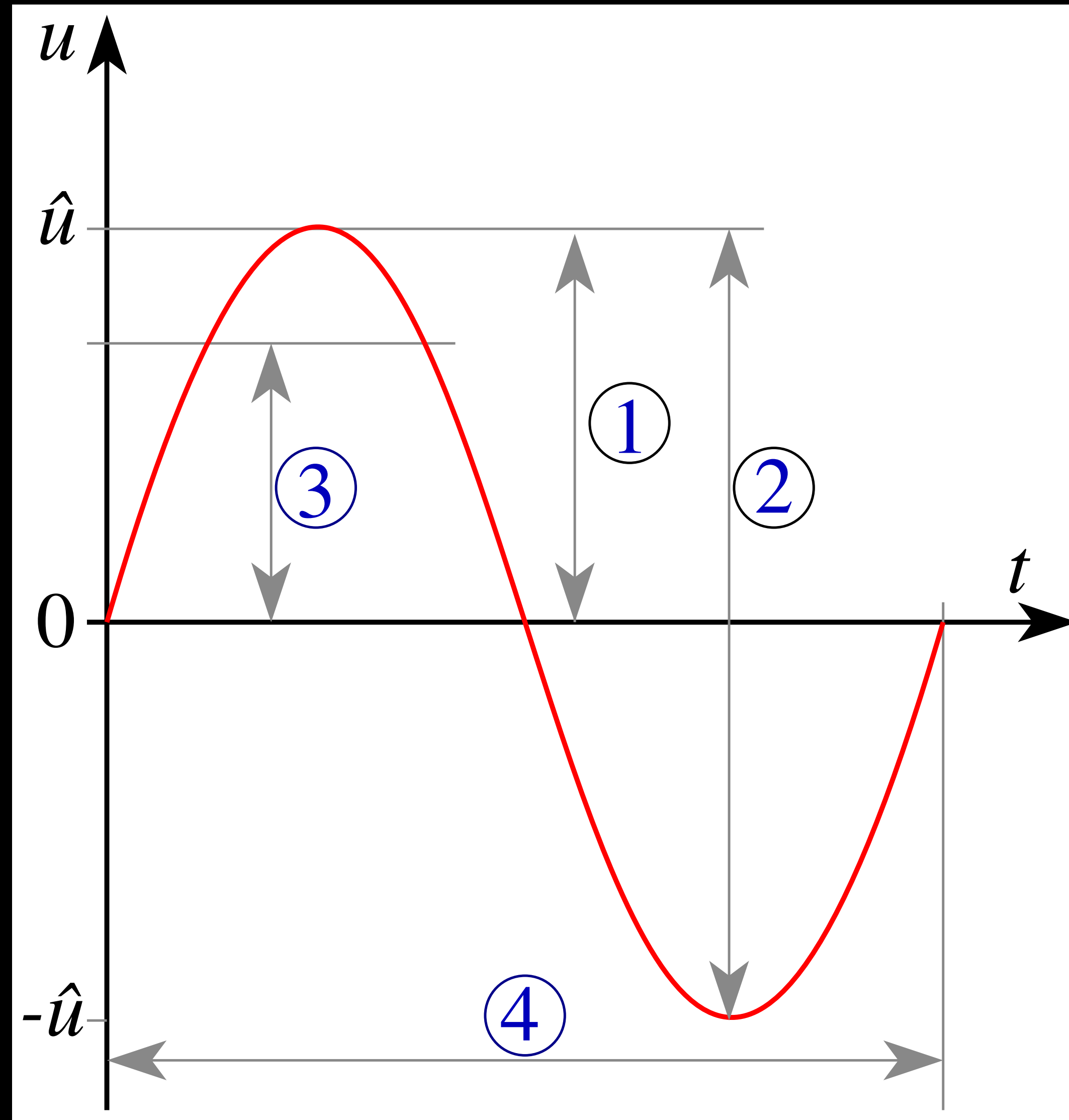
Figure 16-2 A sound wave is set up in an air-filled pipe by moving a piston back and forth. Because the oscillations of an element of the air (represented by the dot) are parallel to the direction in which the wave travels, the wave is a *longitudinal wave*.

Key concepts



Key concepts

1. Peak amplitude (y_m),
2. Peak-to-peak amplitude ($2y_m$),
3. Root mean square amplitude ($y_m/\sqrt{2}$)
4. Wave length



Key concepts

- A sinusoidal wave moving in the positive direction of an x -axis has the mathematical form:

- $y(x, t) = y_m \sin(kx - \omega t)$

- y_m = amplitude of the wave

- amplitude = magnitude of the maximum displacement of the wave

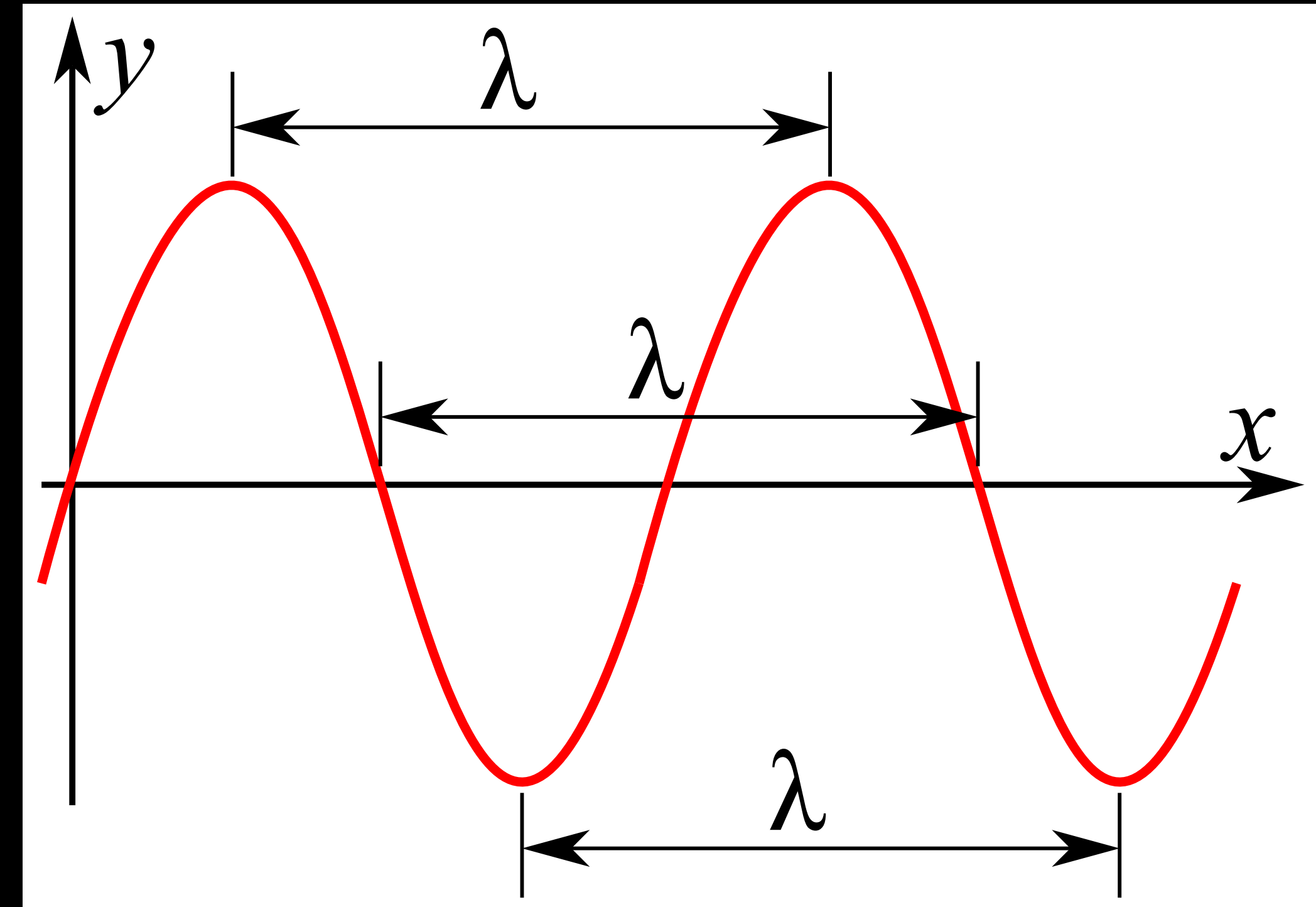
- k is the angular wave number

- ω is the angular frequency

- $kx - \omega t$ is the phase

- The wavelength λ is related to k by:

- $k = \frac{2\pi}{\lambda}$



Key concepts

- The period of oscillation T and frequency f of the wave are related to ω by:

- $$\frac{\omega}{2\pi} = f = \frac{1}{T}$$

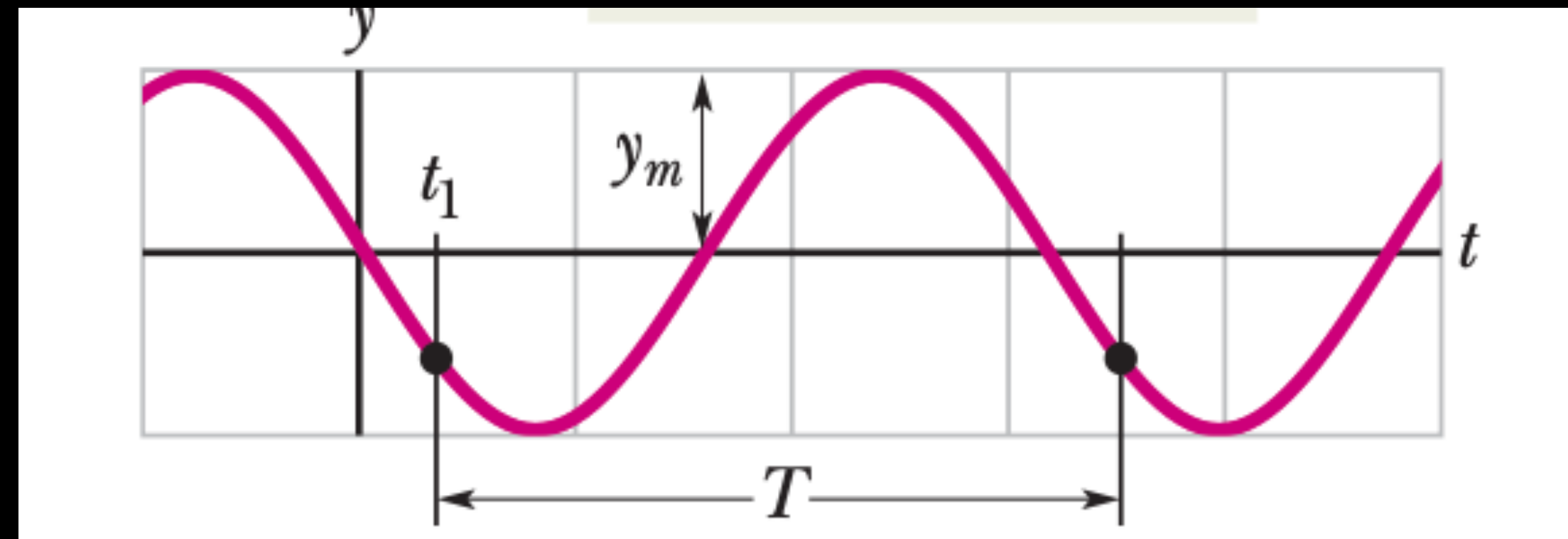
- The wave speed v (the speed of the wave along the string) is:

- $$v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$$

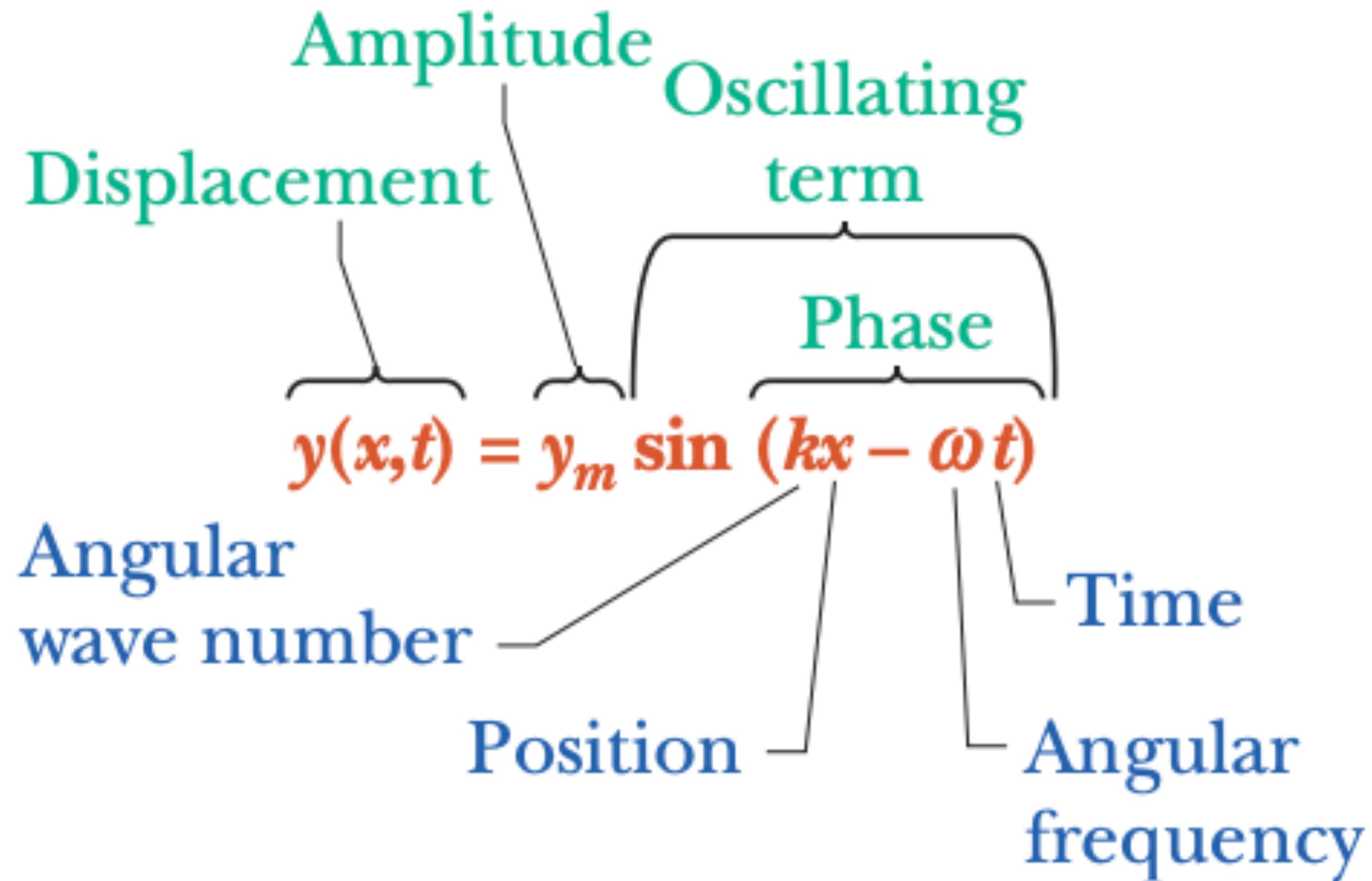
- Any function of the form: $y(x, t) = h(kx \pm \omega t)$ can represent a wave

- Sign (\pm) represents direction of motion:

- $+$ negative direction of x -axis
- $-$ positive direction of x -axis



Key concepts



The drawing shows the vertical position of points along a string
versus

distance as a wave travels along the string.

Between which two points is the length of the segment equal to one wavelength?

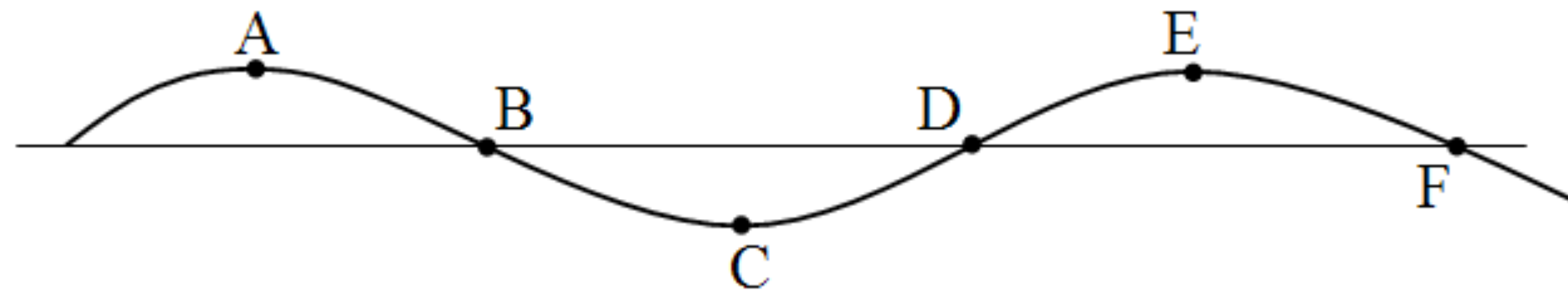
a) A to E

b) B to D

c) A to C

d) A to F

e) C to F



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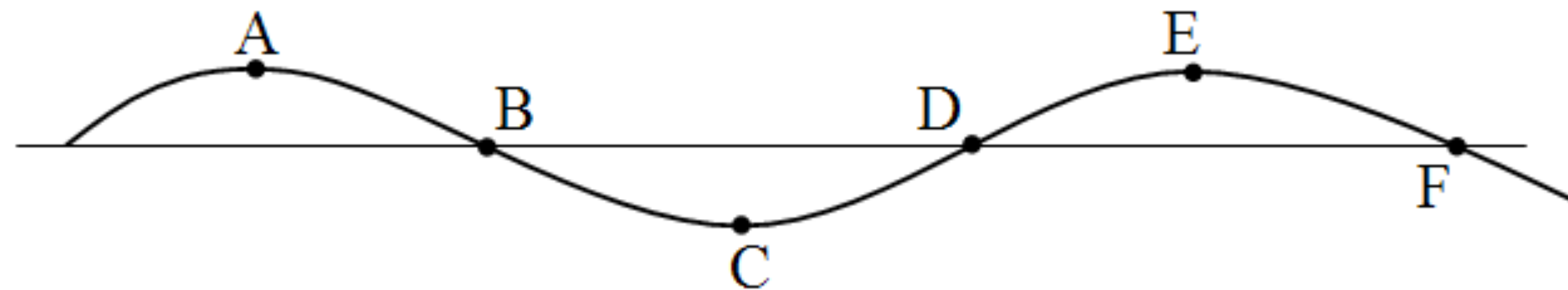
a) A to E

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e) C to F



A transverse wave with an amplitude of 0.2 m moves along a string with a speed of 2 m/s.

Which one of the following statements concerning this wave is true?

- a) Each particle in the string moves a distance of 2 m each second.
- b) Each particle in the string moves a distance of 0.8 m perpendicular to the wave during each period.
- c) Each particle in the string moves a distance of 0.8 m parallel to the wave during each period.
- d) Each particle in the string moves a distance of 0.4 m perpendicular to the wave during each period.
- e) Each particle in the string has a wavelength of 0.4 m.

A transverse wave with an amplitude of 0.2 m moves along a string with a speed of 2 m/s.

Which one of the following statements concerning this wave is true?

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- b) Each particle in the string moves a distance of 0.8 m perpendicular to the wave during each period. (**Calculation:** Total distance = $4 \times \text{Amplitude}$, Distance = $4 \times 0.2 \text{ m} = 0.8 \text{ m}$)
- c) Each particle in the string moves a distance of 0.8 m parallel to the wave during each period.
- d) Each particle in the string moves a distance of 0.4 m perpendicular to the wave during each period.
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Key concepts

- Rewriting the equation of a sinusoidal wave moving in the positive direction of an x -axis:

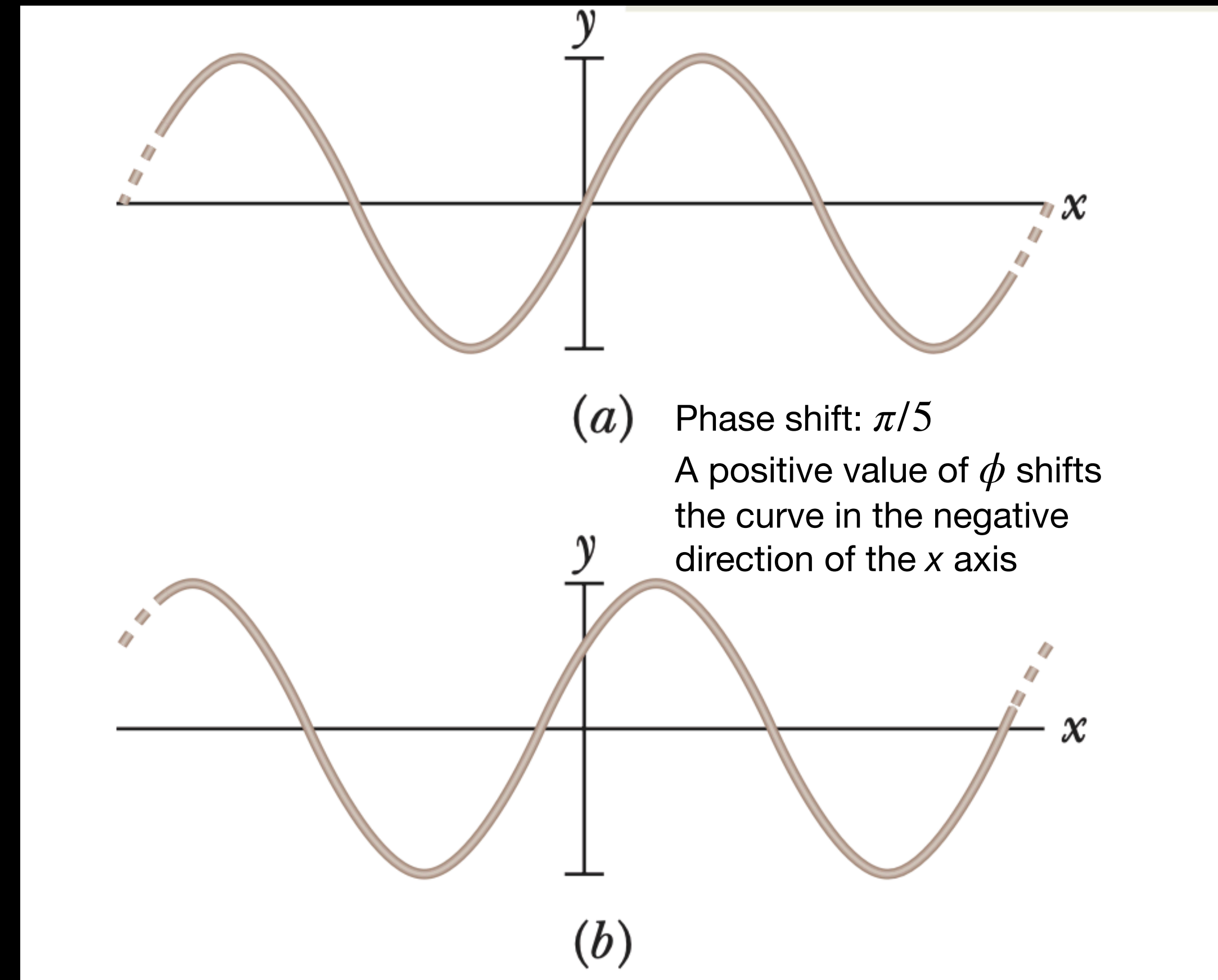
- $y(x, t) = y_m \sin(kx - \omega t)$

- Let's introduce a phase constant:

- $y = y_m \sin(kx - \omega t + \phi)$

- A positive value of ϕ shifts the curve in the negative direction of the x axis

- A negative value of ϕ shifts the curve in the positive direction of the x axis



- Sign (\pm) represents direction of motion:
 - + negative direction of x -axis
 - - positive direction of x -axis

A “right moving” wave is: $A \cos(kz - \omega t + \delta)$

Which of these do you prefer for a “left moving” wave?

A) $f_L(z, t) = A \cos(kz + \omega t + \delta)$

B) $f_L(z, t) = A \cos(kz + \omega t - \delta)$

C) $f_L(z, t) = A \cos(-kz - \omega t + \delta)$

D) $f_L(z, t) = A \cos(-kz - \omega t - \delta)$

E) more than one of these!

(Assume k , ω , δ are positive quantities)

To think about; Is(are) the answer(s) really just “preference” (i.e. human convention) or are we forced into a choice?

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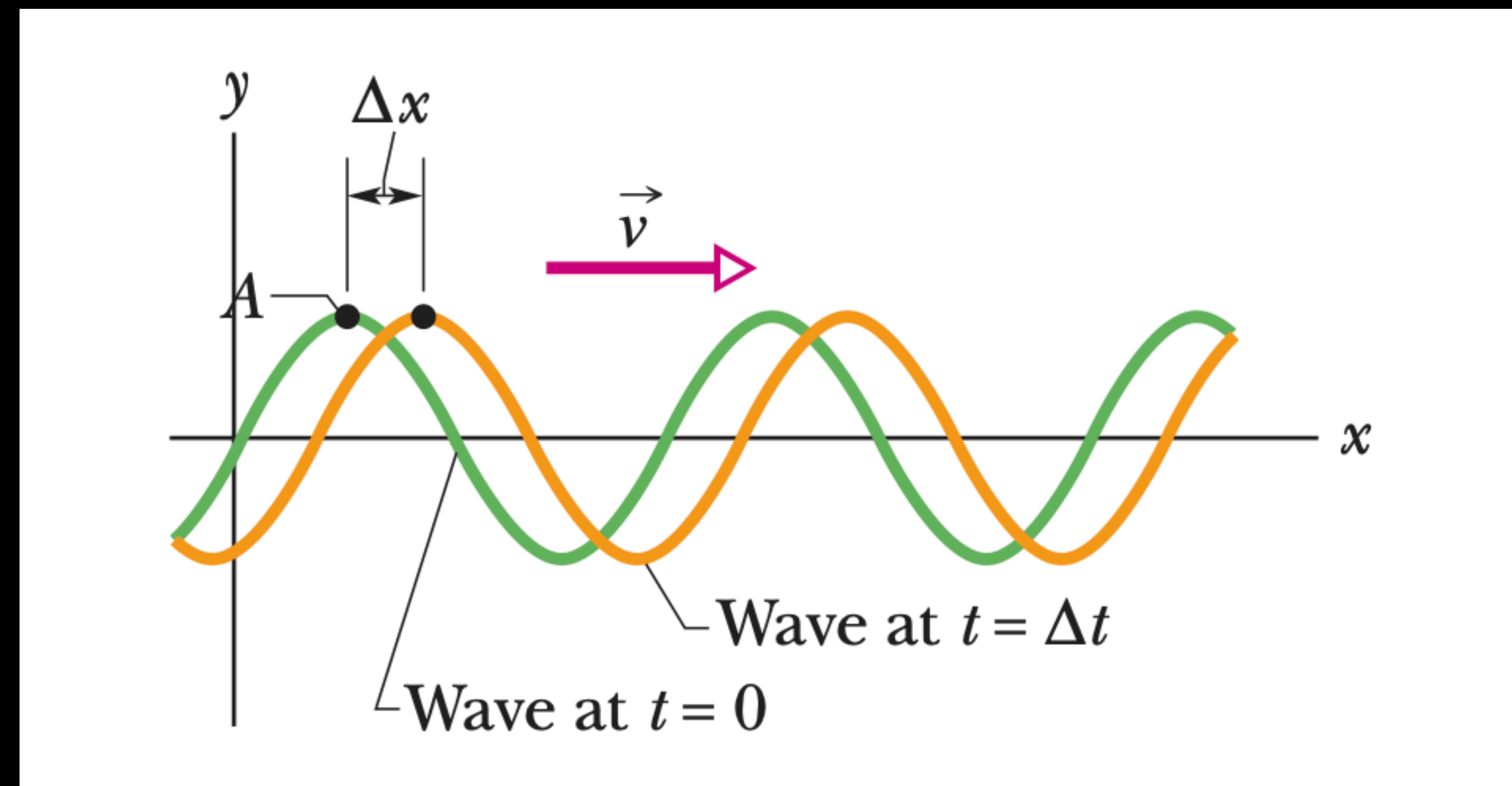
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To think about; Is(are) the answer(s) really just “preference” (i.e. human convention) or are we forced into a choice?

Key concepts

- Rewriting the equation of a sinusoidal wave moving in the positive direction of an x-axis:
 - $y(x, t) = y_m \sin(kx - \omega t)$
- Computing the speed of the wave v
 - Note that $kx - \omega t = \text{constant}$
 - Follows from the very nature of a periodic motion
 - To find speed, take derivative of $(kx - \omega t)$



Curve shifts a distance Δx during Δt
Point A “rides” with the wave form, but the string elements move up and down

Key concepts

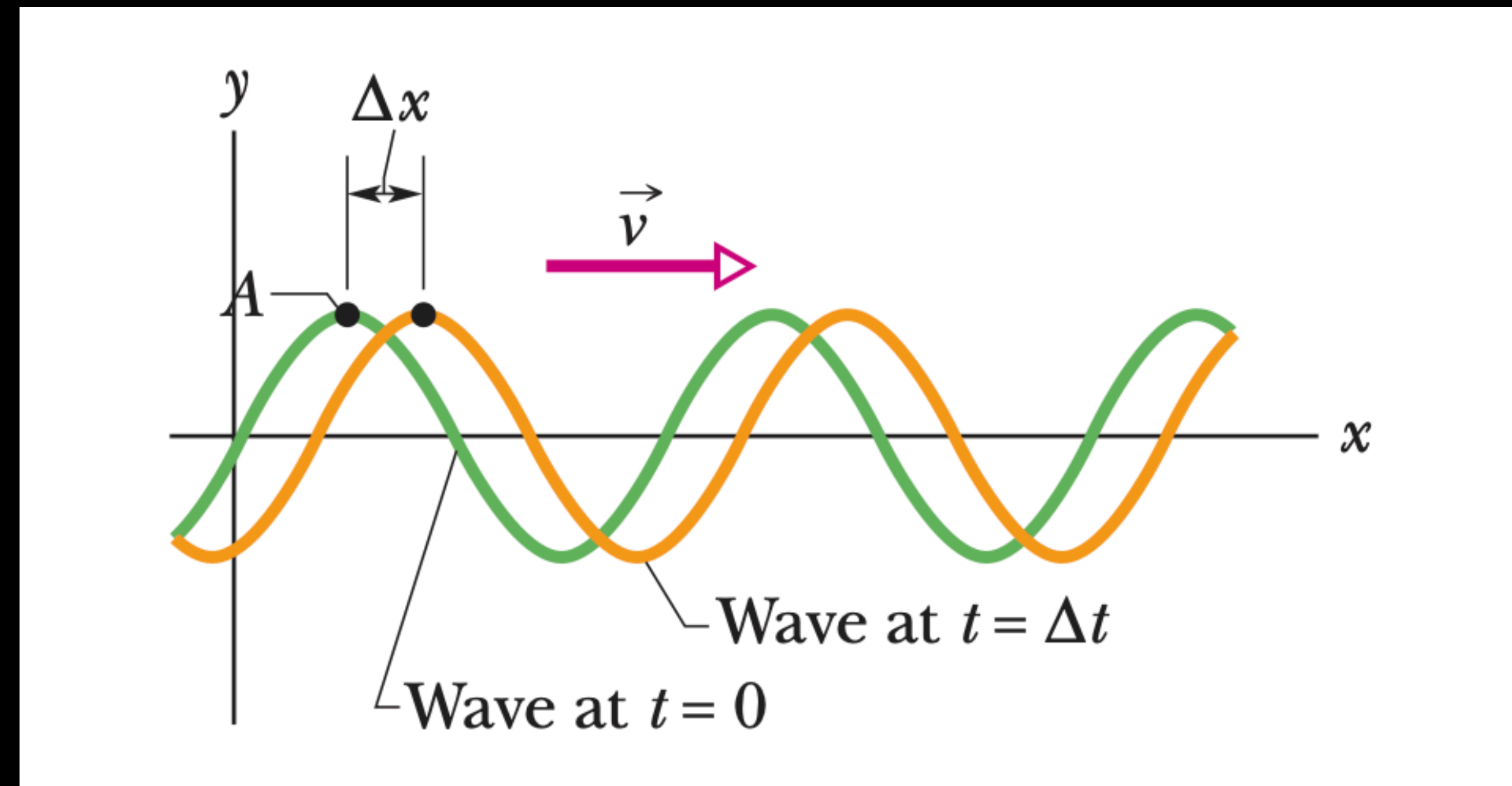
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 - To find speed, take derivative of $(kx - \omega t)$

- $k \frac{dx}{dt} - \omega = 0$

- $\frac{dx}{dt} = v = \frac{\omega}{k}$

- $k = 2\pi/\lambda$ and $\omega = 2\pi/T$

- $v = \frac{\omega}{k} = \frac{\lambda}{T} = \lambda f$ (wave speed)



Curve shifts a distance Δx during Δt
Point A “rides” with the wave form, but the string elements move up and down

The equation for a certain transverse wave is

$$y = 8 \sin [4t + 2x]$$

where y and x are measured in meters and t is measured in seconds.

What is the velocity of this wave?

- a) 2 m/s in the $+x$ direction
- b) 2 m/s in the $-x$ direction
- c) 4 m/s in the $-x$ direction
- d) 4 m/s in the $+x$ direction
- e) 8 m/s in the $+x$ direction

The equation for a certain transverse wave is

$$y = 8 \sin [4t + 2x]$$

where y and x are measured in meters and t is measured in seconds.

What is the velocity of this wave?

- a) 2 m/s in the $+x$ direction
- b) 2 m/s in the $-x$ direction**
- c) 4 m/s in the $-x$ direction
- d) 4 m/s in the $+x$ direction
- e) 8 m/s in the $+x$ direction

$$y = 8 \sin [4t + 2x]$$

Solution

The general form of a traveling wave is given by:

$$y(x, t) = A \sin(\omega t \pm kx) \tag{2}$$

1. Identifying Parameters

By comparing the given equation to the general form, we identify the following constants:

- Angular frequency (ω): 4 rad/s
- Wave number (k): 2 rad/m

2. Calculating Wave Speed

The wave speed (v) is defined as the ratio of the angular frequency to the wave number:

$$v = \frac{\omega}{k} \quad (3)$$

Substituting the values:

$$v = \frac{4}{2} = 2 \text{ m/s} \quad (4)$$

A wave is

$$\cos(kz - \omega t + \delta)$$

If δ is small (and > 0), is this wave “delayed” or “advanced”?

A) delayed

B) advanced

C) neither, depends on values of z and t .

A wave is

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A) **delayed**

B) advanced

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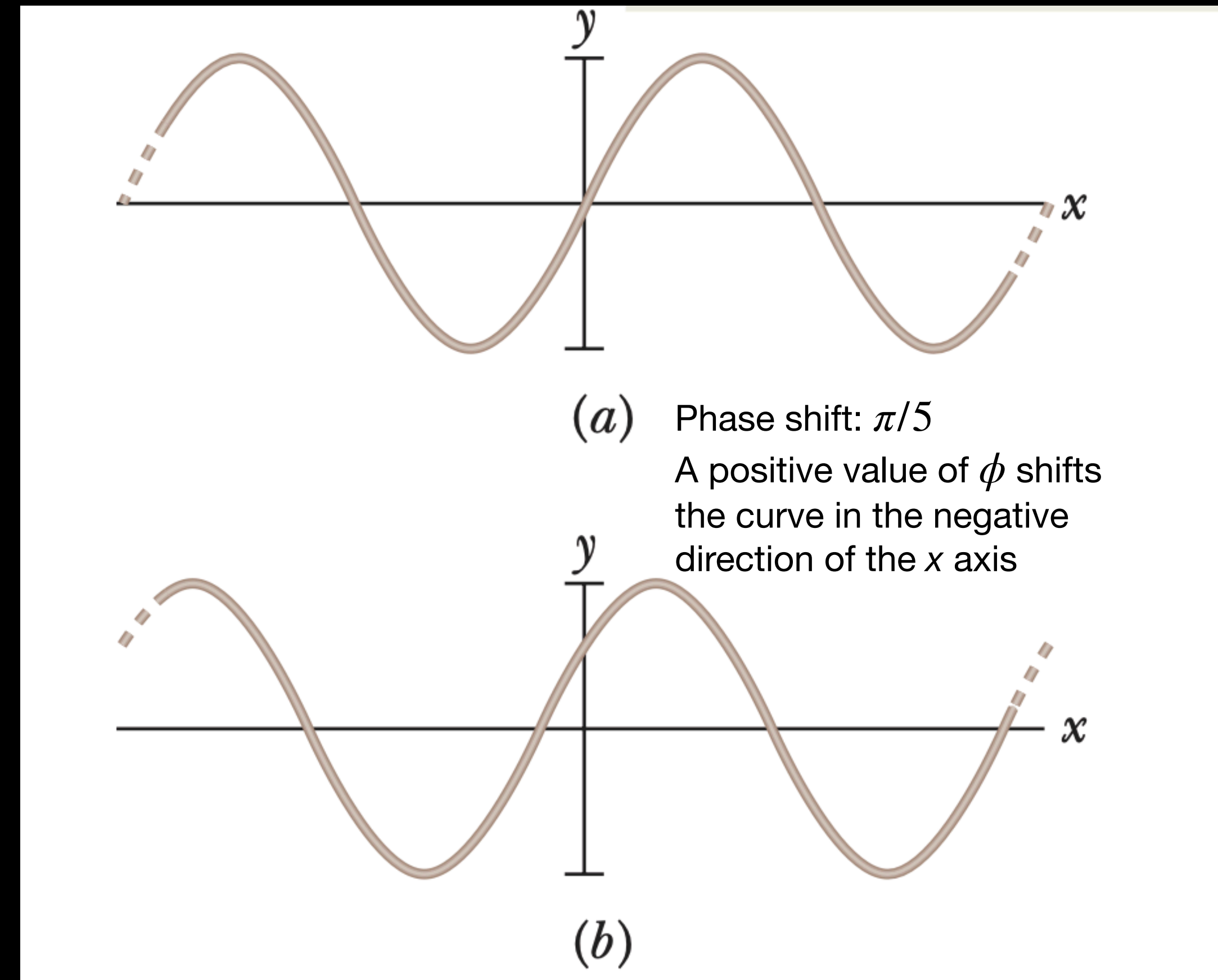
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A tsunami initiated off the western coast of South America reaches the Hawaiian Islands within 15 hours. Assume it's a transverse wave.

Which one of the following statements concerning the tsunami is correct?

- a) The tsunami carried water from the earthquake center to Hawaii, but it did not carry energy to Hawaii from South America.
- b) The tsunami carried energy and water from the earthquake center to Hawaii.
- c) The tsunami carried energy from the earthquake center to Hawaii, but it did not carry water to Hawaii from South America.
- d) The tsunami did not carry energy or water from the earthquake center to Hawaii.

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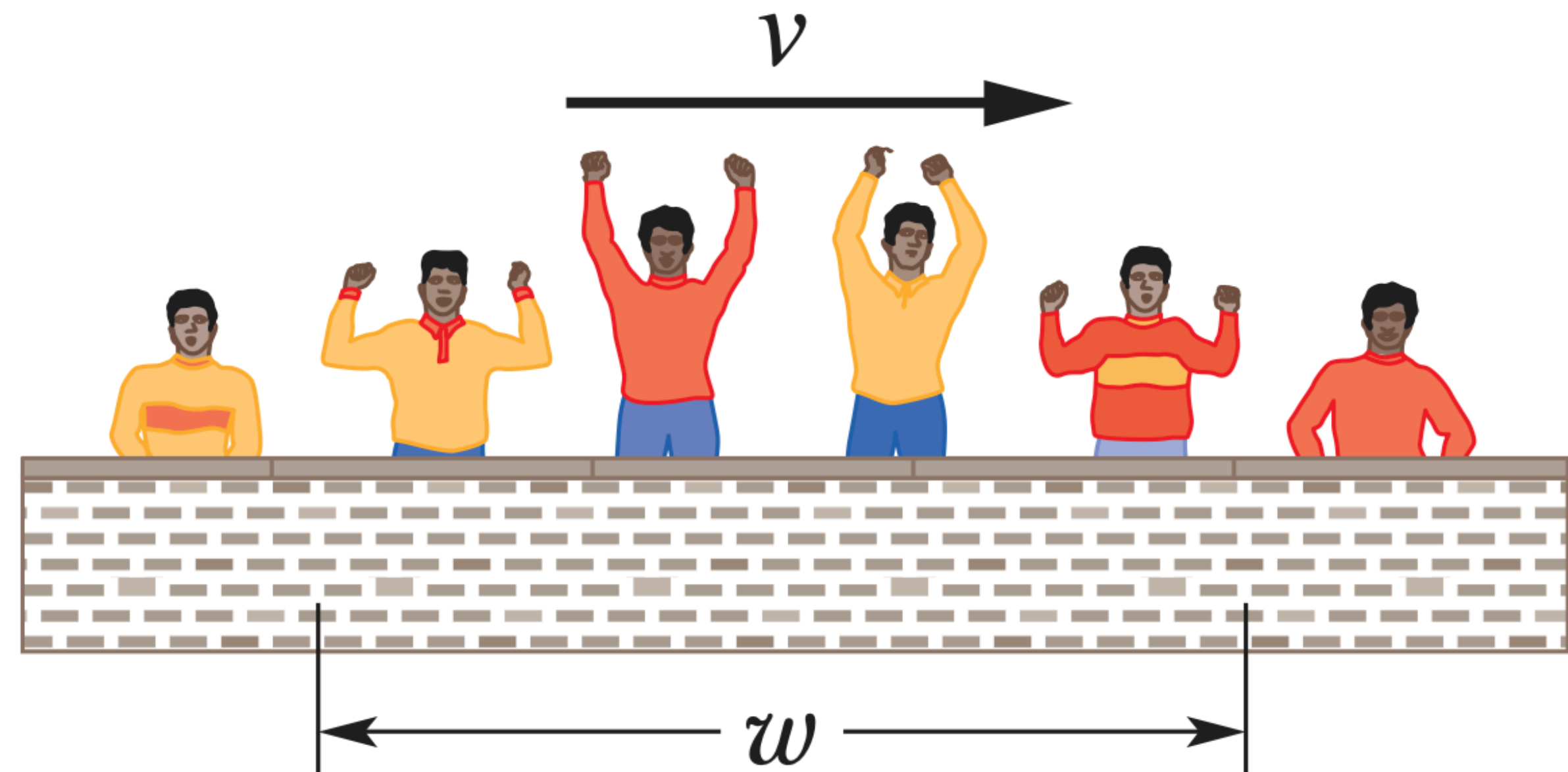
- a) Incorrect:** claims energy is not carried, which is the primary function of a wave.
- b) Incorrect:** claims matter (water) is carried across the ocean as part of the wave
- c) Correct:** This accurately states that energy is transported, but the actual water (matter) stays in the same general area.
- d) Incorrect:** claims neither energy nor water is carried.

A Human Wave

At any instant, the width w of this transverse wave is the distance from the leading edge (people in the crowd are just about to stand) to the trailing edge (people have just sat down). Suppose a human wave travels a distance of 884 seats around a stadium in 37.3 s, with spectators requiring about 1.9 s to respond to the wave's passage by standing and then sitting.

(a) What is the wave speed v ?

(b) What is the width w ?



A Human Wave

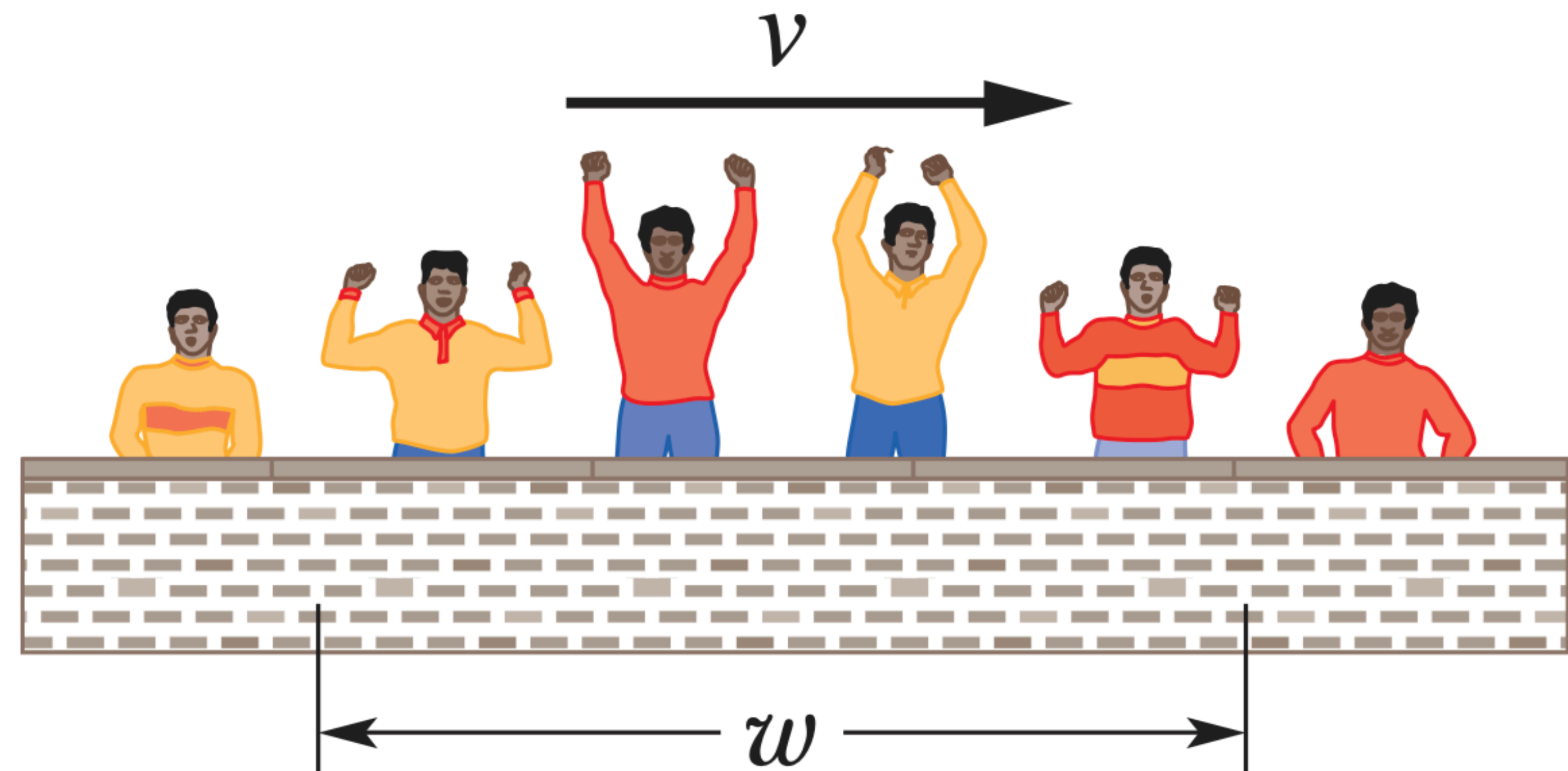
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(a) What is the wave speed v ?

23.7 seats/sec

(b) What is the width w ?

45 seats



(a) What is the wave speed v ?

The wave travels a distance of **884 seats** in a time of **37.3 s**.

Using the standard formula for speed:

$$v = \text{distance} / \text{time}$$

$$v = 884 / 37.3 \text{ s}$$

$$v \approx \mathbf{23.7 \text{ seats/s}}$$

(b) What is the width w ?

The width w is the distance between the leading edge (people starting to stand) and the trailing edge (people who have just sat down).

The problem states that it takes a spectator **1.9 s** to complete the cycle of standing and then sitting. This time interval represents the “duration” of the wave at any single point. To find the physical width w of the wave, we multiply the wave speed by this time interval:

$$w = v \times \text{time interval}$$

$$w = 23.7 \text{ seats/s} \times 1.9 \text{ s}$$

$$\mathbf{w \approx 45 \text{ seats}}$$

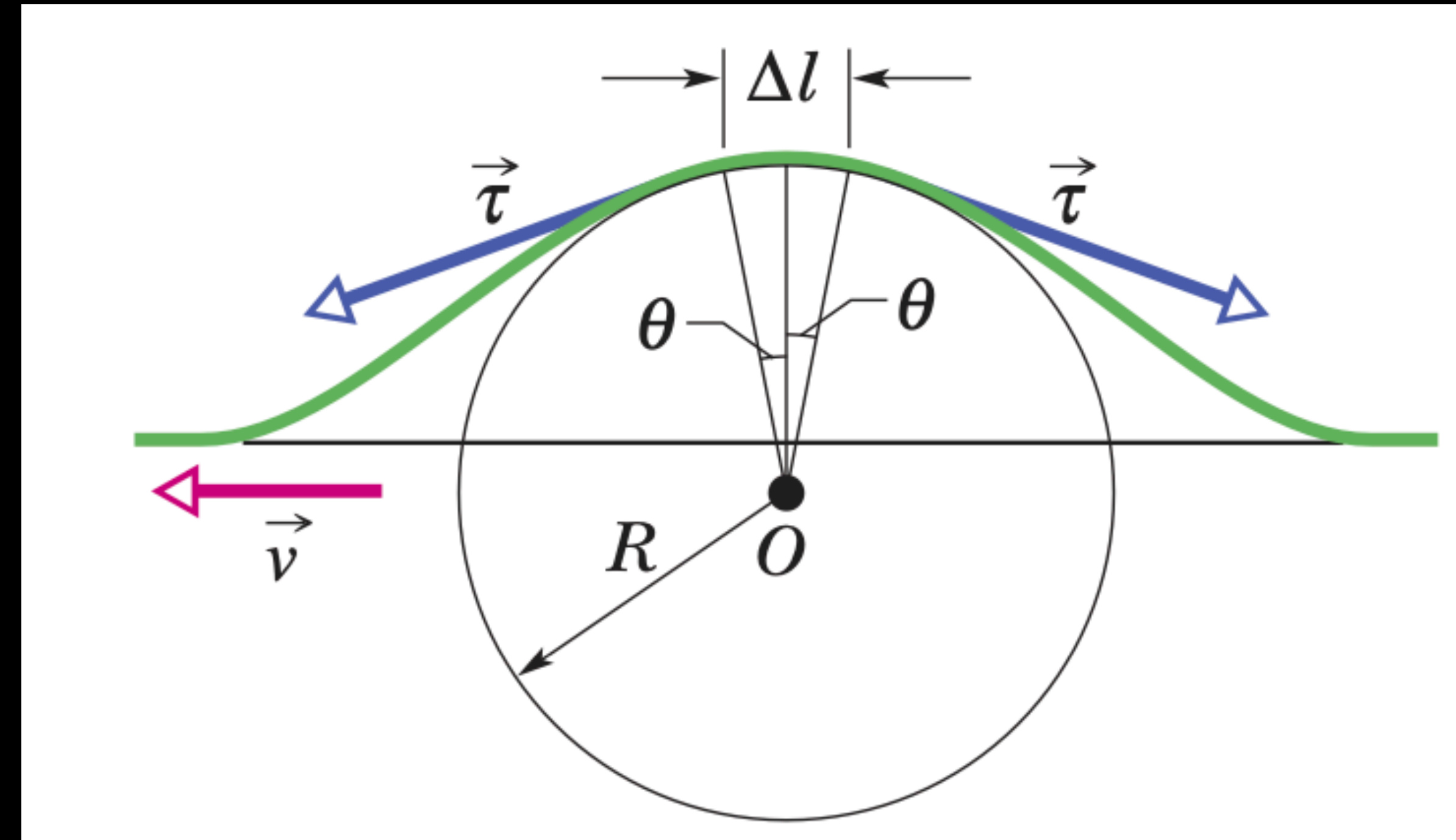
Key concepts

- The speed of a wave on a stretched string is set by the properties of the string (not properties of the wave)
- The speed of a wave on a string with tension τ and linear density μ is:

- $$v = \sqrt{\frac{\tau}{\mu}}$$

- Centripetal acceleration:

- $$a = \frac{v^2}{R}$$



Key concepts

- The kinetic energy associated with a string element of mass dm is given by:

- $dK = \frac{1}{2}dmu^2$

- Getting u by differentiating with respect to time:

- $u = \frac{\partial y}{\partial t} = -\omega y_m \cos(kx - \omega t)$

- $dK = \frac{1}{2}(\mu dx)(-\omega y_m)^2 \cos^2(kx - \omega t)$

- The average rate of kinetic energy transported is:

- $\left(\frac{dK}{dt}\right)_{avg} = \frac{1}{2}\mu\nu\omega^2 y_m^2 [\cos^2(kx - \omega t)]_{avg} = \frac{1}{4}\mu\nu\omega^2 y_m^2$