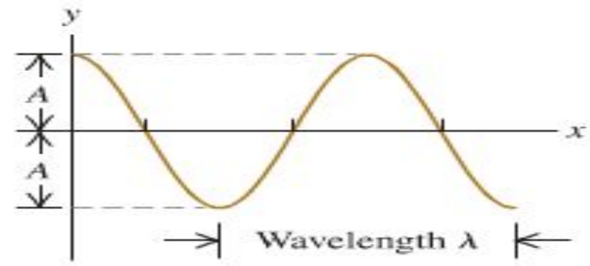
Lecture 4
(Mechanical Waves)

Physics 2310-01 Fall 2019

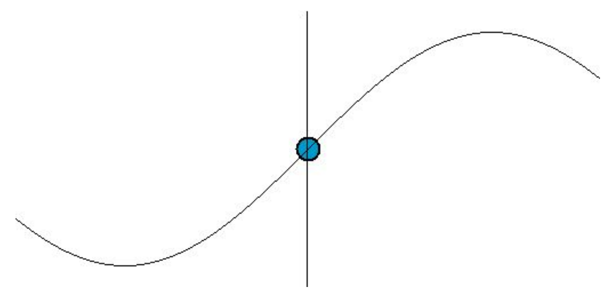
Douglas Fields

Characteristics of "Waves"

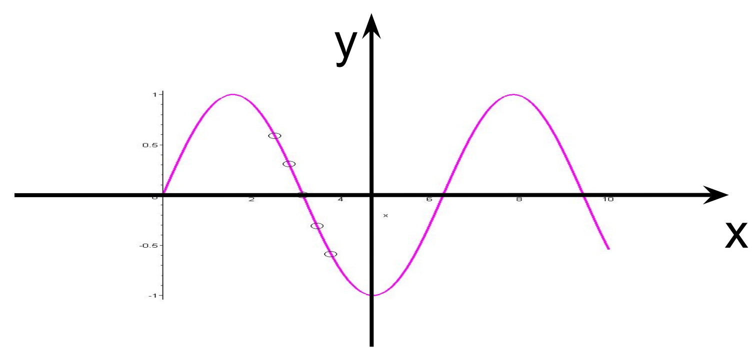
- Amplitude, A:
- Wavelength, λ:



- Frequency, f or ω:



- Wave speed, v:



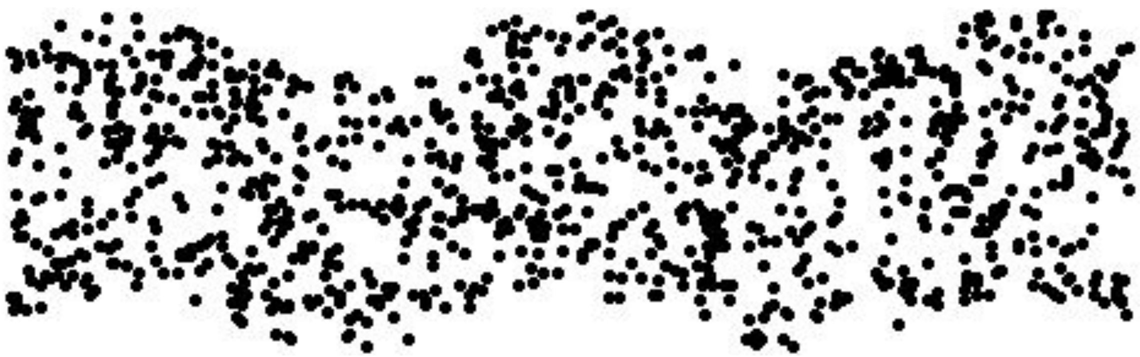
Types of Waves

- There are three general types of mechanical waves:
  - Transverse – particle motion is perpendicular to wave motion.
  - Longitudinal – particle motion is in the same direction as wave motion.
  - Combined – sea waves.

CAUTION **Wave motion vs. particle motion** Don't confuse the motion of the *transverse wave* along the string and the motion of a *particle* of the string. The wave moves with constant speed v *along* the length of the string, while the motion of the particle is simple harmonic and *transverse* (perpendicular) to the length of the string.

Transverse Waves

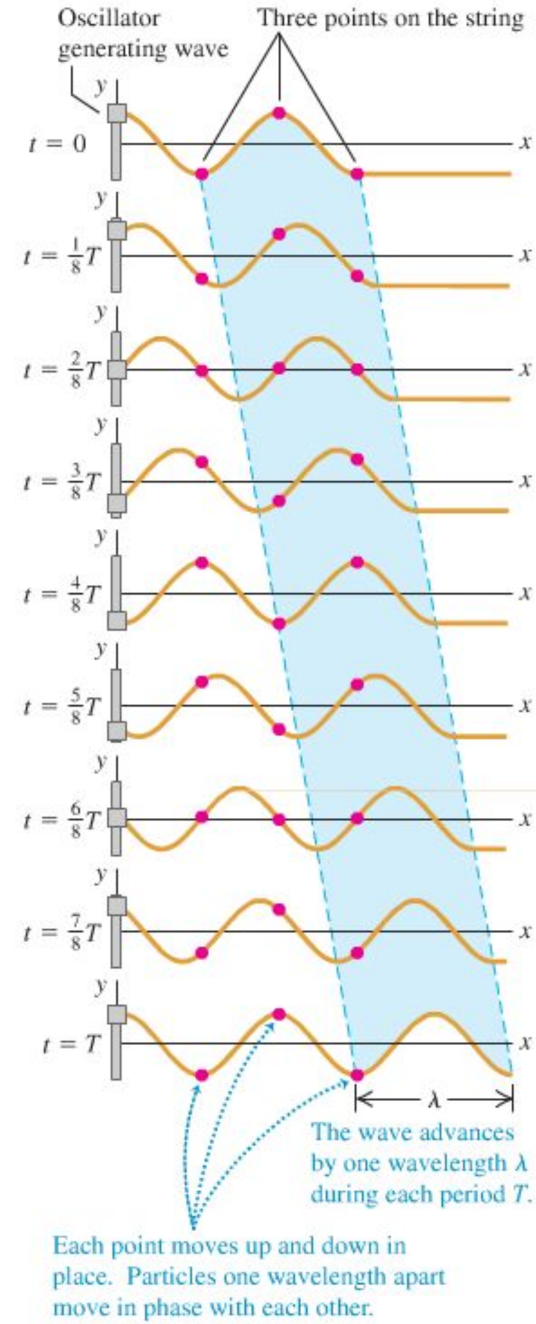
- Particle motion is perpendicular to wave motion.



- Notice that it takes one period of time for the wave to move one wavelength in distance:

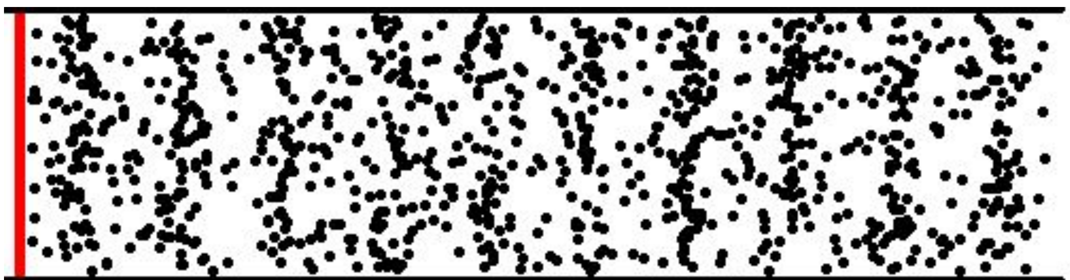
$$v = \frac{\lambda}{T} = f\lambda = 2\pi f\,\frac{\lambda}{2\pi} = \frac{\omega}{k}$$

$$\omega = 2\pi f, \quad k = \frac{2\pi}{\lambda}$$



Longitudinal Waves

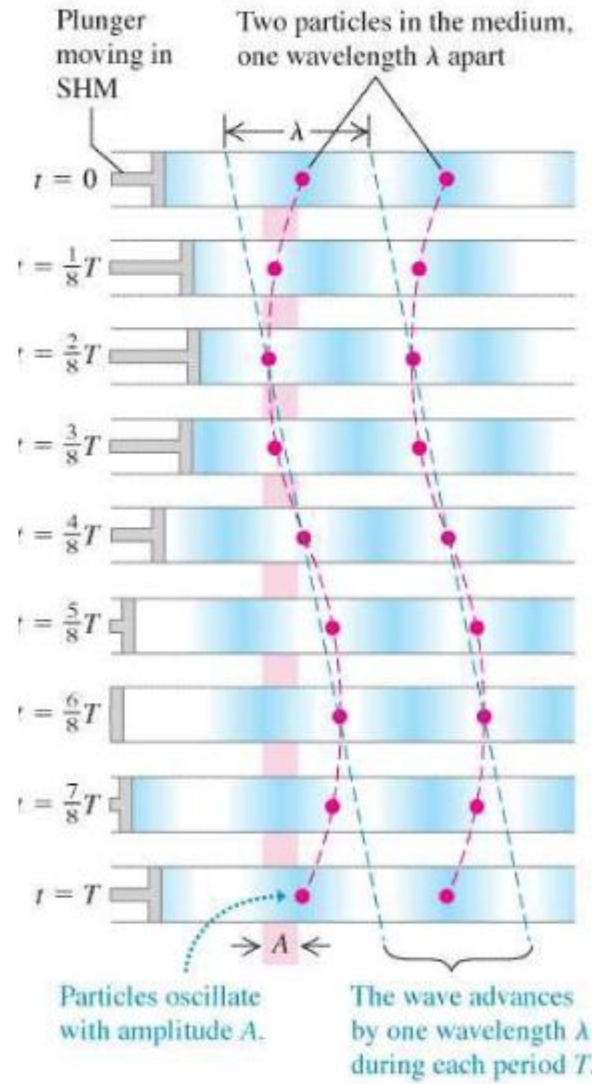
- Particle motion is in the same direction as wave motion.



- Again, notice that it takes one period of time for the **wave** to move one wavelength in distance:

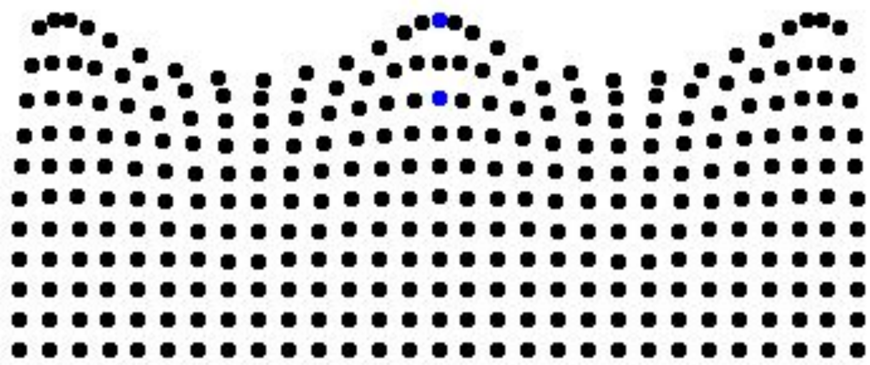
$$v = \frac{\lambda}{T} = f\lambda = 2\pi f\,\frac{\lambda}{2\pi} = \frac{\omega}{k}$$

$$\omega = 2\pi f, \quad k = \frac{2\pi}{\lambda}$$



Combined Waves

- Water waves…



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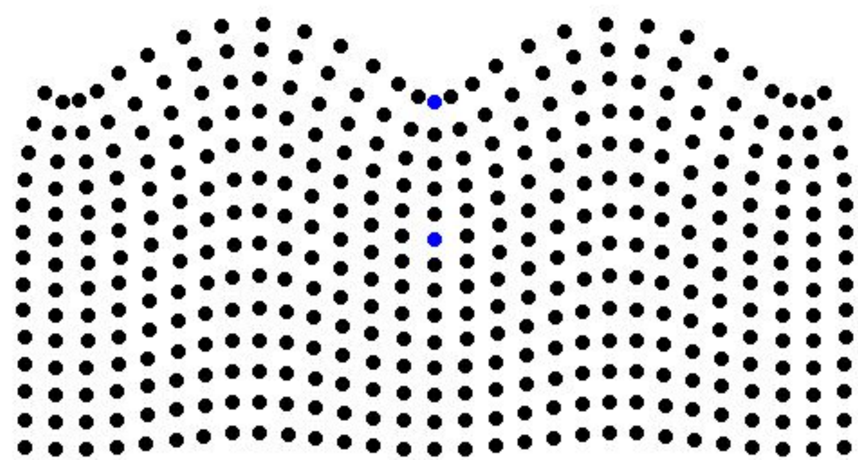

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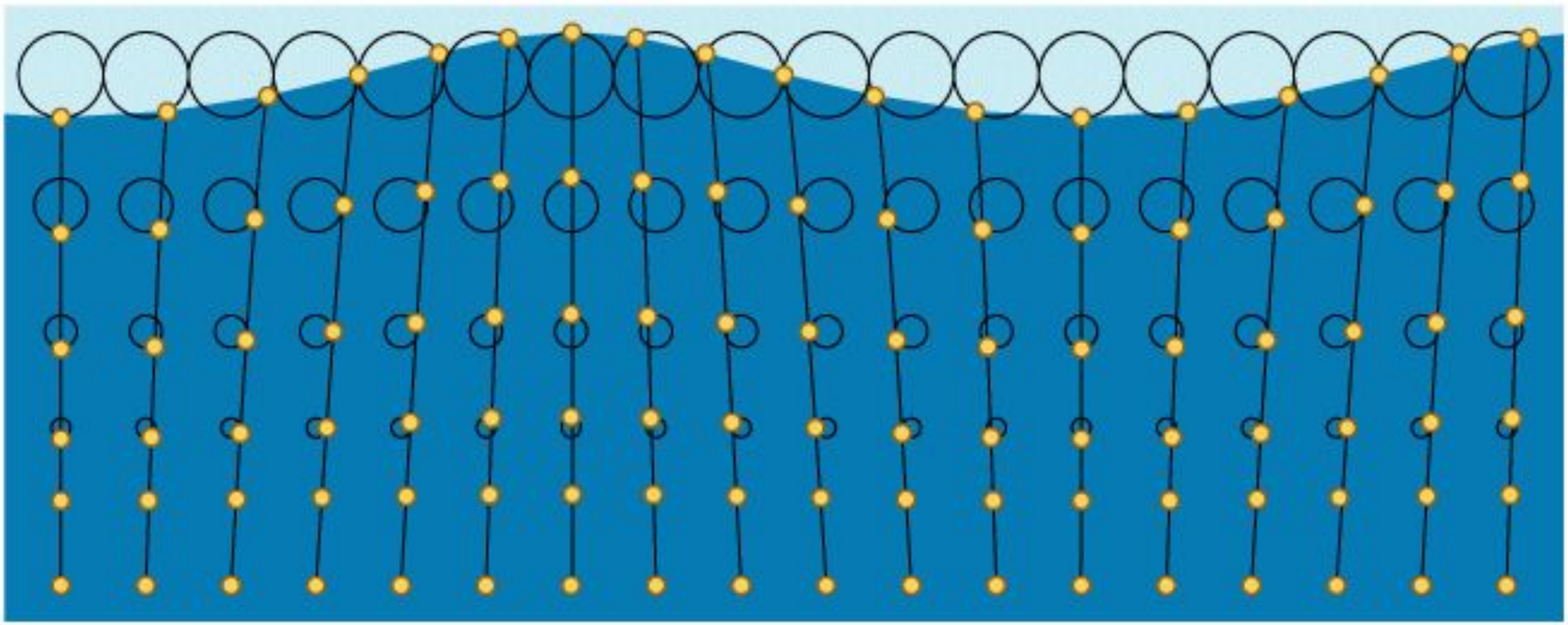
Combined Waves

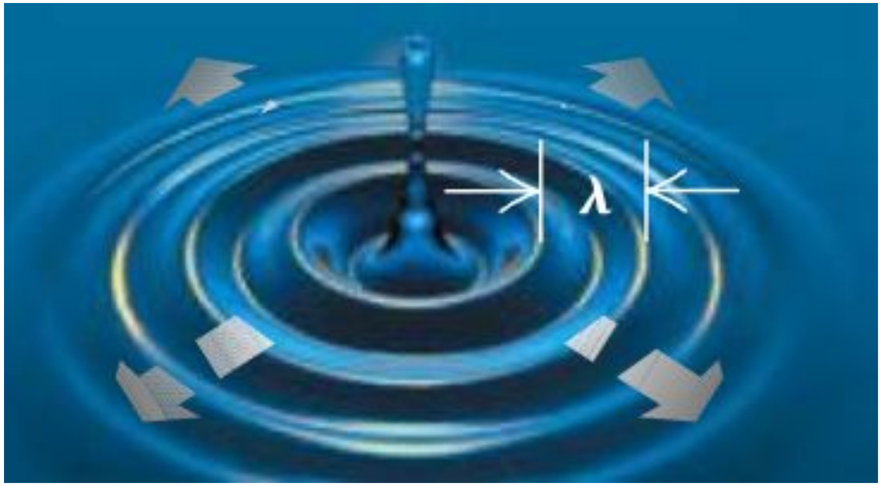
- Water waves…



Which way are the waves moving?
It is important to differentiate wave and particle motion!!!

2-Dimensional Waves

- Waves can, of course, move in more than one dimension:



2-Dimensional Waves

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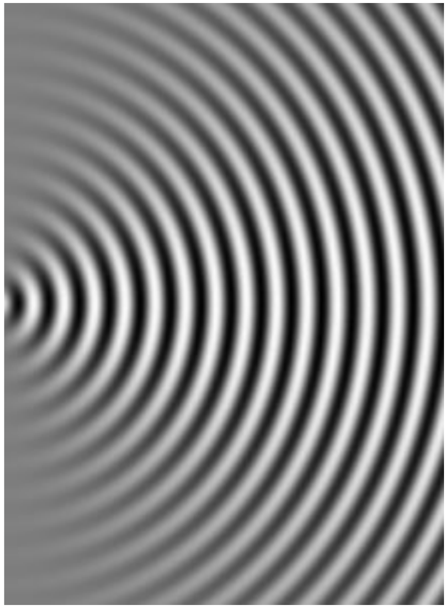
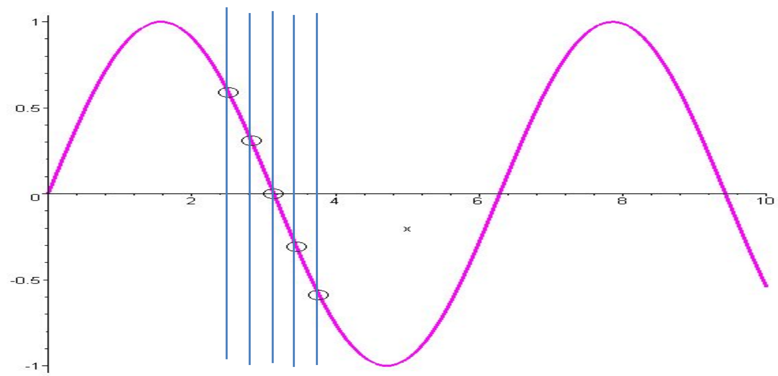


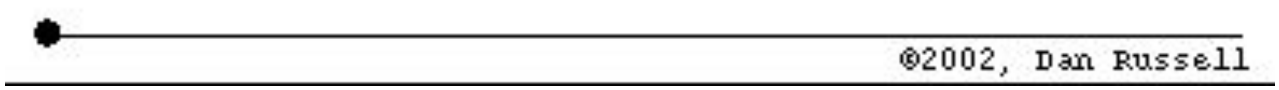
Diffraction!!!

Periodic vs. Non-periodic Waves

- Periodic means that it repeats itself:

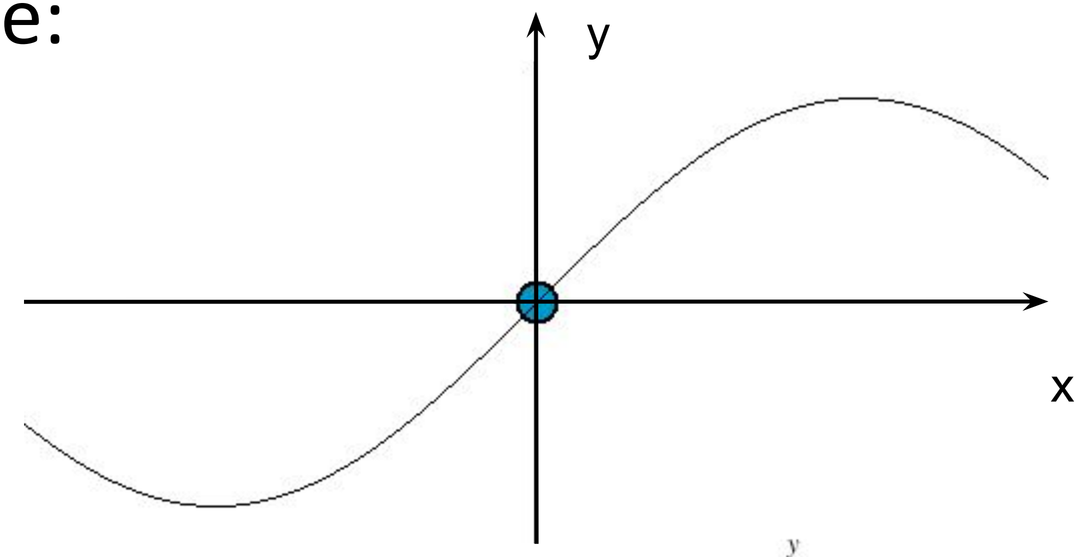


- Non-periodic can be, e.g., a pulse:



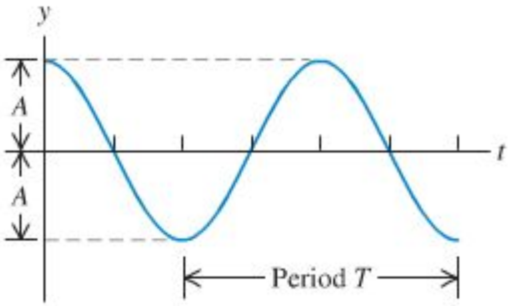
Periodic Wave Description

- Displacement for a fixed position as a function of time:



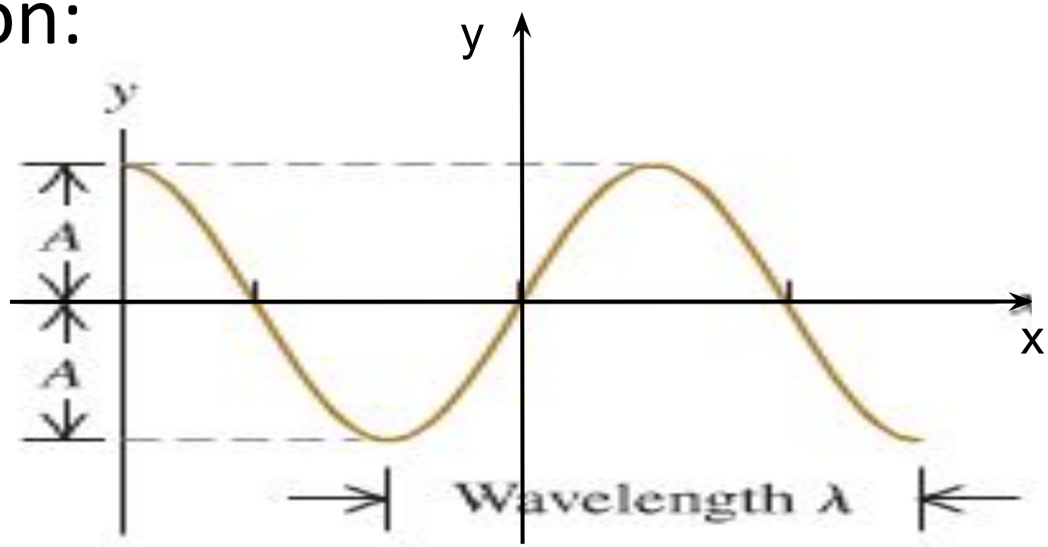
$$y\left(x=0,t\right)=A\cos\left(\omega t\right)$$

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



Periodic Wave Description

- Displacement for a fixed time as a function of position:



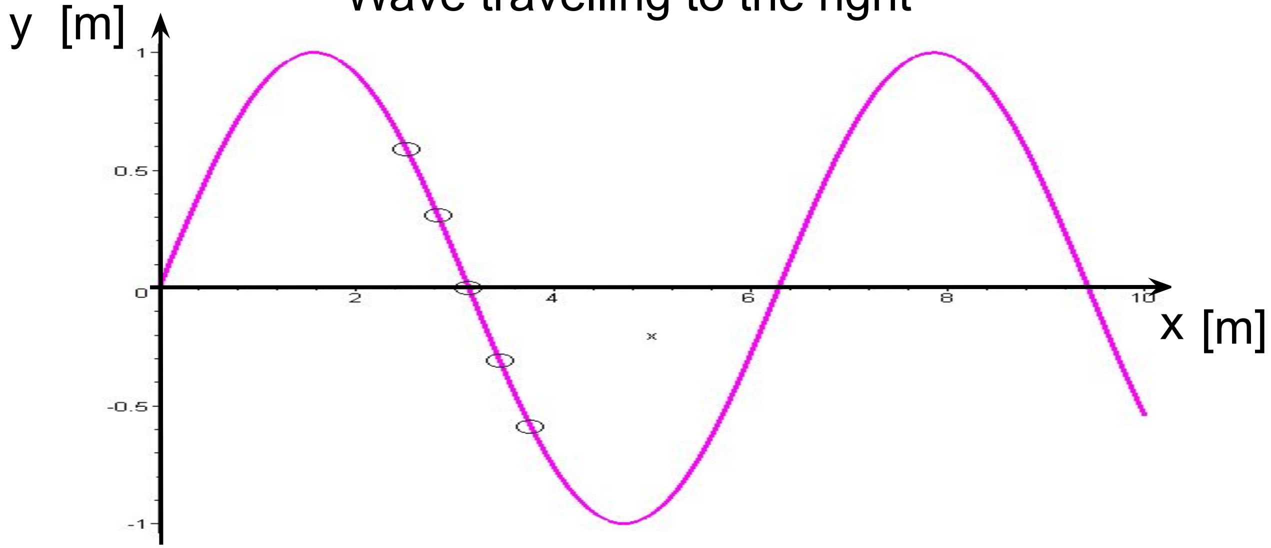
$$y(x,t=0)=A\cos(kx)$$ Or, in this case, sin(kx)

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

Periodic Wave Description

- We can put these together:

Wave travelling to the right



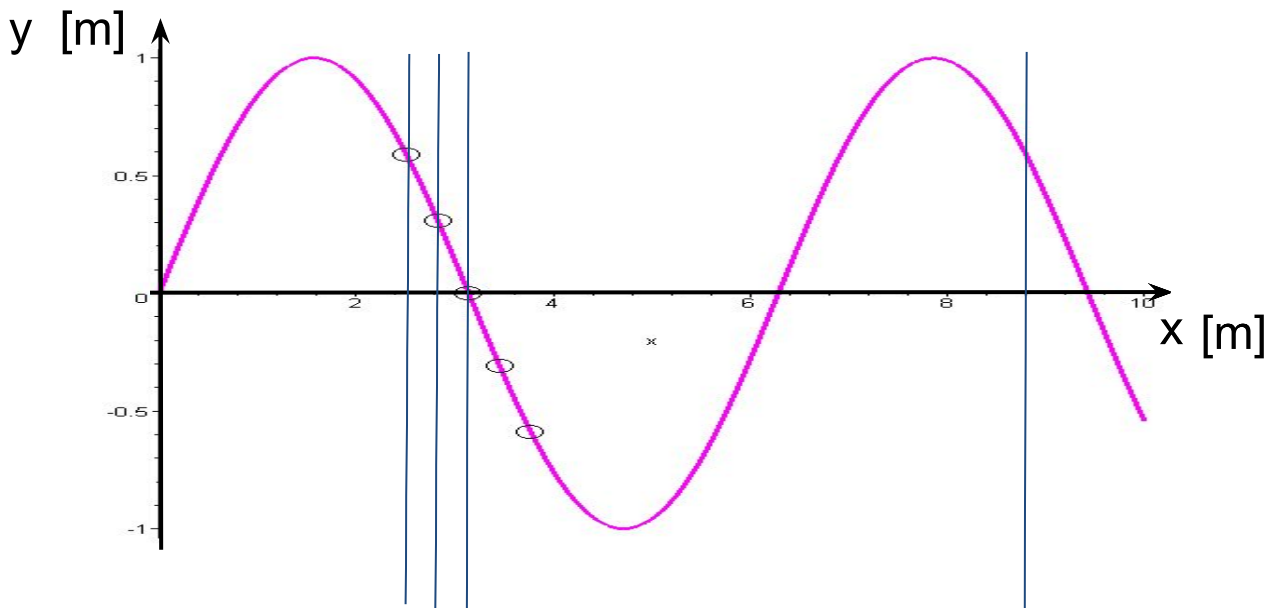
$$y(x,t) = A\sin(kx - \omega t)$$

$$k = \frac{2\pi}{\lambda}, \quad \omega = \frac{2\pi}{T}, \quad v = \frac{\omega}{k}$$

What is A? k? ω? v?

Periodic Wave Description

- Look at just one point at a time on the medium:



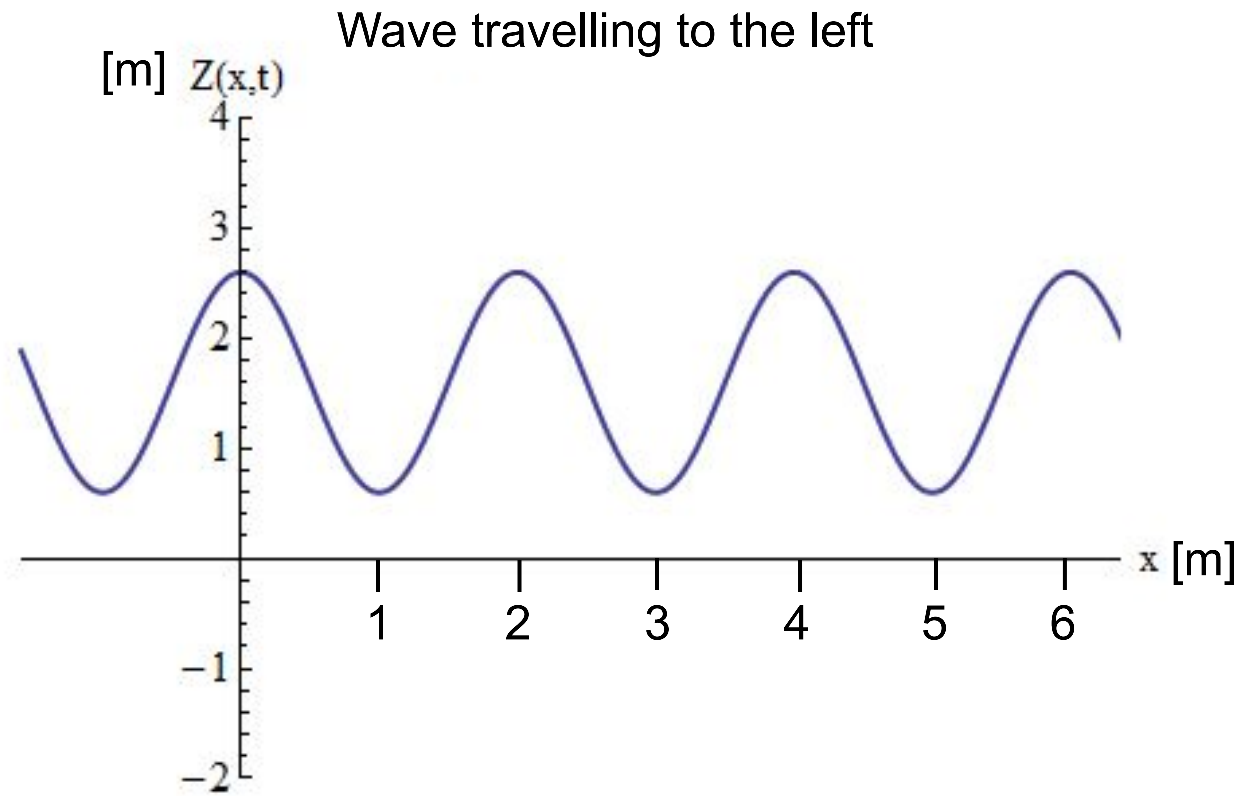
$$y(x=2.5,t) = cos(\omega t + \phi)$$

$$y(x=2.9,t) = cos(\omega t - \delta\phi + \phi)$$

$$y(x=3.3,t) = cos(\omega t - 2\delta\phi + \phi)$$

$$y(x=2.5+\lambda,t) = cos(\omega t - 2\pi + \phi)$$

Periodic Wave Description



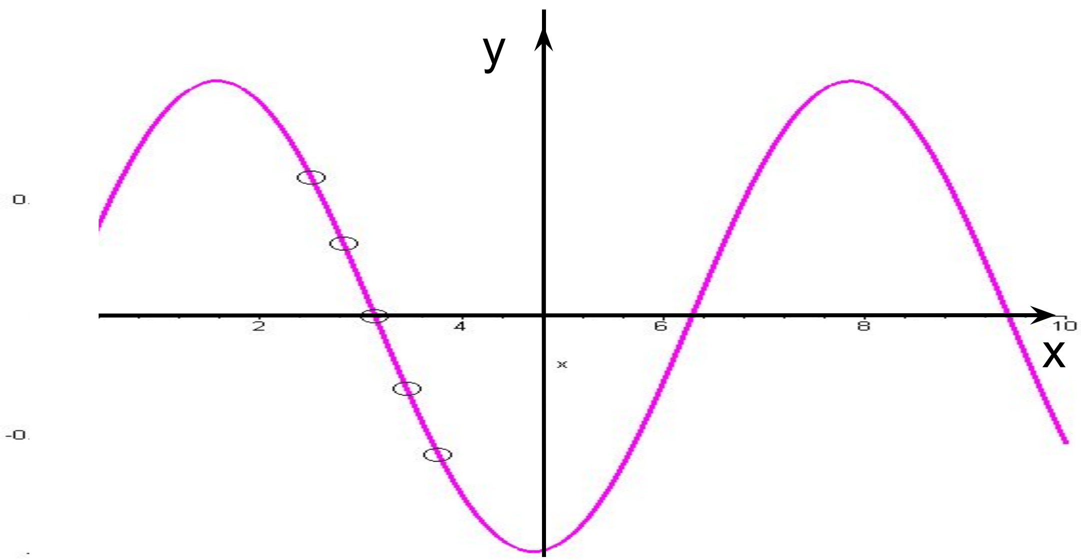
$$Z(x,t) = 1.5 + A\cos(kx + \omega t)$$

What is A? k? ω? v?

$$k = \frac{2\pi}{\lambda}, \quad \omega = \frac{2\pi}{T}, \quad v = \frac{\omega}{k}$$

Periodic Wave Description

- How fast is the wave moving?



$$y(x,t) = 0 = A\cos(kx - \omega t) \Rightarrow$$

$$kx - \omega t = \frac{\pi}{2} \Rightarrow$$

$$x = \frac{\pi}{2k} + \frac{\omega}{k} t \Rightarrow$$

$$v = \frac{dx}{dt} = 0 + \frac{\omega}{k} = \frac{\omega}{k} = \frac{2\pi f}{\frac{2\pi}{\lambda}} = f\lambda$$

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

This is known as the phase velocity, for reasons that will become clearer later.