Physics 122 – Class #6 – Outline

- Announcements/Reading Assignment
- Speed of waves in a string
- Wave energy and intensity
- History and snapshot plots
- Properties of sinusoidal waves
- Velocity of the string (not the wave)
- Doppler Effect (next time)

Announcements

- IGo clicker may work …
- HW-WR-01 Solutions posted

http://kestrel.nmt.edu/~rsonnenf/phys122/homeworksolns/

Homework/Reading

If you can follow the examples in the reading, you (probably) have a working knowledge of the material.

Read ALL OF Chapter 20 (except 570.5-571, 579.5-580.5)

Homework WR-02, Problems 20-4, 20-5, 20-6, 20-41.

HW-OL-03 (Waves) is posted.

MP includes problems: 20.1, 20.3, 20.13, 20.14, 20.22, 20.23, 20.26, 20.29, 20.32, 20.37, 20.53, 20.57, 20.65, 20.74

Ch. 20: Traveling Waves

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

$$D(x,t) = A\sin(kx - \omega t + \Phi)$$

$$I = P/a \qquad I_{spherical} = P_{source}/4\pi r^2$$

sound $$f_{approach} = \frac{f_0}{1 - v_s/v} \qquad f_{recede} = \frac{f_0}{1 + v_s/v}$$

light $$\lambda_{approach} = \sqrt{\frac{1 - v_s/c}{1 + v_s/c}}\lambda_0 \qquad \lambda_{recede} = \sqrt{\frac{1 + v_s/c}{1 - v_s/c}}\lambda_0$$

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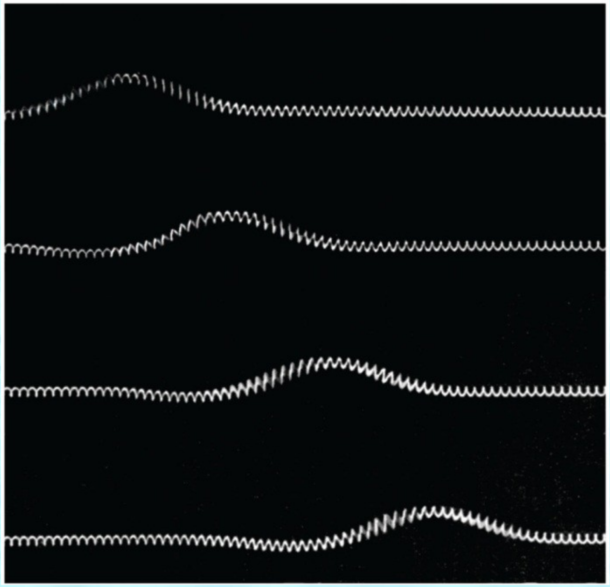
Reading Question #2

A graph showing wave displacement versus time at a specific point in space is called a

A. Snapshot graph.
B. History graph.
C. Bar graph.
D. Line graph.
E. Composite graph.

Wave Speed on a string (HW 20.1, 20.3)

The speed of transverse waves on a string stretched with tension T_s is:



$$v_{string} = \sqrt{\frac{T_s}{\mu}} \qquad \text{(wave speed on a stretched string)}$$

Where μ is the string's mass-to-length ratio, also called the **linear density**:

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

Wave Speed on a string

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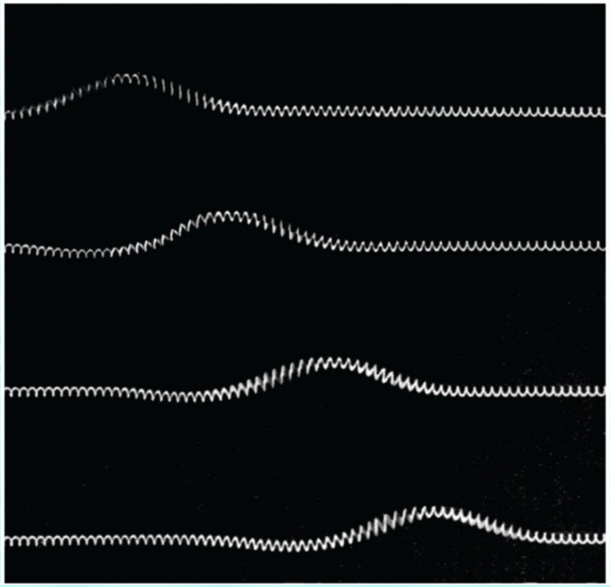

$$v_{string} = \sqrt{\frac{T_s}{\mu}} \qquad \text{(wave speed on a stretched string)}$$

Where μ is the string's mass-to-length ratio, also called the **linear density**:

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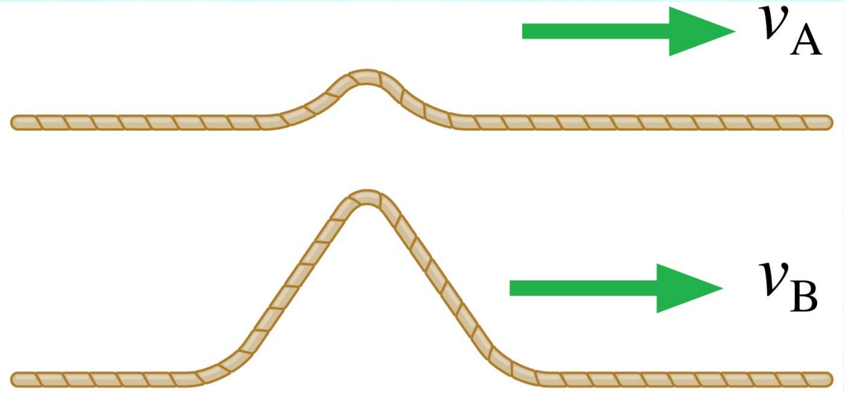
CLICKER QUESTION

For a wave pulse on a string to travel twice as fast, the string tension must be

A. Increased by a factor of 4.
B. Increased by a factor of 2.
C. Decreased to one half its initial value.
D. Decreased to one fourth its initial value.
E. Not possible. The pulse speed is always the same.

CLICKER QUESTION

These two wave pulses travel along the same stretched string, one after the other. Which is true?



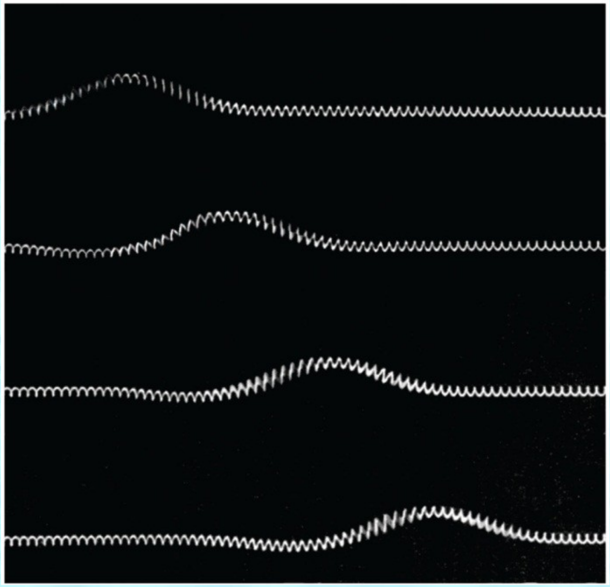
A. $v_A > v_B$

B. $v_B > v_A$

C. $v_A = v_B$

D. Not enough information to tell.

Waves in one dimension do not weaken except by friction



http://phet.colorado.edu/sims/wave-on-a-string/wave-on-a-string_en.html

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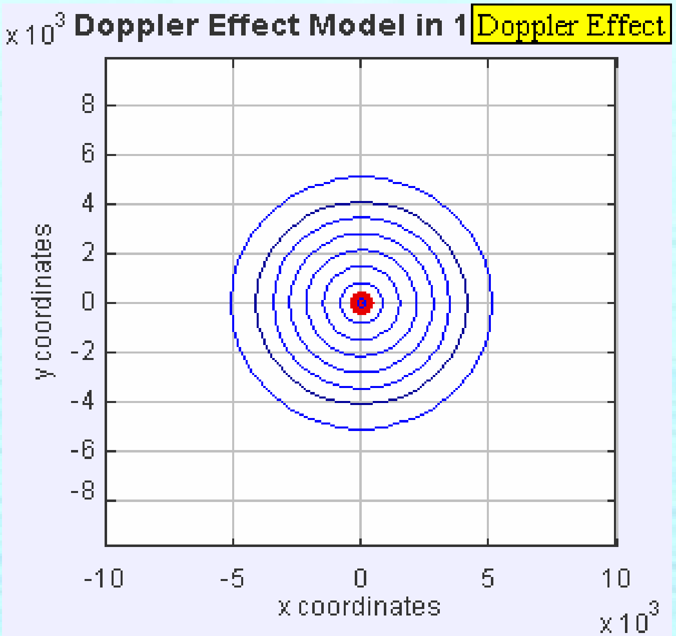
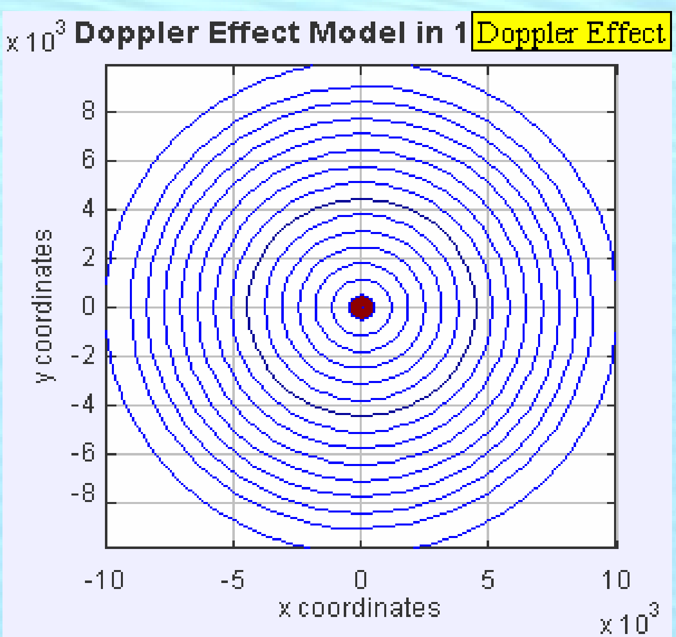
Two or Three dimensional waves





- The figures show “wave fronts” (wave peaks) as a continuous wave progresses.
- Notice that the wave fronts move outward a distance $\Delta r = v \Delta t$ during the time interval Δt.
- That is, the wave moves with *constant speed.*

Waves carry energy (HW 20.28, 29, 32)

Energy per unit area is called “intensity”

$$I = P/a$$

$$I_{spherical} = P_{source}/4\pi r^2$$

Problem 32. Sun emits 4x10^26 W and is 150 million kilometers from Earth. What is intensity received at Earth?

Waves carry energy

$$I = P/a$$

$$I_{spherical} = P_{source}/4\pi r^2$$

Waves carry energy

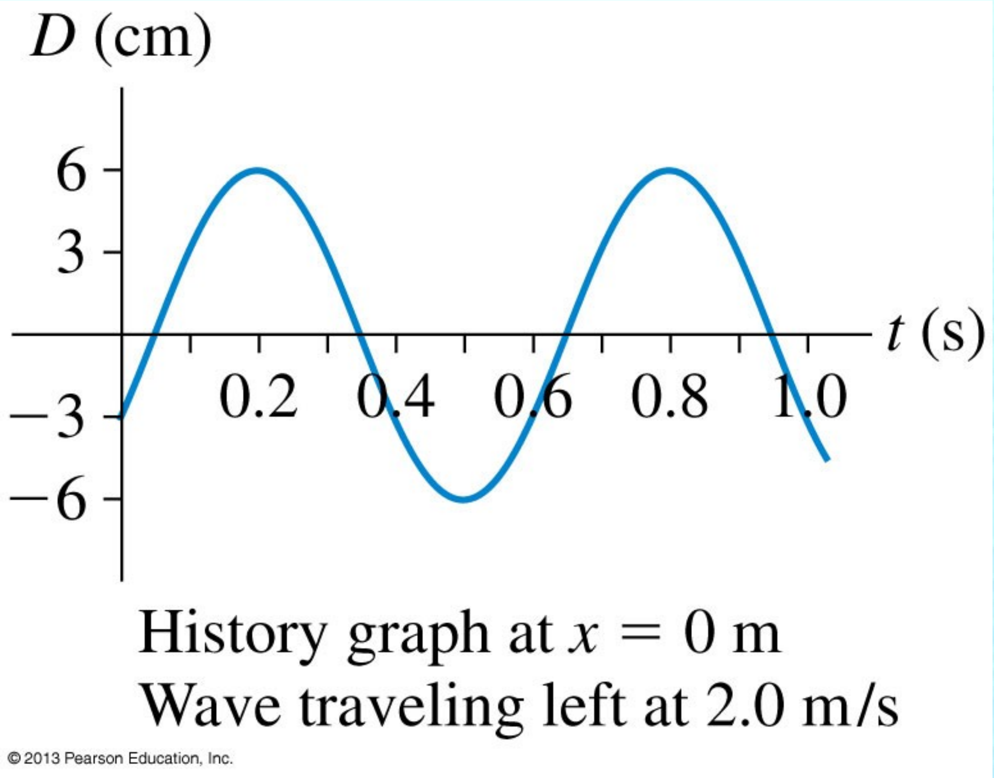
Tinyurl.com/duckgen
Tinyurl.com/wellsturbine

What about electromagnetic waves?
PheT and radio waves … shows
Amplitude and intensity
Falling off with distance.

Homework 20.13, 20.14

$$D(x,t) = A\sin(kx - \omega t + \Phi)$$

- What are amplitude, frequency, wavelength, and phase of this wave?
- What is the equation of the wave?



$$D(x,t) = 6\sin\left(\frac{2\pi}{0.6}x + \frac{4\pi}{0.6}t + \Phi\right)$$

$$D(0,0) = -3 = 6\sin\left(\frac{2\pi}{0.6}0 + \frac{4\pi}{0.6}0 + \Phi\right)$$

$$-3 = 6\sin(\Phi)$$

$$\sin(\Phi) = -1/2$$

$$\Phi = -\pi/6$$

The Mathematics of Sinusoidal Waves

HW 20.22, 20.23, 20.26

- Define the *angular frequency* of a wave:

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

- Define the *wave number* of a wave:

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

- The displacement caused by a traveling sinusoidal wave is:

$$D(x, t) = A \sin(kx - \omega t + \phi_0)$$

(sinusoidal wave traveling in the positive x-direction)

This wave travels at a speed $v = \omega/k$.
(or $v = f\lambda$)

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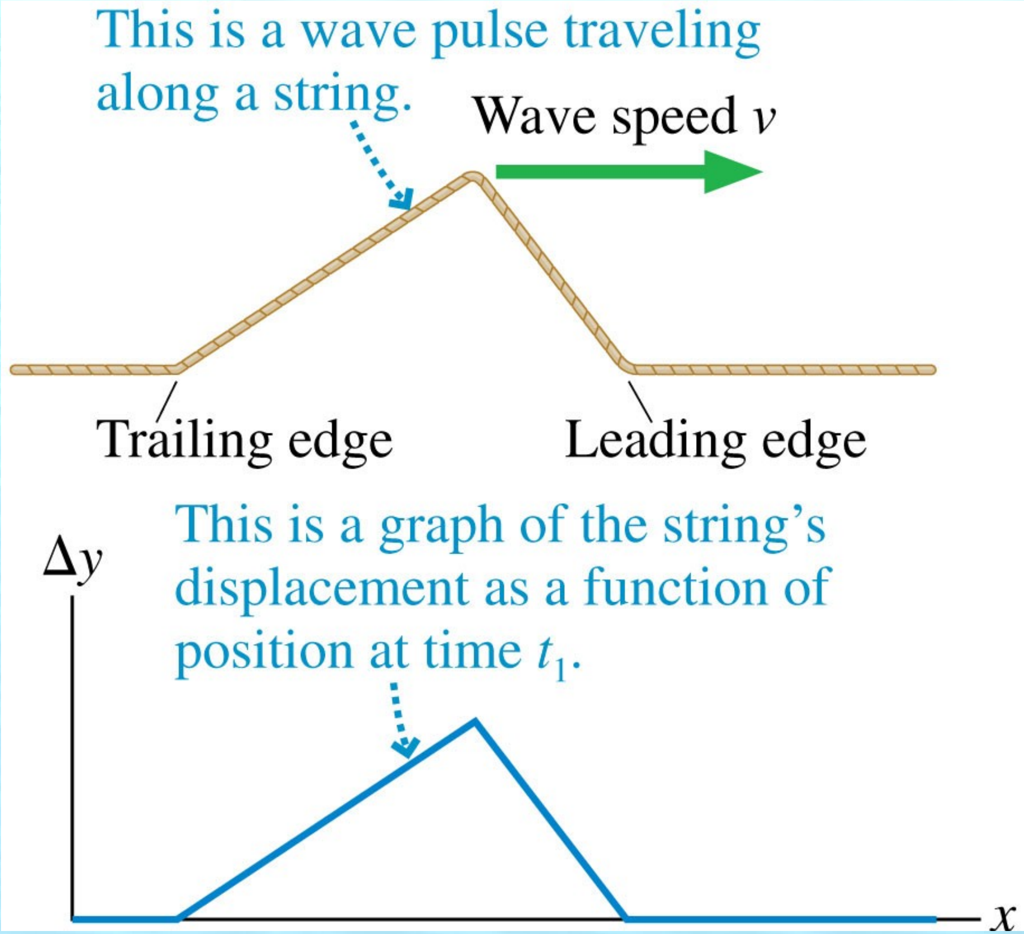
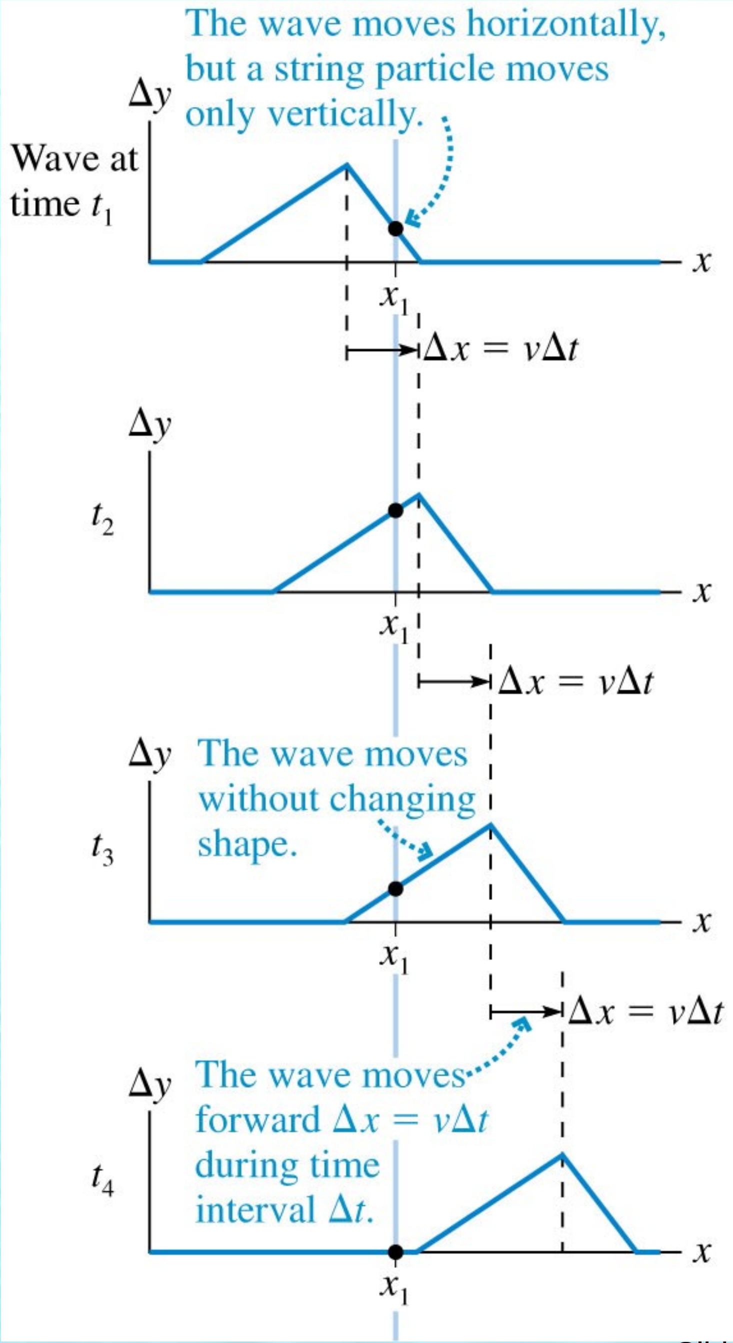
Snapshot Graph

- A graph that shows the wave's displacement as a function of position at a single instant of time is called a **snapshot graph**.
- For a wave on a string, a snapshot graph is literally a picture of the wave at this instant.



One-Dimensional Waves

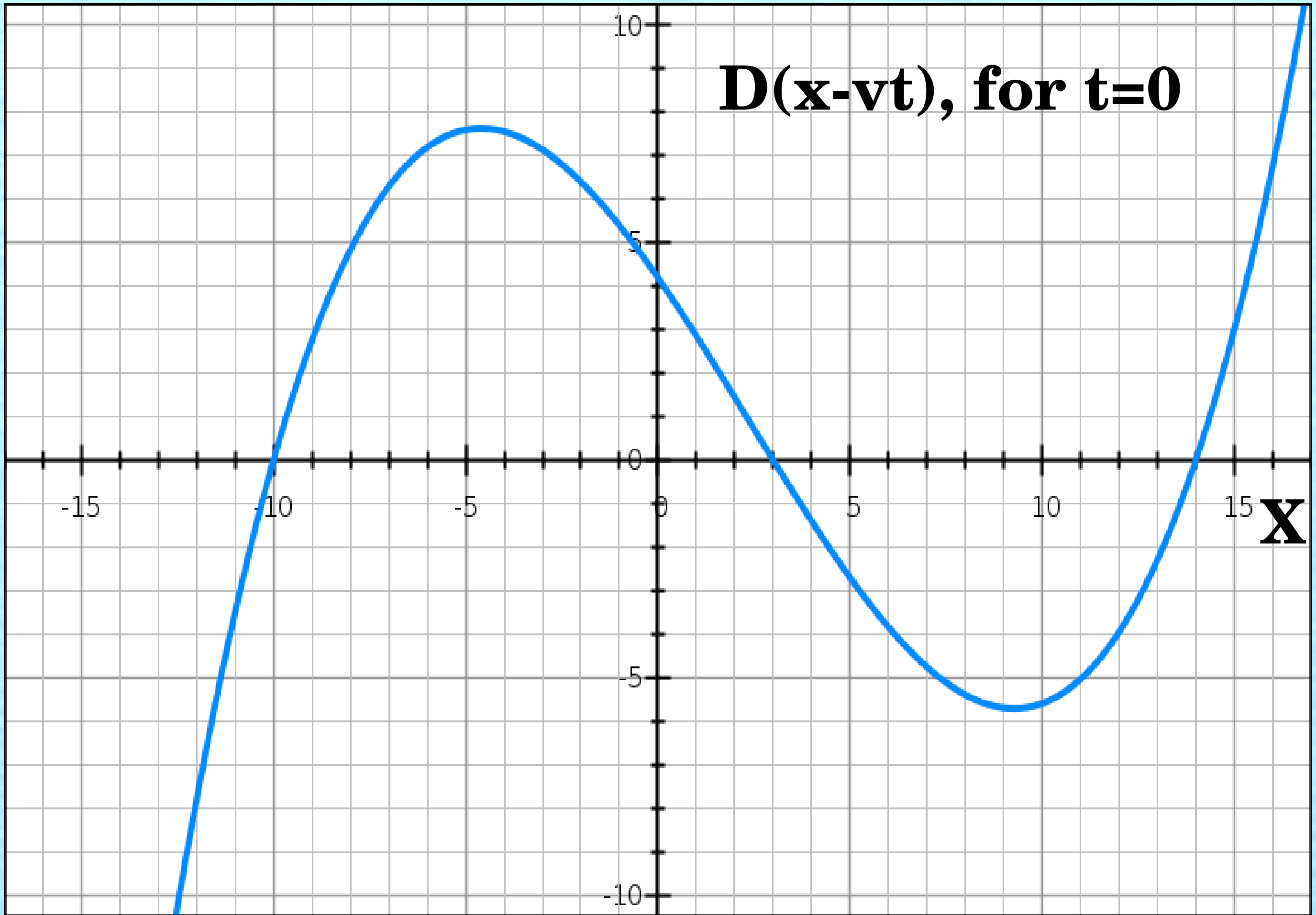
- The figure shows a sequence of snapshot graphs as a wave pulse moves.
- These are like successive frames from a movie.
- Notice that the wave pulse moves forward distance $\Delta x = v\Delta t$ during the time interval Δt.
- That is, the wave moves with *constant speed.*



Going from a static "shape" to a traveling "wave"

Given any function D(x), you can "make it move" by replacing x by x-vt.

Let v = 3 m/s and plot D(x) at 0, 1, 2 sec)

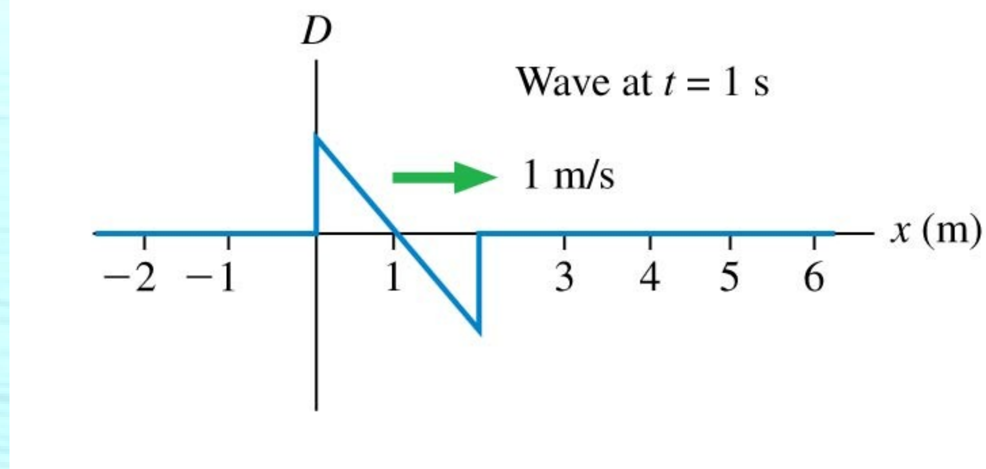


x-vt
(moves right)

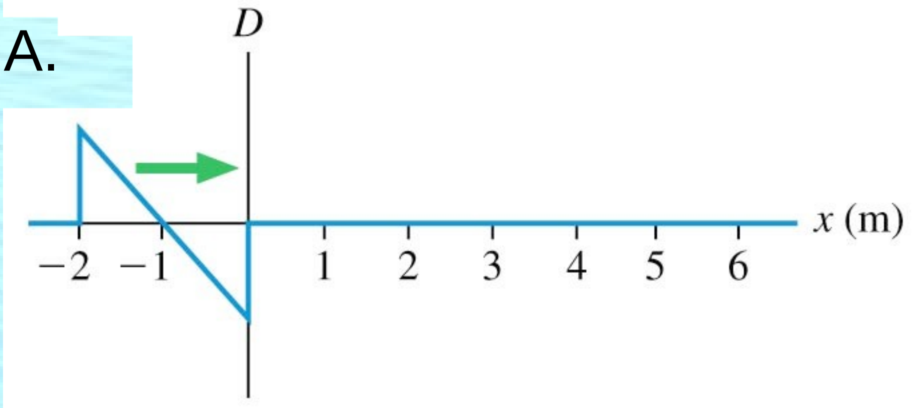
x+vt
(moves left)

Clicker Question

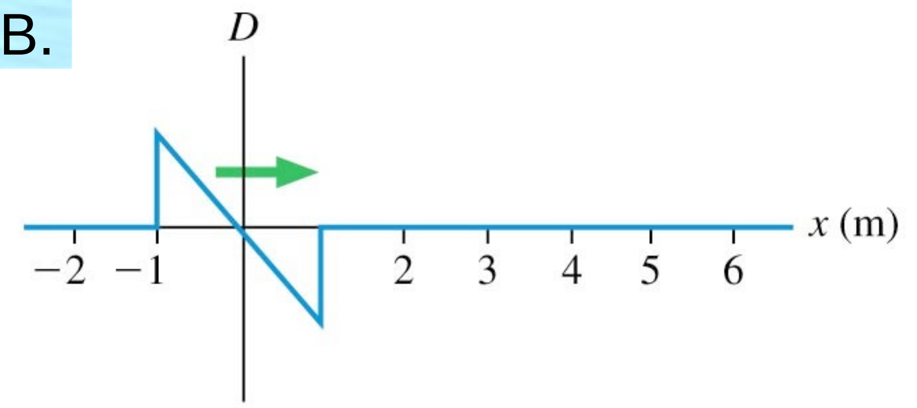
This is a snapshot graph at $t = 1$ s of a wave pulse traveling to the right at 1 m/s. Which graph below shows the wave pulse at $t = -1$ s?



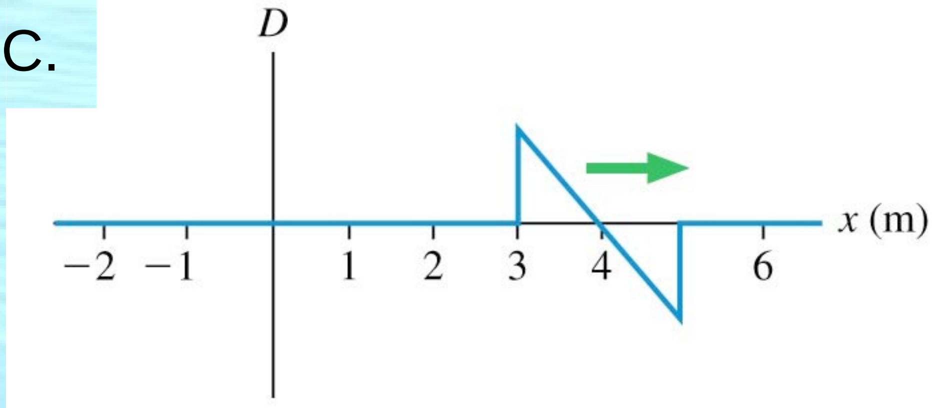
A.



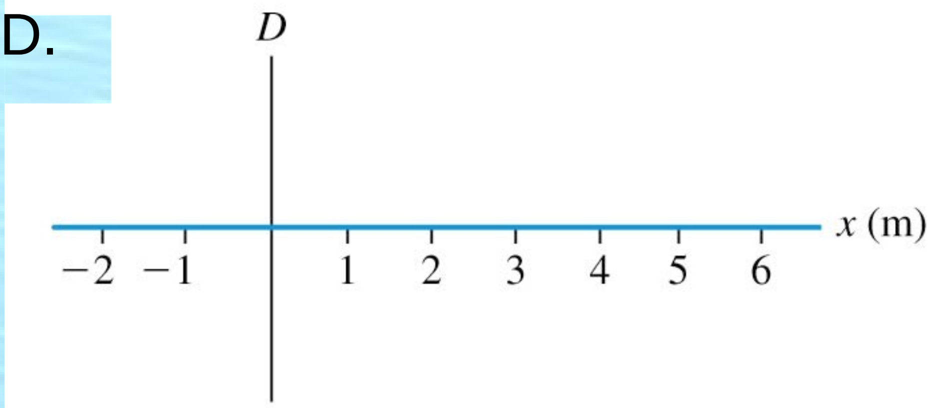
B.



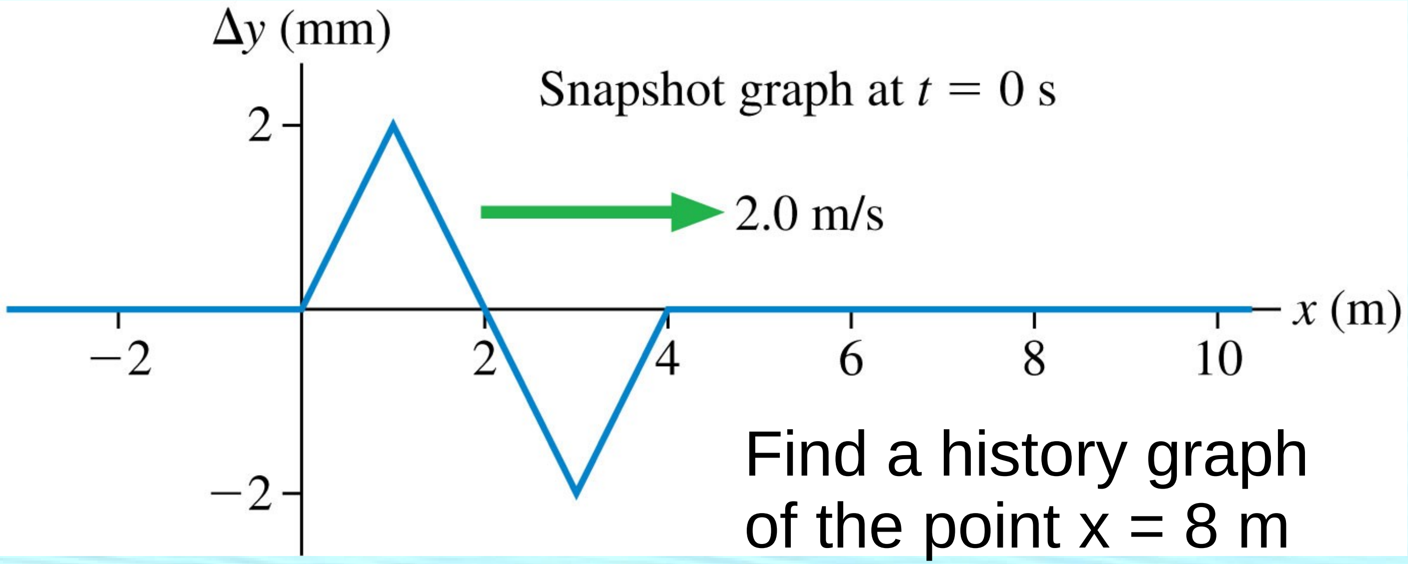
C.



D.

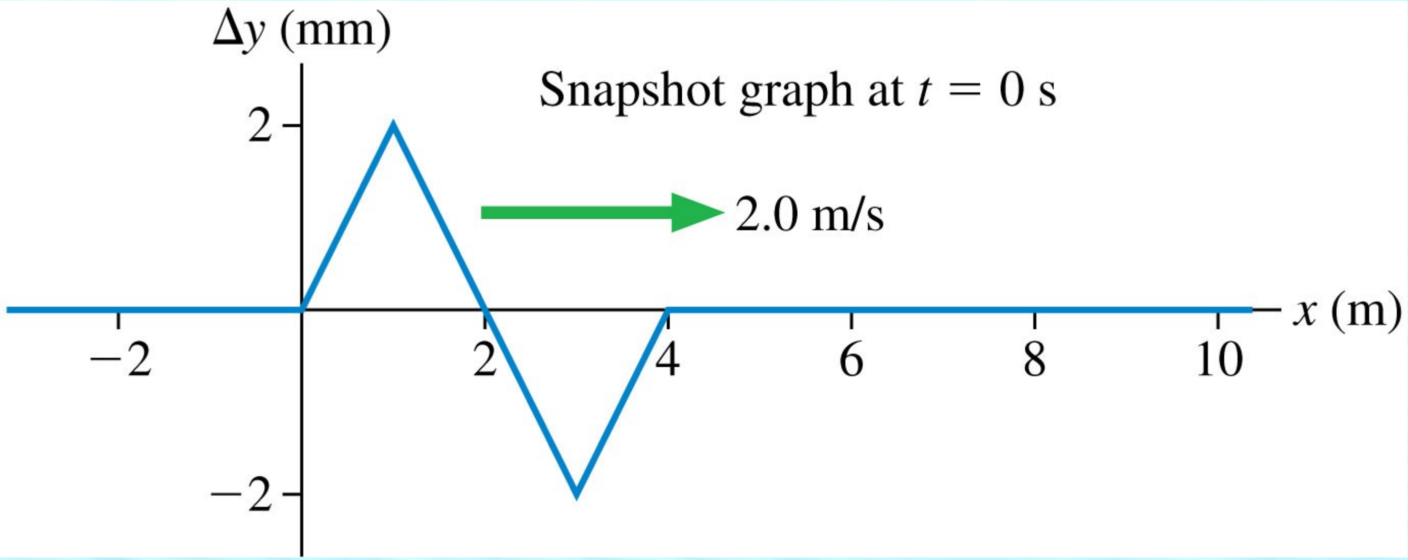


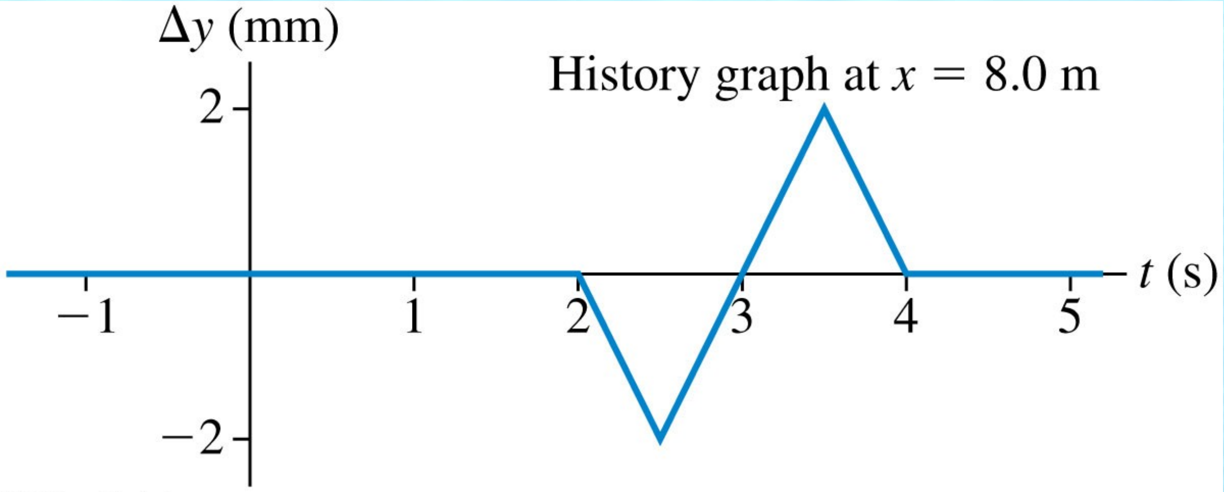
Finding a History Graph From a Snapshot Graph



Find a history graph of the point x = 8 m

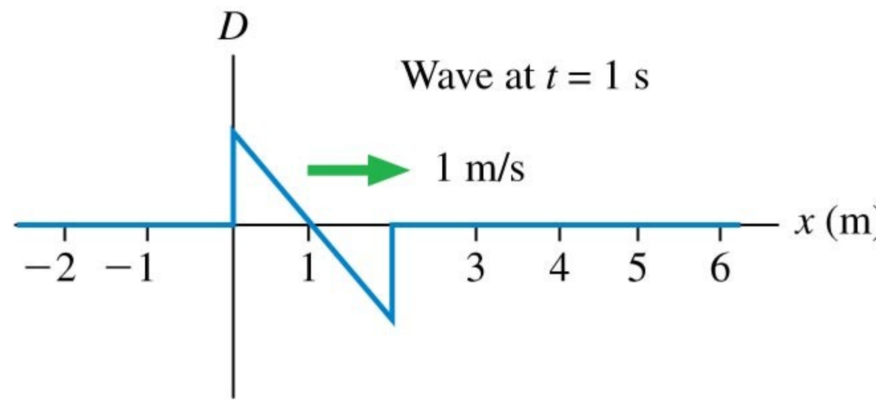
Example 20.2 Finding a History Graph From a Snapshot Graph



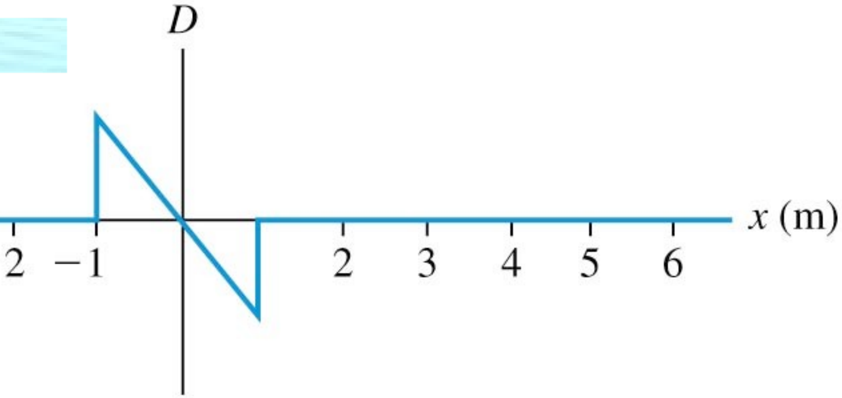


Clicker Question

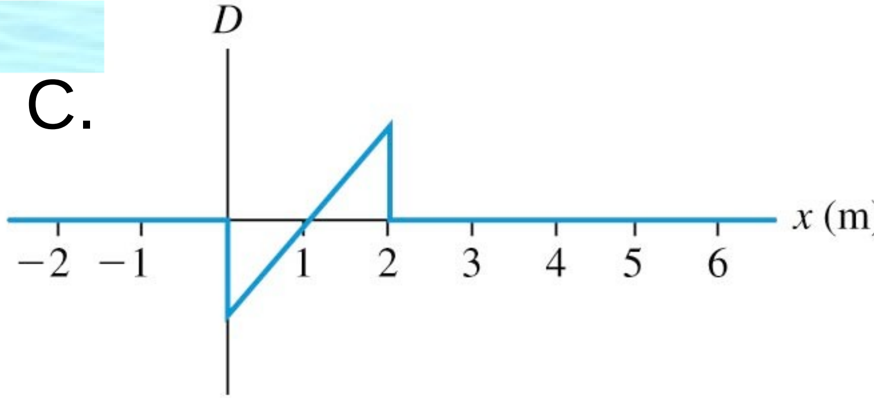
This is a snapshot graph at $t = 1$ s of a wave pulse traveling to the right at 1 m/s. Which graph below shows the history graph at $x = 1$ m?



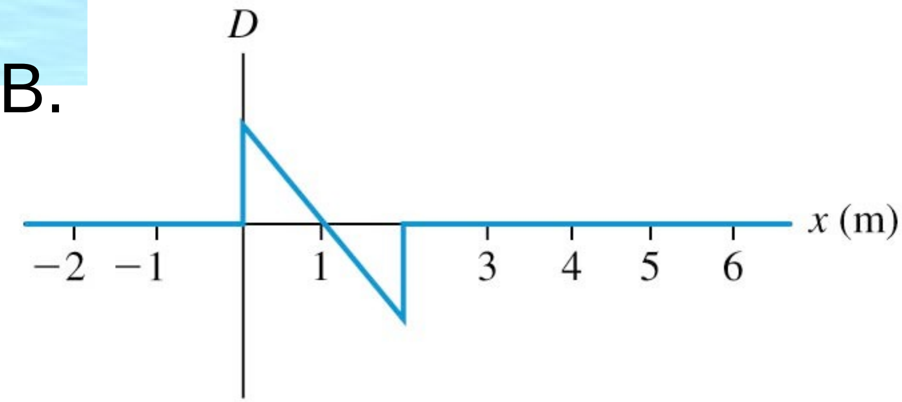
A.



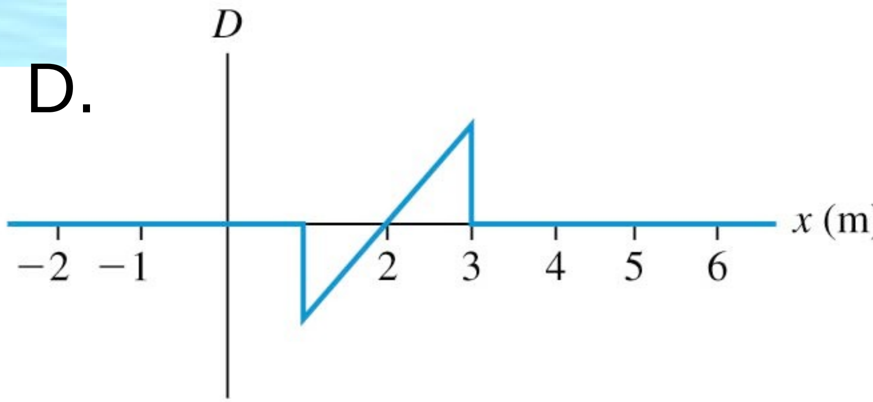
C.



B.



D.



The Mathematics of Sinusoidal Waves

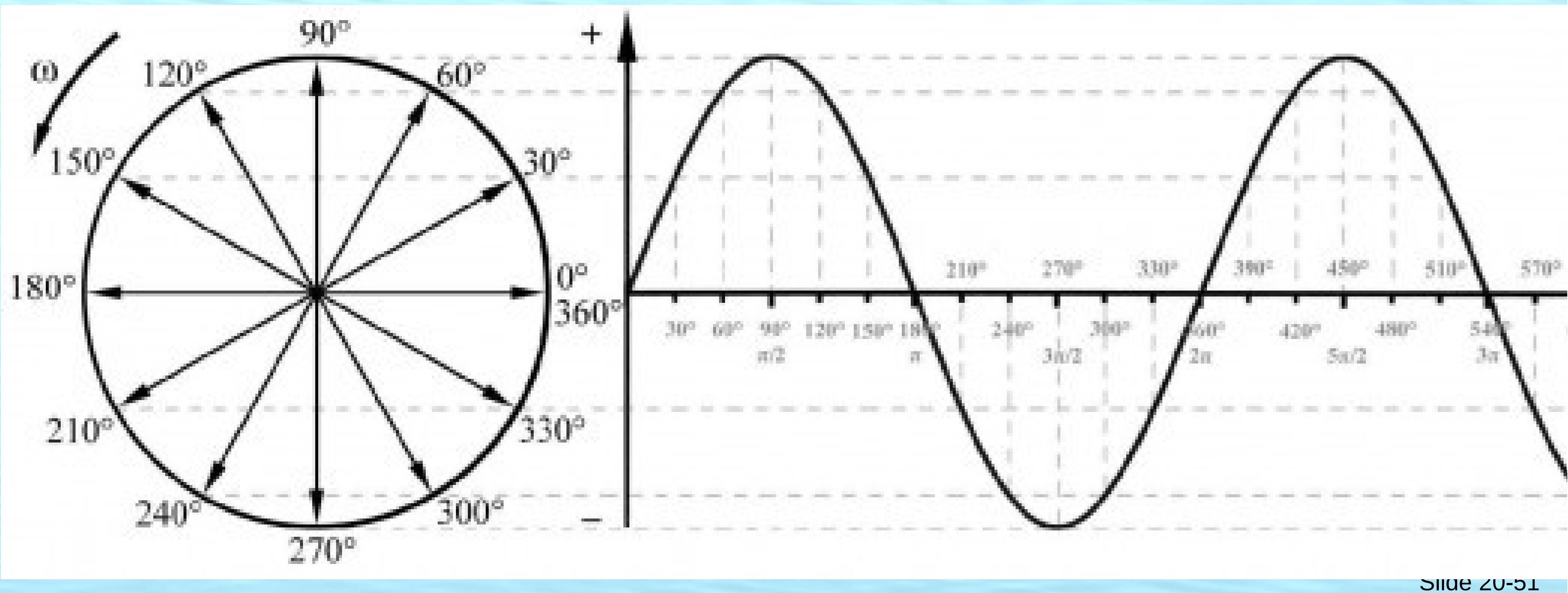
There is a link between rotation
And sine/cosine waves.

If you remember it, you will never forget that the sine and cosine repeat every 2 pi radians.

Tinyurl.com/rotationsine

The Mathematics of Sinusoidal Waves

There is a link between rotation
And sine/cosine waves.
A rotation such that $\Phi = \omega t$
Gives also $y = \sin(\omega t),\ x = \cos(\omega t)$



Make a sine-wave move

Given $D(x) = A\sin(2\pi x/\lambda)$

Replace $x \rightarrow x - vt$

Then $D(x,t) = A\sin(2\pi(x-vt)/\lambda)$

$$D(x,t) = A\sin(2\pi x/\lambda - 2\pi vt/\lambda)$$

But $v = f\lambda \rightarrow v/\lambda = f$

$$D(x,t) = A\sin(2\pi x/\lambda - 2\pi ft)$$

And $\omega = 2\pi f$

$$D(x,t) = A\sin(2\pi x/\lambda - \omega t)$$

Make a sine-wave move

Given $D(x,t) = A\sin(2\pi x/\lambda - \omega t)$

Define $2\frac{\pi}{\lambda} \rightarrow k$

Then $D(x,t) = A\sin(kx - \omega t)$

Make a sine-wave move

Given $D(x,t) = A\sin(kx - \omega t)$

A wave has angular frequency 30 rad/s wavelength 2.0 cm. What are its wave number and wave speed?

CLICKER QUESTION

Which of these waves is traveling to the left? (all parameters are positive numbers)

[A] $f(x,t) = 3\sin(4x + 3t)$

[B] $f(x,t) = A\sin(kx - \omega t)$

[C] $f(x,t) = A\sin\left(2\pi\frac{x}{\lambda} + 2\pi\frac{t}{T}\right)$

[D] $f(x,t) = 3\sin(4x - 3t)$

[E] A, C

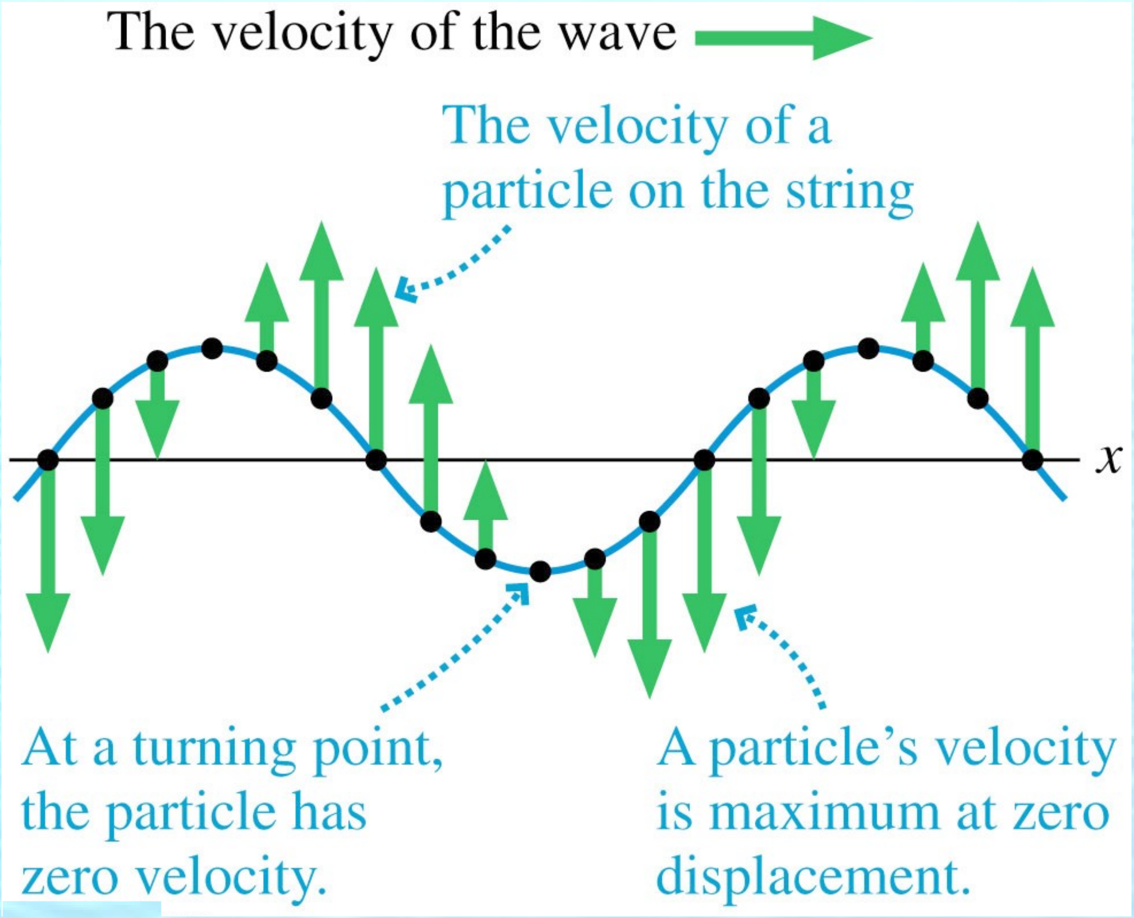
Make a sine-wave move

Given $D(x,t) = 3.5\sin(2.7x - 124t)$

What are v? F, lambda?

Wave Motion on a String (20.53, 20.57)

- Shown is a snapshot graph of a wave on a string with vectors showing the velocity of the string at various points.
- As the wave moves along *x*, the velocity of a particle on the string is in the *y*-direction.



$$v_y = \frac{dy}{dt} = -\omega A \cos(kx - \omega t + \phi_0)$$

Next Time

Properties of Waves