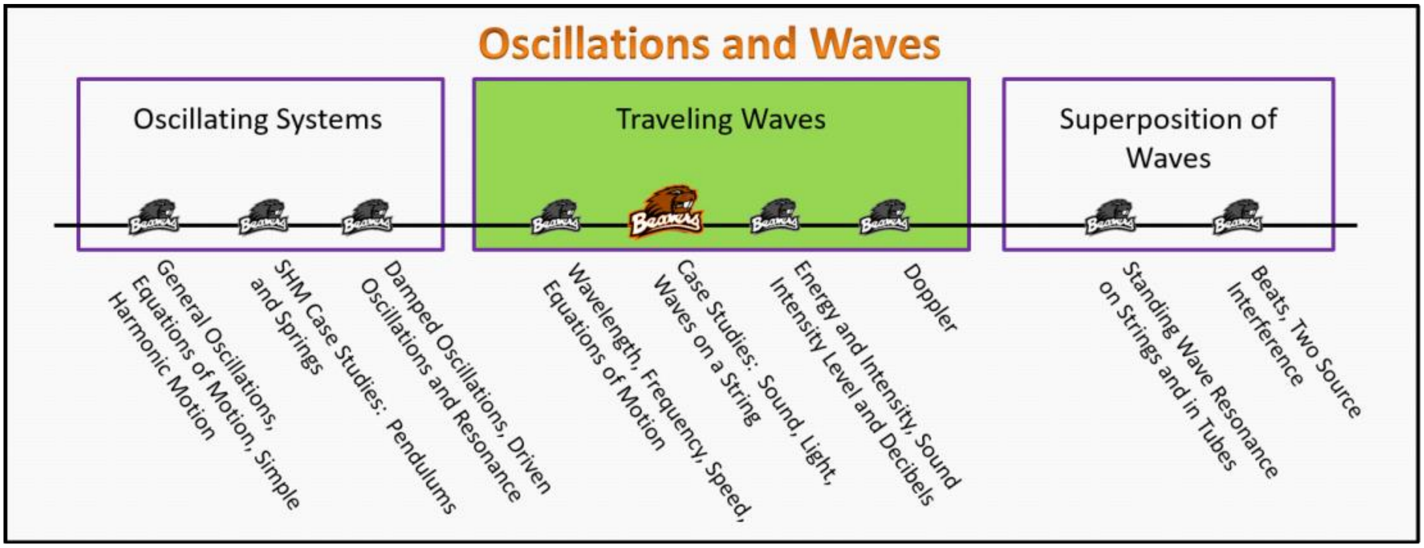
(TW.2.L2.sol) Foundation Stage Solutions

Thursday, March 29, 2018 8:34 PM

Traveling Waves

Foundation Stage (TW.2.L2)

Lecture 2
Case Studies: Sound, Light, Waves on a String



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos (Traveling Waves)
- **Knight** (College Physics : A strategic approach 3rd) :: 15.2 ; 15.4
- ***Knight** (Physics for Scientists and Engineers 4th) :: 16.1 ; 16.4 ; 16.5
- **Giancoli** (Physics Principles with Applications 7th) :: 11-8

Warm up

TW.2.L2-1:

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: Traveling waves arise from a collection of coupled oscillators. For each of the following waves, identify what the oscillators are. For example, the oscillators of a water wave are the water molecules.

(a) Waves on a string.

THE STRING

(c) Light waves.

ELECTRIC AND MAGNETIC FIELDS

(b) Sound waves.

(d) Gravity waves.

AIR MOLECULES

SPACE - TIME

Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- No new key terms.

Key Equations

Key Concepts

- Coming soon to a lecture template near you.

Questions

Act I: Waves on a string

TW.2.L2-2:

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

Learning Objectives: [1, 12, 13]

Problem Statement: The speed of a traveling wave on a rope is dependent on which of the following quantities/actions?

T (1) How tightly the rope is stretched.
T (2) The mass per length of the rope.
F (3) How hard you wiggle the rope. (amplitude).
F (4) How quickly you wiggle the rope.
F (5) What planet you are on while wiggling the rope.

STRING

$$v = \sqrt{\frac{|\vec{F}^T|}{\mu}}$$

* REMEMBER

$v = f\lambda$ IS STILL TRUE TOO

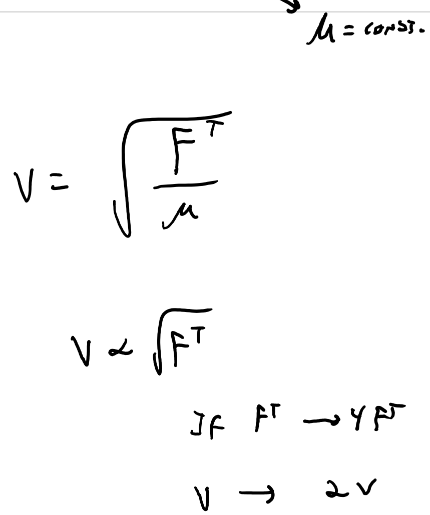
TW.2.L2-3:

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

Learning Objectives: [1, 12, 13]

Problem Statement: A wave is traveling on a string. If the same material string is used but is twice as long, and the tension quadruples, what happens to the speed of the wave?

(1) Doubles.
(2) Halves.
(3) Increases by square root of 8
(4) Decreases by square root of 8
(5) Triples.



TW.2.L2-4:

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

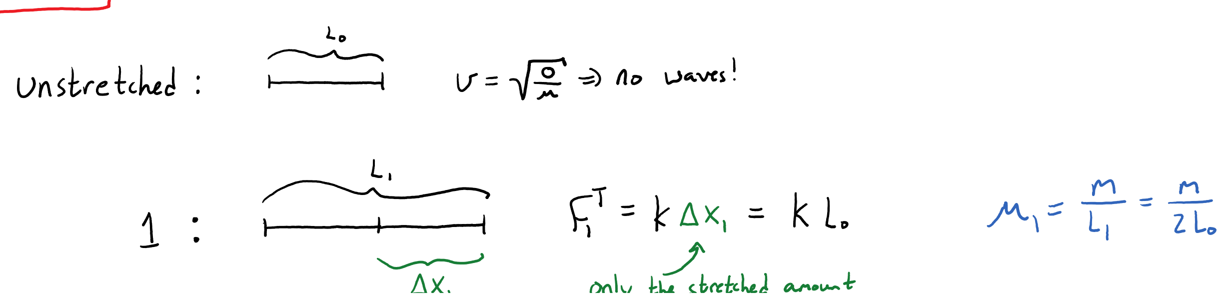
Learning Objectives: [1, 12, 13]

Problem Statement: An unstretched rubber band has no tension, and so it will not support a travelling wave. Assume a rubber band can be modeled as an ideal spring with a spring force equal to $|F| = k\,\Delta x$.

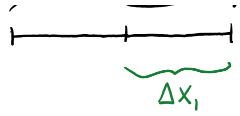
The rubber band is initially stretched to twice its relaxed length. You observe the speed of a wave in the band and call it $\mathbf{v_1}$.

If you then stretch the rubber band so that its length doubles again (from when you measured $\mathbf{v_1}$), how does the new speed of a wave compare to $\mathbf{v_1}$?

(1) $\sqrt{2}v_1$
(2) $\sqrt{3}v_1$
(3) $2v_1$
(4) $\sqrt{6}v_1$



1 :

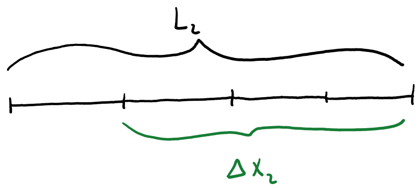


$F_1' = k\Delta x_1 = kL_0$

only the stretched amount not the whole length of band

$\mu_1 = \frac{}{L_1} = \frac{}{2L_0}$

2 :



$F_2^T = k\Delta x_2 = k(3L_0) = 3F_1^T$

$\mu_2 = \frac{m}{L_2} = \frac{m}{4L_0} = \frac{1}{2}\mu_1$

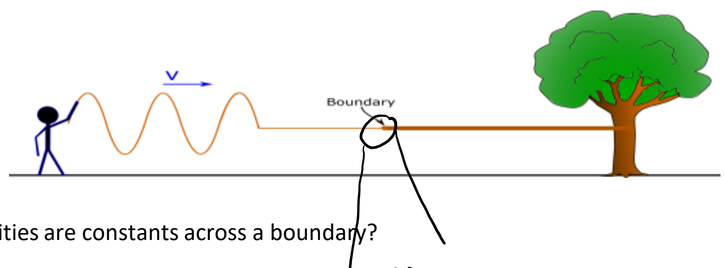
$$v_2 = \sqrt{\frac{F_2^T}{\mu_2}} = \sqrt{\frac{3F_1^T}{\frac{1}{2}\mu_1}} = \sqrt{6\frac{F_1^T}{\mu_1}} = \sqrt{6}\,v_1$$

TW.2.L2-5:

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

Learning Objectives: [1, 12, 13]

Problem Statement: Consider a situation where a light string is tied to a heavy string and a wave is sent down the string.



(a) Which of the following quantities are constants across a boundary?

T (1) Tension
F (2) Speed
T (3) Frequency
F (4) Wavelength

FBD

$\vec{a} = \vec{0}$ So $\Sigma\vec{F} = 0$

(b) Does the speed of the traveling wave increase, decrease, or stay the same as it travels form the light to the heavy string?

(1) Increase.
(2) Decrease.
(3) Stays the same.

$v = \sqrt{\frac{F^T}{\mu}}$ w/ F^T = const

$v \propto \frac{1}{\sqrt{\mu}}$

If $\mu\uparrow$ then $v\downarrow$

(c) Does the wavelength of the traveling wave increase, decrease, or stay the same as it travels from the light to the heavy stri ng?

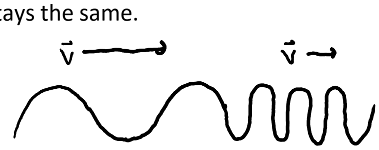
(1) Increase.
(2) Decrease.
(3) Stays the same.

$v = f\lambda$ w/ f = const

$v \propto \lambda$

w/ $v\downarrow$

Then $\lambda\downarrow$



TW.2.L2-6:

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: Yo-Yo Pa, grandmaster of the yo-yo, is twirling his yo-yo in a vertical circle near the surface of the Earth. A spider is holding on for dear life, trying to send Morse code via traveling waves to Mr. Pa about his predicament.

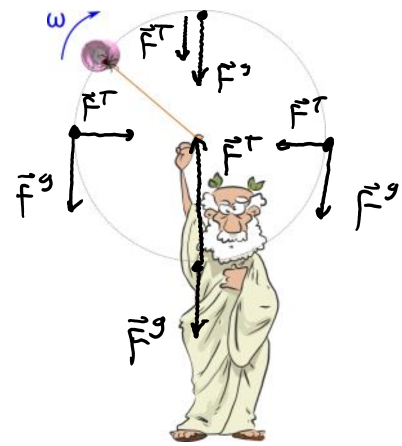
(a) At what point along the path of the yo-yo would the information transfer the quickest?

(1) Top.
(2) Bottom.
(3) Right most point.
(4) Left most point.
(5) Travels the same at all points along the path.

$$V = \sqrt{\frac{F^T}{\mu}} \quad \text{w/ } \mu = \text{const}$$

$$V \propto \sqrt{F^T}$$

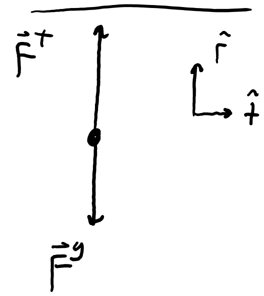
$$V_{max} \text{ @ } F^T_{max}$$



(b) Which of the following expressions for tension emerges after a correct force analysis at the location from part (a)?

(1) **mg**
(2) **mv²/r + mg**
(3) **mv²/r - mg**
(4) 2**mg**
(5) √(2**mg**)

FBD @ Bottom



$$\Sigma F_r = m a_r$$

$$F^T - F^g = \frac{m V_t^2}{r}$$

$$F^T - mg = \frac{m V_t^2}{r}$$

$$F^T = mg + \frac{m V_t^2}{r}$$

Act II: Sound Waves

TW.2.L2-7:

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

Learning Objectives: [1, 12, 13]

Problem Statement: Which of the following mediums can sound propagate through?

(1) Air.
(2) Walls.
(3) Concrete.
(4) Outer space.
(5) Earth.
(6) Glass.
(7) Near the center of a black hole.

TW.2.L2-8:

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

Learning Objectives: [1, 12, 13]

Problem Statement: The speed of sound traveling through a gas can be roughly modeled by the equation below where **γ** is a constant with a value that is dependent on the type of gas molecue (i.e. monatomic, diatomic, etc.). **R** is the ideal gas constant, **T** is temperature, and **M** is the molar mass of the gas. If the temperature increases by 50%, how much does the speed change?

$$v_{sound} = \sqrt{\frac{\gamma R T}{M_{mol}}}$$

(1) 0.5
(2) 0.667
(3) 0.707
(4) 0.816
(5) 1.22
(6) 1.41
(7) 1.5
(8) 2

w/ γ, R, M_{mol} constants

$v \propto \sqrt{T}$

w/ $T \to 1.5\,T$

$v \to \sqrt{1.5}\,v$

$v \rightarrow \sqrt{1.5}\, v$

≈ 1.22

TW.2.L2-9:

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

Learning Objectives: [1, 12, 13]

Problem Statement: Trillium the Trumpeting Trilobite is playing a constant 440 Hz tone in a concert hall at room temperature.

(a) If the frequency is increased to 880 Hz, what is the speed of the traveling sound wave?

(1) 243 m/s
(2) 343 m/s
(3) 485 m/s

V_{SOUND} INDEPENDENT OF f

(b) If Trillium is originally playing at 50 dB, but increases the volume to 100 dB, what is the new speed of the wave?

(1) 243 m/s
(2) 343 m/s
(3) 485 m/s

V_{SOUND} INDEPENDENT OF AMPLITUDE

TW.2.L2-10:

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

Learning Objectives: [1, 12, 13]

Problem Statement: A volcano erupts just off shore. Sound waves from the event travel through the Earth, air, water, and light also travels from the volcano to the shore.

(a) Rank each of these waves based on the time it will take to reach the other end of the shore warning the villagers of the pend ing Tsunami.

w/ $\vec{a} = \vec{0}$

(a) Rank each of these waves based on the time it will take to reach the other end of the shore warning the villagers of the pend ing Tsunami.

(1) Δt_{earth}
(2) Δt_{air}
(3) Δt_{water}
(4) Δt_{light}

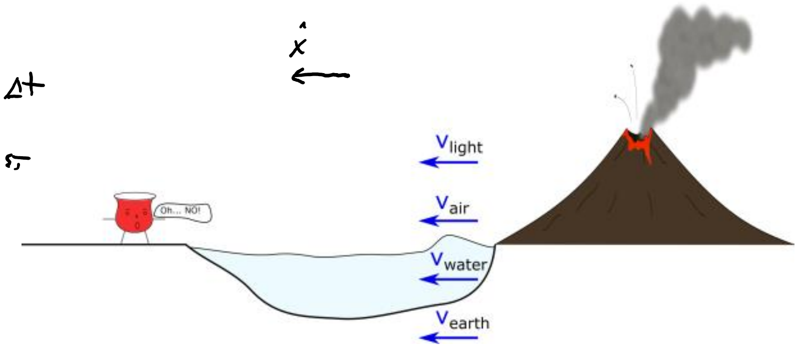
w/ $\vec{a} = \vec{0}$

$\hat{x}$ ←

$\Delta x = v_{ix} \Delta t$

w/ $\Delta x = \text{const}$

$\Delta t \propto \frac{1}{v_{ix}}$



$V_{air} < V_{water} < V_{earth} < V_{light}$

so

$\Delta t_{light} < \Delta t_{earth} < \Delta t_{water} < \Delta t_{air}$

(b) A baby volcano, equidistant from the shore as the volcano above, produces a more quiet and higher pitched eruption. Rank the time it will take each wave to reach the shore.

(1) Δt_{earth}
(2) Δt_{air}
(3) Δt_{water}
(4) Δt_{light}

SAME AS PART (a)

V IS INDEPENDENT OF f & AMPLITUDE

Act III: Light Waves

TW.2.L2-11:

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

Learning Objectives: [1, 12, 13]

Problem Statement: Two massive black holes collide in interstellar space. Which of the following information reaches Earth informing us of the event?

(1) Gravitational waves.
(2) Light waves.
(3) Sound waves.

TW.2.L2-12:

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

Learning Objectives: [1, 12, 13]

Problem Statement: Which light travels faster through a vacuum?

(1) Red.
(2) Green.
(3) Blue.
(4) Ultraviolet.
(5) Infrared.
(6) Radio.
(7) Microwaves.
(8) X-rays.
(9) All travel the same speed.

ALL ELECTROMAGNETIC WAVES.

THE FREQUENCIES ARE DIFFERENT BUT

V IS INDEPENDENT OF F

$$V_{light} = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

PROPERTIES OF SPACE

TW.2.L2-13:

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: A lightning strike occurs 5 miles away. What is the time difference between the light observed from it, vs the sound heard from the thunder created by the lightning? Hint: 1 mile is equal to 1609.34 meters. The speed of light is about 3.0 x 10^8 m/s.

(1) 1/5 seconds
(2) 1/3 seconds
(3) 3 seconds
(4) 5 seconds
(5) 23 seconds

w/ $a_x = 0$

$\Delta x = V_{ix} \Delta t$

$\Delta t = \frac{\Delta x}{V_{ix}}$

SI

$5\,\text{mi} \times \frac{1609.34\,\text{m}}{1\,\text{mi}} = 8046.7\,\text{m}$

SOUND

$\Delta t_s = \frac{8046.7\,\text{m}}{343\,\text{m/s}}$

$\Delta t_s = 23.4598\,\text{s}$

LIGHT

$\Delta t_L = \frac{8046.7\,\text{m}}{3 \times 10^8\,\text{m/s}}$

$\Delta t_L = 2.68 \times 10^{-5}\,\text{s}$

$\Delta t_s - \Delta t_L \approx \boxed{23.5\,\text{s}}$

Conceptual questions for discussion

1. Coming soon to a lecture template near you.

Hints

TW.2.L2-1: No hints.

TW.2.L2-2: No hints.

TW.2.L2-3: No hints.

TW.2.L2-4: No hints.

TW.2.L2-5: No hints.

TW.2.L2-6: No hints.

TW.2.L2-7: No hints.

TW.2.L2-8: No hints.

TW.2.L2-9: No hints.

TW.2.L2-10: No hints.

TW.2.L2-11: No hints.

TW.2.L2-12: No hints.

TW.2.L2-13: No hints.