Waves and Oscillation

Course- PHY 2105 / PHY 105

Lecture 10

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Types of Waves in different media

Material Wave	Electromagnetic Wave	Matter Wave
❑ Requires material medium ❑ Governed by Newton's Laws *Example:* *Waves in water, air, steel, etc*	❑ Does not require any material medium ❑ Travels at the speed of light *Example:* *All kinds of EM radiation like light, heat, gamma rays*	❑ Wave properties of fundamental particles ❑ Governed by Laws of modern physics *Example:* *Waves electron, protons, etc*

Wave Properties

$$\overbrace{y(x,t)}^{\text{Displacement}} = \overbrace{y_m}^{\text{Amplitude}}\ \overbrace{\sin\,(\overbrace{\underbrace{k}_{\text{Angular wave number}}\underbrace{x}_{\text{Position}} - \underbrace{\omega}_{\text{Angular frequency}}\,\underbrace{t}_{\text{Time}}}^{\text{Phase}})}^{\text{Oscillating term}}$$

Equation for a Progressive Wave

y = A sin (ωt-ϕ)

$$y = A\sin(\omega t - \frac{2\pi x}{\lambda})$$

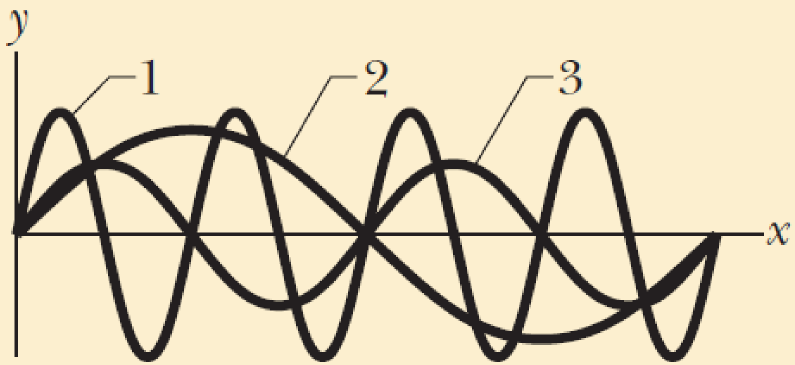
$$y = A\sin\frac{2\pi}{\lambda}(vt - x)$$

Differential Equation for Wave Motion

$$\frac{d^2y}{dt^2} = v^2\frac{d^2y}{dx^2}$$

Checkpoint 1

The figure is a composite of three snapshots, each of a wave traveling along a particular string. The phases for the waves are given by (a) $2x - 4t$, (b) $4x - 8t$, and (c) $8x - 16t$. Which phase corresponds to which wave in the figure?



Example 10.1

A student takes a 30.00-m-long string and attaches one end to the wall in the physics lab. The student then holds the free end of the rope, keeping the tension constant in the rope. The student then begins to send waves down the string by moving the end of the string up and down with a frequency of 2.00 Hz. The maximum displacement of the end of the string is 20.00 cm. The first wave hits the lab wall 6.00 s after it was created.

(a) What is the speed of the wave?

(b) What is the period of the wave?

(c) What is the wavelength of the wave?.

Superposition & Interference

Table 16-1 Phase Difference and Resulting Interference Types[a]

Phase Difference, in			Amplitude of Resultant Wave	Type of Interference
Degrees	Radians	Wavelengths		
0	0	0	$2y_m$	Fully constructive
120	$\frac{2}{3}\pi$	0.33	y_m	Intermediate
180	π	0.50	0	Fully destructive
240	$\frac{4}{3}\pi$	0.67	y_m	Intermediate
360	2π	1.00	$2y_m$	Fully constructive
865	15.1	2.40	$0.60y_m$	Intermediate

[a] The phase difference is between two otherwise identical waves, with amplitude y_m, moving in the same direction.

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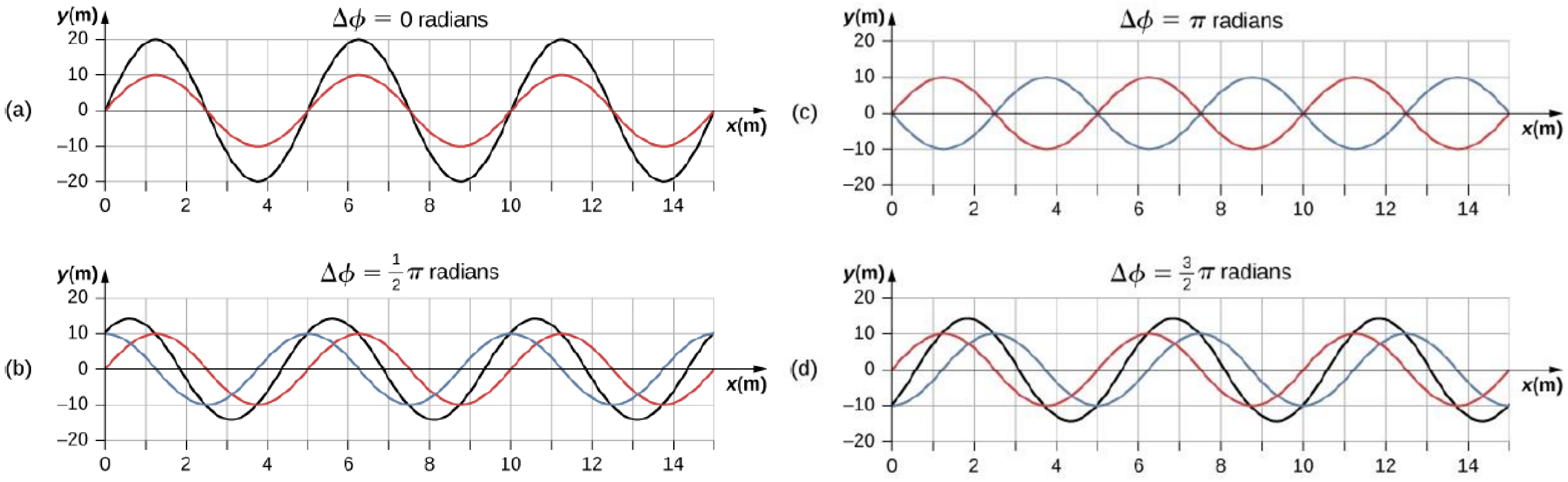
Superposition & Interference



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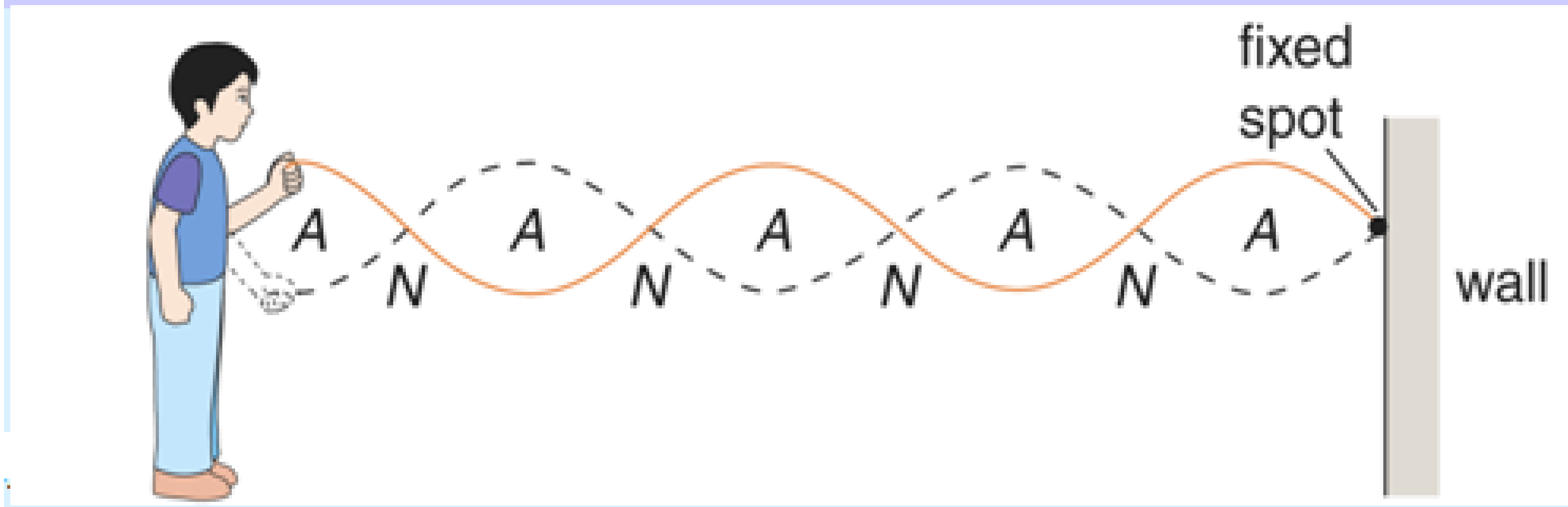
Stationary Wave

When an incident wave is reflected by a wall, then the superposition of two progressive waves (with same amplitude and same frequency, travelling in opposite directions) create a stationary wave.



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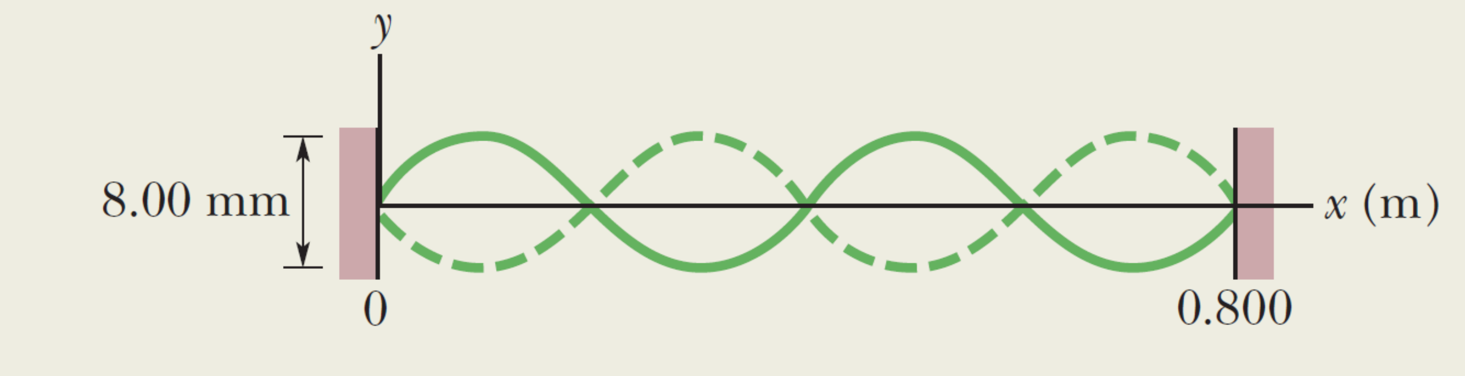
Example 10.2

The figure shows resonant oscillation of a string of mass m = 2.500 g and length L = 0.8 m and that is under tension T= 325.0 N.

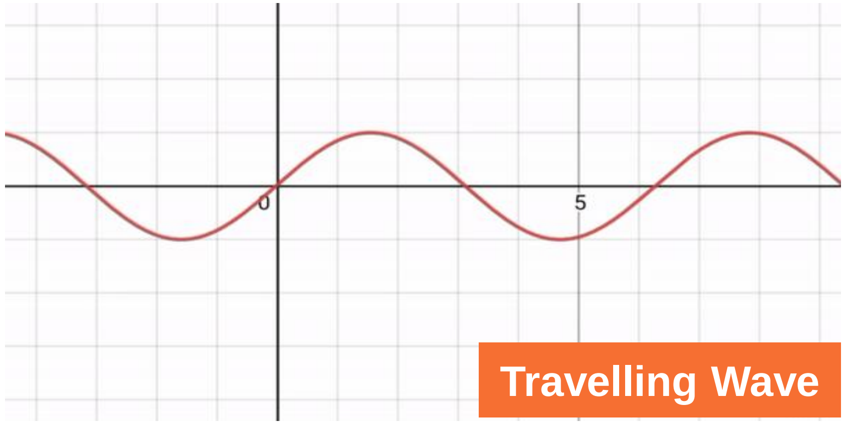
(a) What is the wavelength of the transverse waves producing the standing wave pattern, and what is the harmonic number n?

(b) What is the frequency f of the transverse waves and of the oscillations of the moving string elements?

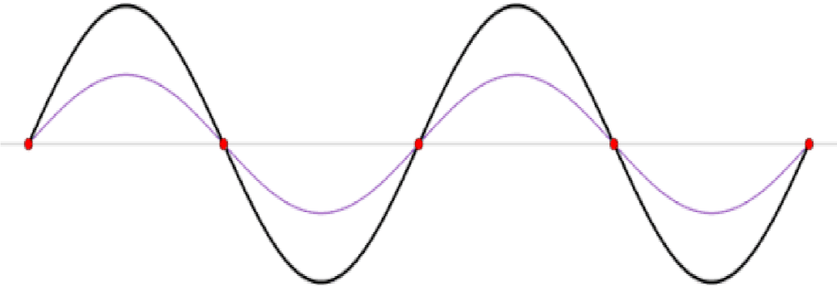
(c) What is the maximum magnitude of the transverse velocity u_max of the element oscillating at coordinate x0.180 m? At what point during the element's oscillation is the transverse velocity maximum?



Differences



Travelling Wave



Standing Wave

Progressive wave	Stationary wave
Energy is transferred along the direction of propagation.	No energy is transferred along the direction of propagation.
The wave profile moves in the direction of propagation.	The wave profile does not move in the direction of propagation.
Every point along the direction of propagation is displaced.	There are points known as nodes where no displacement occurs.
Every point has the same amplitude.	Points between two successive nodes have different amplitudes.
Neighbouring points are not in phase.	All points between two successive nodes vibrate in phase with one other.

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Wave Intensity and Power

Power is the *instantaneous* rate at which energy is transferred along the string.

$$P_{max} = \omega F k A^2 \cos^2(\omega t - kx)$$

$$P_{max} = \mu \omega^2 A^2 v \cos^2(\omega t - kx)$$

$$P_{max} = \omega^2 A^2 \sqrt{F\mu} \cos^2(\omega t - kx)$$

Waves on a string carry energy in just one dimension of space (along the direction of the string). But other types of waves, including sound waves in air and seismic waves in the body of the earth, carry energy across all three dimensions of space.

The time average rate at which energy is transported by the wave, per unit area, across a surface perpendicular to the direction of propagation is called Wave Intensity.

$$I = \frac{P}{4\pi r^2} \qquad \frac{I_1}{I_2} = \frac{{r_2}^2}{{r_1}^2}$$

Intensity follows Inverse Square Law

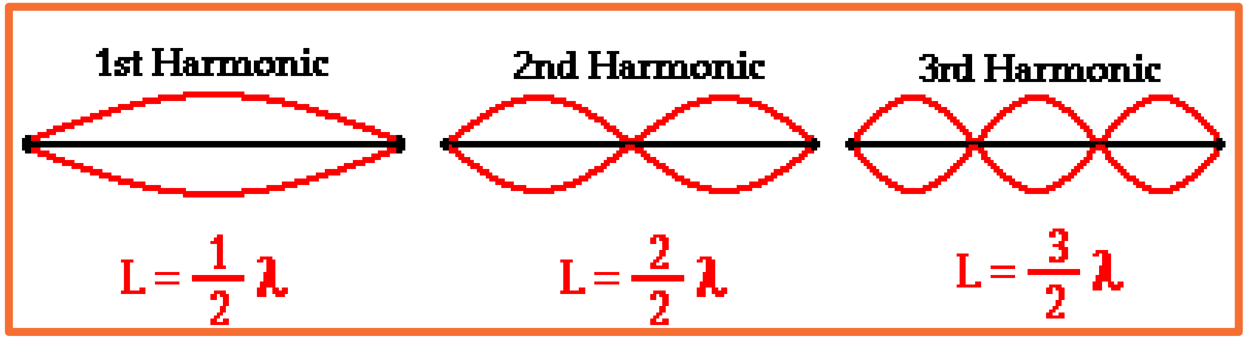
Example 10.3

Consider a string of attached to a Melde’s Appartus. The waves produced travel down the string and are reflected by the fixed boundary condition at the pulley. The string, which has a linear mass density of is passed over a frictionless pulley of a negligible mass, and the tension is provided by a 2.00-kg hanging mass. The string, which has a linear mass density of 0.006 kg/m

(a) What is the velocity of the waves on the string?

(b) List the frequencies produced in the first three normal modes of the standing waves.

(List the first three harmonic frequencies)

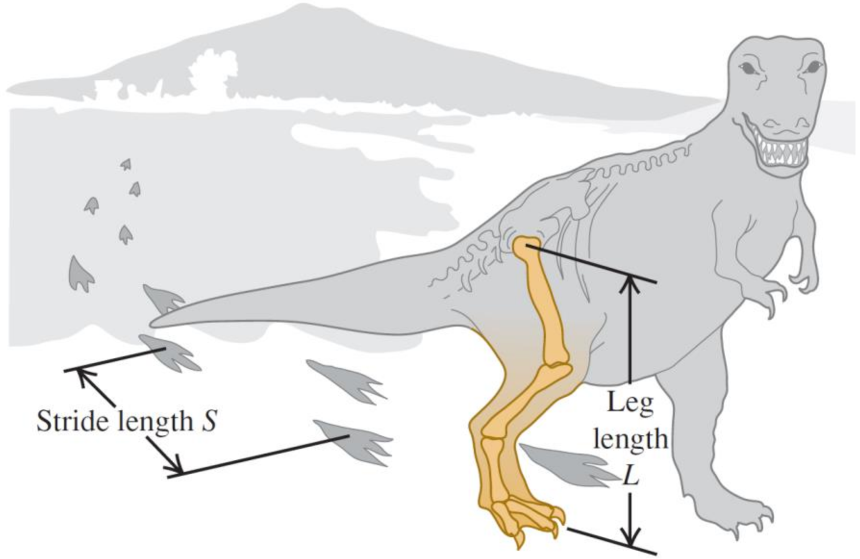


Example 10.4 (The T-Rex Problem)

All walking animals, including humans, have a natural walking pace—a number of steps per minute that is more comfortable than a faster or slower pace. Suppose that this pace corresponds to the oscillation of the leg as a physical pendulum.

(a) How does this pace depend on the length L of the leg from hip to foot? Treat the leg as a uniform rod pivoted at the hip.

(b) Fossil evidence shows that *T. rex,* a two-legged dinosaur that lived about 65 million years ago, had a leg length of 3.1 m and a stride length of 4 m (the distance from one footprint to the next print of the same foot). Estimate the walking speed of *T. rex.*



EXECUTE: The moment of inertia of a uniform rod about an axis through one end is $I = \frac{1}{3}ML^2$. The distance from the pivot to the rod's center of gravity is $d = L/2$. Then from Eq. (14.39),

$$T = 2\pi\sqrt{\frac{I}{mgd}} = 2\pi\sqrt{\frac{\frac{1}{3}ML^2}{MgL/2}} = 2\pi\sqrt{\frac{2L}{3g}}$$


That's all Folks!