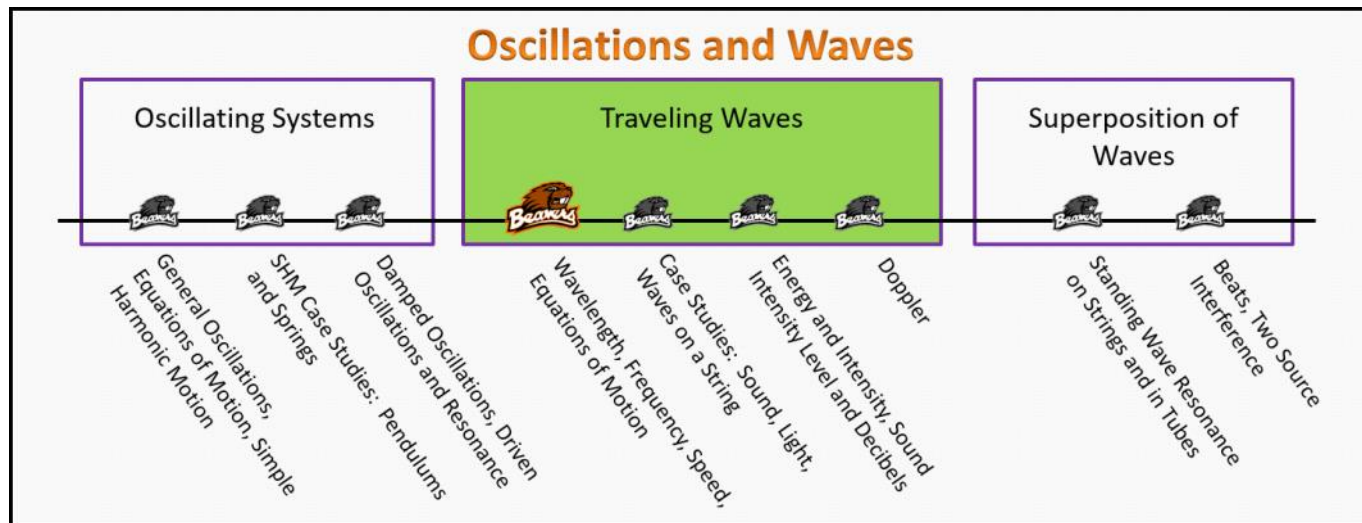


Traveling Waves Foundation Stage (TW.2.L1)

Lecture 1 Wavelength, Frequency, Speed, Equations of Motion



Textbook Chapters (* Calculus version)

- o **BoxSand** :: KC videos ([Traveling Waves](#))
- o **Knight** (College Physics : A strategic approach 3rd) :: 14.1 ; 14.2 ; 14.3 ; 14.4
- o ***Knight** (Physics for Scientists and Engineers 4th) :: 15.1 ; 15.2 ; 15.3 ; 15.4
- o **Giancoli** (Physics Principles with Applications 7th) :: 11-1 ; 11-2 ; 11-3

Warm up

TW.2.L1-1:

Description: Using a graphing device, plot a sin function and determine its motion based on adding and subtracting a constant in the argument.

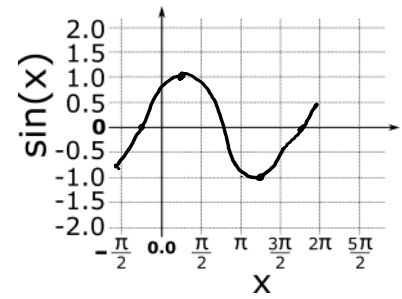
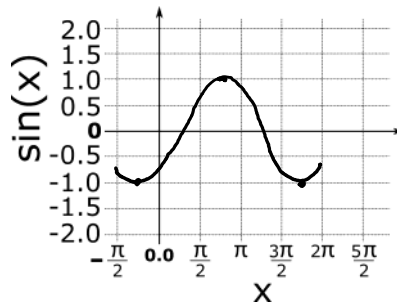
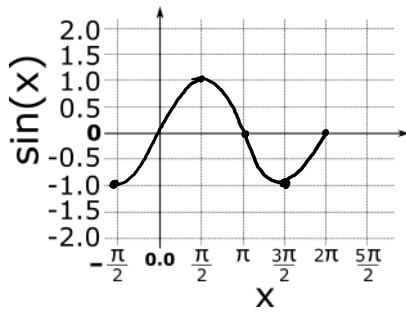
Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement: Using your favorite graphing device (e.g. graphing calculator, WolframAlpha, Mathematica, MATLAB, etc..) sketch the following plots on the given graphs below from $x = -\pi/2$ and $x = 2\pi$.

(a) $\sin(x)$

(b) $\sin(x - \pi/8)$

(c) $\sin(x + \pi/8)$



(d) What can you conclude about the direction of motion of the sin function if you subtract or add a value in the argument?

SUBTRACTING $\frac{\pi}{8}$ MOVED $\sin(x)$ TO THE RIGHT

ADDING $\frac{\pi}{6}$ MOVED $\sin(x)$ TO THE LEFT

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Mechanical wave
- Electromagnetic wave
- Matter wave
- Gravity wave
- Transverse wave
- Longitudinal wave
- Combination of transverse and longitudinal waves
- Wavelength
- Wave number
- Wave speed
- Oscillator speed
- Snapshot graph
- History graph

Key Equations

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Key Concepts

- Coming soon to a lecture template near you.

Questions

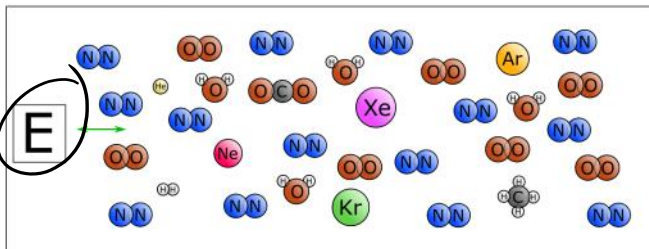
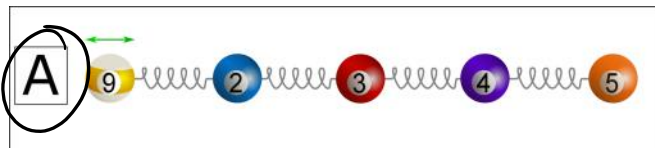
Act I: Classifying Waves

TW.2.11-2:

Description: Conceptual question about features of oscillators. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Which system would sustain a traveling wave if you wiggled the left most end?



TW.2.L1-3:

Description: Given graphs of potential energy vs position identify non-oscillatory motion. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Which of the following are necessarily true about traveling waves?

- (1) Traveling waves transport energy from one location to another.
- (2) Traveling waves are a collection of many oscillators.
- (3) Traveling waves transport matter from one location to another.
- (4) Traveling waves have a velocity that is dependent on the medium through which the wave travels.
- (5) Traveling waves have a frequency determined by the source of the wave.

TW.2.L1-4:

Description: Conceptual question about features of oscillators. (2 minutes + 2 minutes + 2 minutes + 2 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Match the wave phenomena with the wave type.

- | | |
|--|---------------------------|
| (a) Crowd at sporting event. <i>4</i> | (1) Gravity wave. |
| (b) Diffraction pattern of accelerated electrons through two small slits. <i>3</i> | (2) Electromagnetic wave. |
| (c) HAM Radio waves. <i>2</i> | (3) Matter wave. |
| (d) A ripple of space-time. <i>1</i> | (4) Mechanical wave. |

TW.2.L1-5:

Description: Given graphs of potential energy vs position identify simple harmonic oscillators. (3 minutes).

Learning Objectives: [1, 12, 13]

Problem Statement: Match the wave phenomena with the mode of the wave.

- | | |
|--|---|
| (a) Crowd at sporting event. <i>1 or 2</i> | (1) Transverse wave. |
| (b) Earthquake wave. <i>3</i> <i>S & P waves</i> | (2) Longitudinal wave. |
| (c) Water wave. <i>3</i> | (3) Combination of transverse and longitudinal. |

Act II: Characteristics of Waves

TW.2.L1-6:

Description: Given force equations as a function of displacement from equilibrium, identify which would give rise to simple harmonic motion. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: A friend shows you a picture of a series of periodic ripple on the surface of a pond from a stone thrown into the pond.

(a) Your friend tells you the picture was taken 2.3 seconds after the source began emitting the wave. From this picture what can you determine?

- (1) Wave length.
- (2) Period.
- (3) Frequency.
- (4) Wave speed.
- (6) Amplitude.

$$\# \lambda = 7$$

$$\frac{7 \text{ osc}}{2.3 \text{ sec}} \approx 3 \text{ Hz} \quad \text{or} \quad T = \frac{1}{3} \text{ s}$$



(b) What if your friend showed you the picture and instead only told you that the outermost ripple is 10.0 m from the source of the ripples. What could you determine then?


- (1) Wave length.
- (2) Period.
- (3) Frequency.
- (4) Wave speed.
- (6) Amplitude.

$$\# \lambda = 7$$

$$\frac{10 \text{ m}}{7} = 1.43 \text{ m}$$



$$\frac{10 \text{ m}}{7} = 1.43 \text{ m}$$



w/ (a) + (b) we can get v

$$v = f\lambda \approx 4.3 \text{ m/s}$$

TW.2.L1-7:

Description: Conceptual question about period for simple harmonic motion. (2 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: With regards to a traveling wave in a single medium, which of the following are constant?

- T ① Wave speed.
- T ② Frequency.
- F ③ Oscillator speed.
- T ④ Wavelength.
- F ⑤ Displacement from equilibrium.

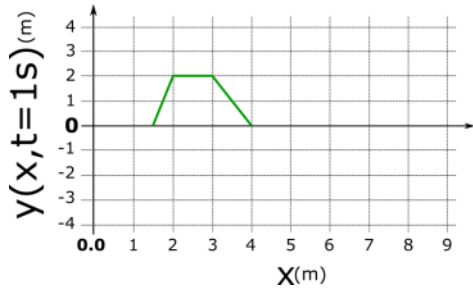
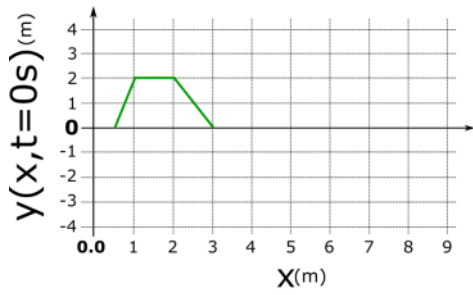
Act III: Equation Modeling

TW.2.L1-8:

Description: Conceptual question about equilibrium position for simple harmonic motion. (4 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Consider the two snapshots of a wave pulse traveling along the x-direction. Assume the pulse does not change its shape in the time intervals we are interested in.

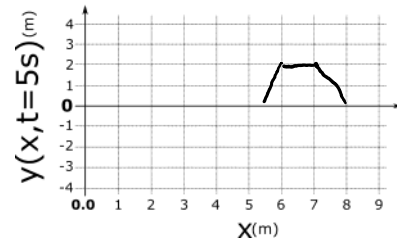
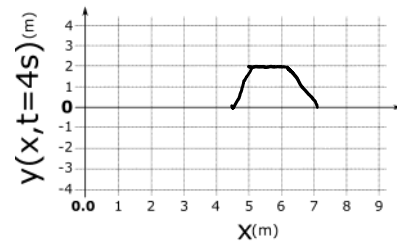
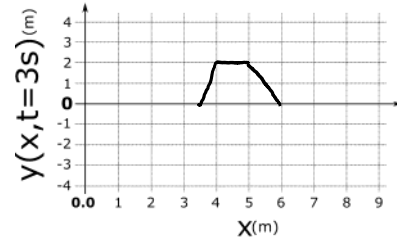
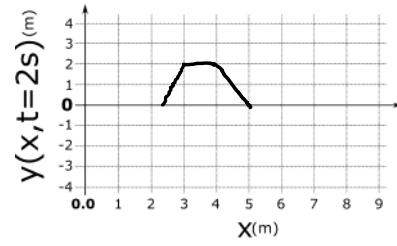


(a) What is the speed of the wave?

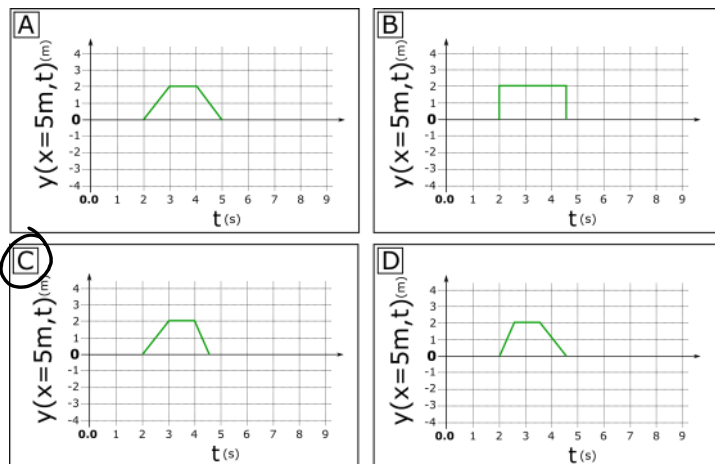
assume no a

$$v = \frac{\Delta x}{\Delta t} = \frac{1}{1} = 1 \text{ m/s}$$

(b) Sketch the wave pulse at $t = 2 \text{ s}$, 3 s , 4 s , and 5 s .



(c) Which of the following plots represents the history graph for the wave pulse at $x = 5 \text{ meters}$?

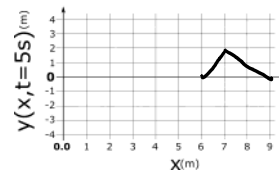
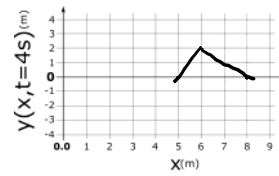
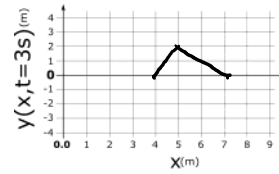
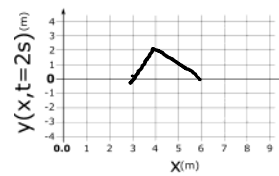
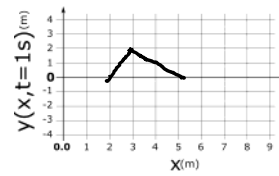
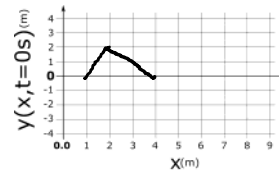
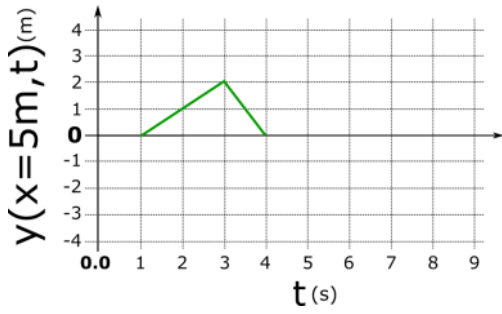


TW.2.L1-9:

Description: Complete an energy flow diagram for a SHO. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Consider the history plot for a traveling wave pulse that maintains its shape. The history plot was created at $x = 5$ m. Sketch snapshots of the wave pulse on the provided graphs given that the pulse has a velocity of $+1$ m/s.



TW.2.L1-10:

Description: Conceptual question relating energy and amplitude of a simple harmonic oscillator. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: A traveling wave is modeled by the equation $D(x,t) = 45 \sin(0.5x - 2t)$, where D and x are in meters, t is in seconds, and all other constants are in SI units.

(a) What is the amplitude of the wave?

45 m

(b) What is the period of the wave?

$\omega = 2$
 $\frac{2\pi}{T} = 2$
 $T = \pi \text{ s}$

(c) What is the wavelength of the wave?

$k = \frac{1}{2}$
 $\frac{2\pi}{\lambda} = \frac{1}{2}$
 $\lambda = 4\pi \text{ m}$

(d) What is the wave speed?

$v = f\lambda$
 $= \left(\frac{1}{\pi}\right)(4\pi)$
 $v = 4 \text{ m/s}$

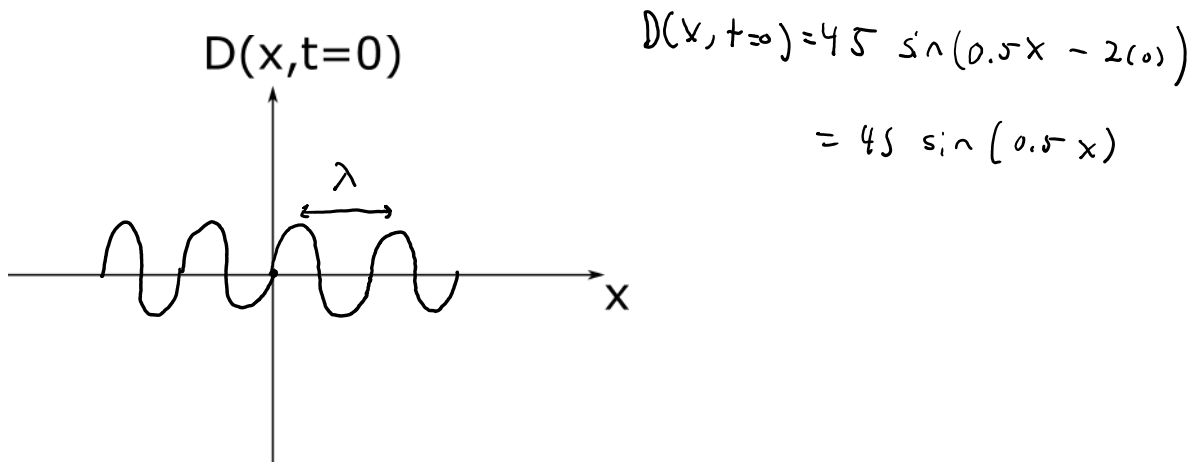
(e) Does the wave travel in the positive x-direction or negative x-direction?

POSITIVE
 OPPOSITE SLOPE

(f) What mode of wave is this?

LONGITUDINAL
 OR
 TRANSVERSE

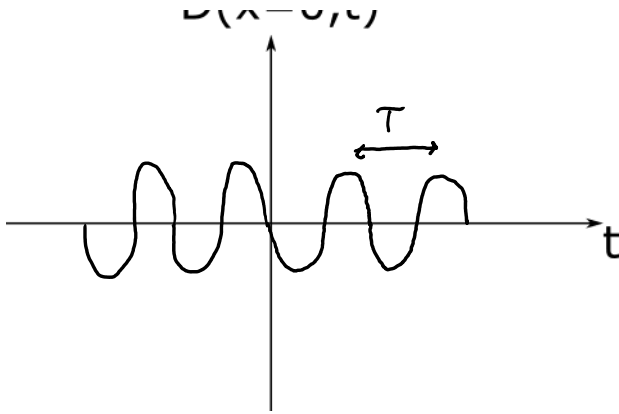
(g) A traveling wave is modeled by the equation $D(x,t) = 45 \sin(0.5x - 2t)$, where D and x are in meters, t is in seconds, and all other constants are in SI units. Sketch a snapshot of the wave at $t = 0$ s as a function of position. Include about two oscillations in both the positive and negative x region.



(h) A traveling wave is modeled by the equation $D(x,t) = 45 \sin(0.5x - 2t)$, where D and x are in meters, t is in seconds, and all other constants are in SI units. Sketch the displacement from equilibrium of the wave at $x = 0$ as a function of time. Include about two oscillations in both the positive and negative t regions.

$D(x=0,t)$

$D(x=0,t) = 45 \sin(0.5(0) - 2t)$
 $= 45 \sin(-2t)$) SW 2.5 m



$$= 45 \sin(-2t)$$

$$= -45 \sin(2t)$$

SW IS AN
OAO FUNCTION

$$\sin(-x) = -\sin(x)$$

TW.2.11-11:

Description: Energy analysis for a SHO. (6 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: A traveling wave is modeled by the graphical representations shown below, a snapshot and a history graph are shown below for $t = 0$ s and $x = 0$ s respectively.

(a) What is the amplitude of the wave?

1.5 m

(b) What is the period of the wave?

0.5 s

(c) What is the wavelength of the wave?

2 m

(d) What is the wave speed?

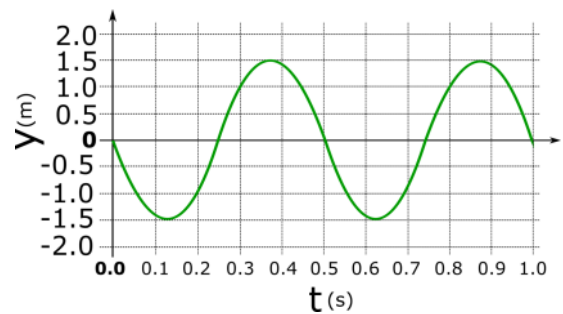
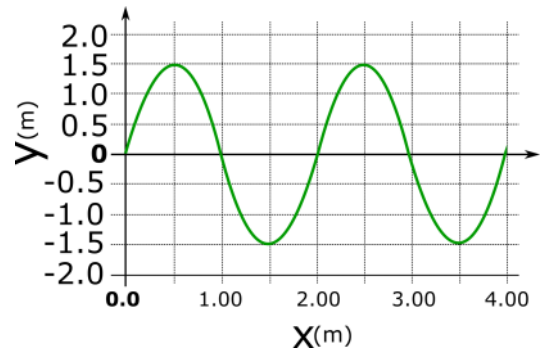
$$v = \frac{\lambda}{T} = \frac{2}{0.5} = 4 \text{ m/s}$$

(e) Does the wave travel in the positive x-direction or negative x-direction?

+ X-DIRECTION SWAP #IS T
SIN -SIN

(f) What mode of wave is this?

T or L



(g) Which of the following equations is a correct mathematical representation for this traveling wave assuming all constants are SI units?

$$\tau \textcircled{1} D(x,t) = 1.5 \sin(\pi x - 4\pi t)$$

$$f \textcircled{2} D(x,t) = 1.5 \sin(2x - 0.5t)$$

$$f \textcircled{3} D(x,t) = 1.5 \cos(2x - 0.5t)$$

$$\tau \textcircled{4} D(x,t) = -1.5 \sin(-\pi x + 4\pi t)$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{\frac{1}{2}} = 4\pi$$

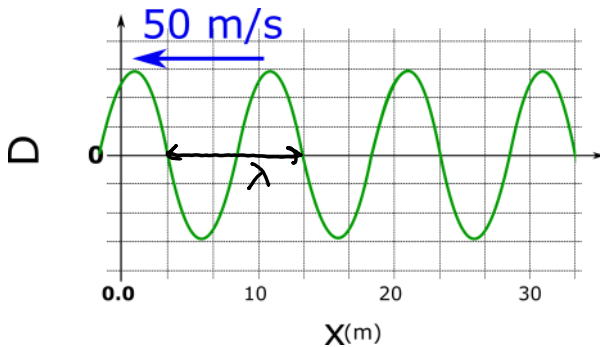
$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{2} = \pi$$

TW.2.L1-12:

Description: Conceptual question about angular frequency vs angular velocity. (4 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: What is the frequency of this traveling wave?



$$v = f \lambda$$

$$f = \frac{v}{\lambda} = \frac{50 \text{ m/s}}{10 \text{ m}}$$

$$f \approx 5 \text{ Hz}$$

$$\lambda \approx 10 \text{ m}$$

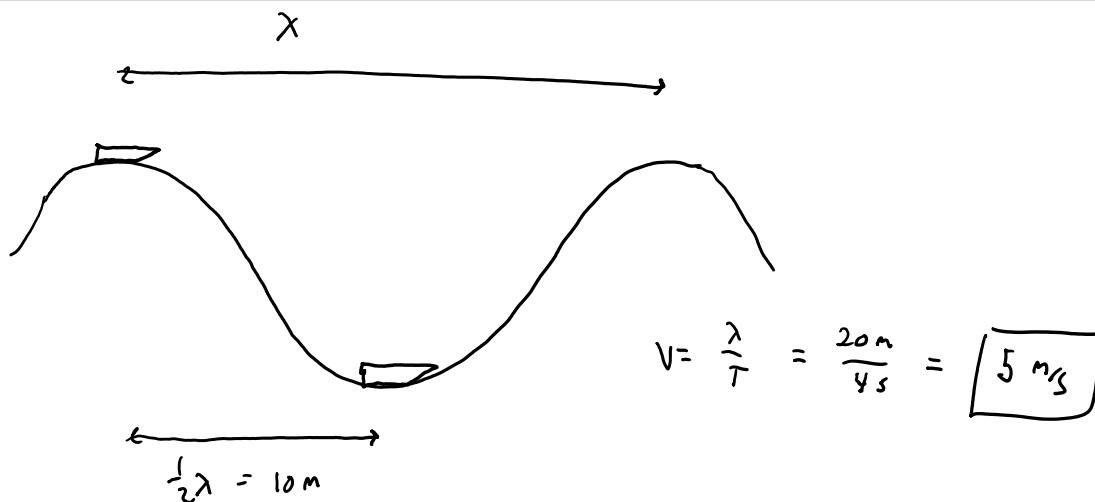
TW.2.L1-13:

Description: Given a mass-spring system and initial conditions via written description and physical representation, identify the correct graphical representation. Find sign of velocities and accelerations at specific points. (3 minutes + 5 minutes + 5 minutes + 3 minutes).

Learning Objectives: [1, 12, 13]

Problem Statement: Two canoes are 10 m apart on a lake. Each bobs up and down with a period of 4.0 seconds. When one canoe is at

its highest point, the other canoe is at its lowest point. Both canoes are always within a single cycle of the waves. Determine the speed of the waves.



Conceptual questions for discussion

1. **Coming soon to a lecture template near you**

Hints

TW.2.L1-1: No hints.

TW.2.L1-2: No hints.

TW.2.L1-3: No hints.

TW.2.L1-4: No hints.

TW.2.L1-5: No hints.

TW.2.L1-6: No hints.

TW.2.L1-7: No hints.

TW.2.L1-8: No hints.

TW.2.L1-9: No hints.

TW.2.L1-10: No hints.

TW.2.L1-11: No hints.

TW.2.L1-12: No hints.

TW.2.L1-13: No hints.