Traveling Waves
An object of mass $M$, hanging from a spring with a spring constant $k$, is set into simple harmonic motion with angular frequency $\omega$. If the mass is increased to $4M$ and the spring constant is changed to $2k$, what is the new angular frequency?

a) $\frac{1}{\sqrt{2}} \omega$.
b) $\omega$.
c) $\sqrt{2} \omega$.
d) $2\omega$.
e) $4\omega$. 
When the mass of a pendulum, with total energy $E_0$, is doubled but the maximum displacement (i.e. angle $\theta_{\text{MAX}}$ with respect to the vertical) and length $L$ are not changed, what will be the total energy?

a) $4E_0$.  
b) $2E_0$.  
c) $E_0$.  
d) $E_0/2$.  
e) $E_0/4$.  
Question (Today’s Material)

Which of the following is NOT an example of a transverse wave?

a) vibrations in a guitar string
b) a Mexican wave in a sports stadium
c) ultrasound waves
d) light waves
e) ripples on the surface of water
The speed of a wave is $v$. If its wavelength is kept fixed but its frequency is tripled, the speed of the resulting wave is

a) $\frac{1}{3}v$
b) $3v$
c) $9v$
d) $\frac{3}{2}v$
e) $\frac{2}{3}v$
Waves

Wave:
A propagating disturbance that carries energy and momentum.

An object (particle) can carry energy and momentum from one point to another. Example: Water Wave.

A wave provides another way of carrying energy and momentum between two points but without any particles physically moving between the two points.
Transverse and longitudinal waves

**Transverse wave:**
Disturbance $f(x,t)$ moves **perpendicular** to the direction of wave motion.

**Longitudinal wave:**
Disturbance $f(x,t)$ moves **parallel** to the direction of wave motion.

As the hand pumps back and forth, compressed regions alternate stretched regions both in space and time.
How describe oscillations

TIME DEPENDENCE at fixed $x$:
Every small segment of the string at fixed position $x$ can be treated as a simple harmonic oscillator, with $A$, $T$, $f$, along the $y$-axis, $y(x,t)$

- **Amplitude:** $A$
  - Maximum distance from equilibrium position.

- **Period:** $T$
  - Time taken for one oscillation.

- **Frequency:** $f$
  - Number of oscillations per second.
Describe wave pattern along x

Wavelength: $\lambda$
Distance, $\lambda$, between two successive points that behave identically. (distance between maxima)

Wave speed: $v$
Speed, $v$, at which a particular part of the wave pattern (say, a crest) moves through the medium or along the string. ($v$ is given by the product of the wave frequency, $f$, and wavelength, $\lambda$.)

$$v = f \lambda$$

We can also write

$$v = \frac{\lambda}{T}$$
Sound waves are longitudinal waves in air. The speed of sound depends on temperature; at 293 K it is 344 m/s (1130 ft/s). What is the wavelength of a sound wave in air at 293 K if the frequency is 262 Hz (the approximate frequency of middle C on a piano)?

a) 1.50 m  
b) 1.10 m  
c) 1.31 m  
d) 1.24 m  
e) 1.47 m
The sinusoidal wave shown here is traveling in the positive x-direction and has a frequency of 18.0 Hz. Its wavelength is:

a) 8.26 cm  
b) 5.20 cm  
c) 10.40 cm  
d) 4.13 cm
Question

A bat can detect small objects, such as an insect, whose size is approximately equal to one wavelength of the sound the bat makes. If bats emit a chirp at a frequency of 60,000 Hz and the speed of sound is 343 m/s, what is the smallest size insect that a bat can detect?

a) 0.0057 mm
b) 0.057 m
c) 0.57 m
d) 0.57 cm
e) 0.057 cm
Velocity of waves on strings

Depends on string tension and string density.

Linear density: \( \mu \)
Mass of the string, per unit length.

For a transverse wave on a string, with linear density \( \mu \) and tension \( F_T \), the wave speed, \( v \), is given by

\[
v = \sqrt{\frac{F_T}{\mu}}
\]

This is the reason you can tune a guitar or violin by tightening or loosening the strings.
Question

If the wavelength of a transverse wave on a string is doubled while keeping its tension and linear density the same,

a) the frequency is halved
b) the propagation speed doubles
c) the frequency doubles
d) the frequency and the speed stay the same
e) the propagation speed is halved
The six strings of a guitar are the same length and under nearly the same tension, but they have different thicknesses. On which string do waves travel the fastest?

a) the thickest string
b) the thinnest string
c) the wave speed is the speed on all the strings
d) Need more information
Interference of Waves

Principle of Superposition:
When two or more traveling waves encounter each other, the resultant wave is found by adding together the displacements of the individual waves point by point.
Constructive Interference

Superposition of Waves in Phase

Crests of a) line up with crests of b)

Combining the two waves in parts (a) and (b) results in a wave with twice the amplitude.
Destructive Interference

Superposition of Waves 180 degrees out of Phase

Crests of a) line up with Troughs in b)

Combining the waves in (a) and (b) results in complete cancellation.
The phenomenon of wave interference is due to

a) conservation of energy
b) the principle of superposition
c) conservation of mass
d) Newton’s second law of motion
e) conservation of momentum
Question

Two sound waves can interfere

a) only when traveling in the same direction
b) only when the frequencies are the same
c) only when both are sinusoidal
d) only when the phase difference is constant
e) None of the above