Basic Physics

Lecture 5: Waves

รวบรวมและเรียบเรียงโดย
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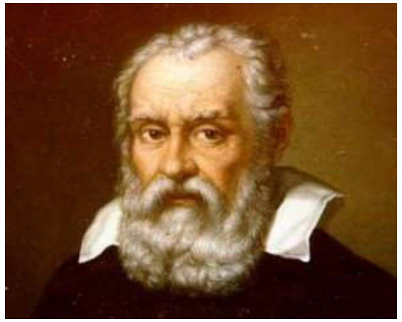
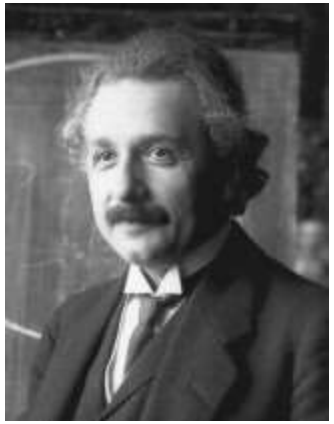
Topics

0. Nature of Science and physics
1. Mechanics
2. Temperature and Heat
3. Fluid
4. Waves
5. Sound and hearing
6. Optics and visualization
7. basic electromagnetism
8. basic quantum mechanics
9. atomic physics
10. basic nuclear physics and radioactivity

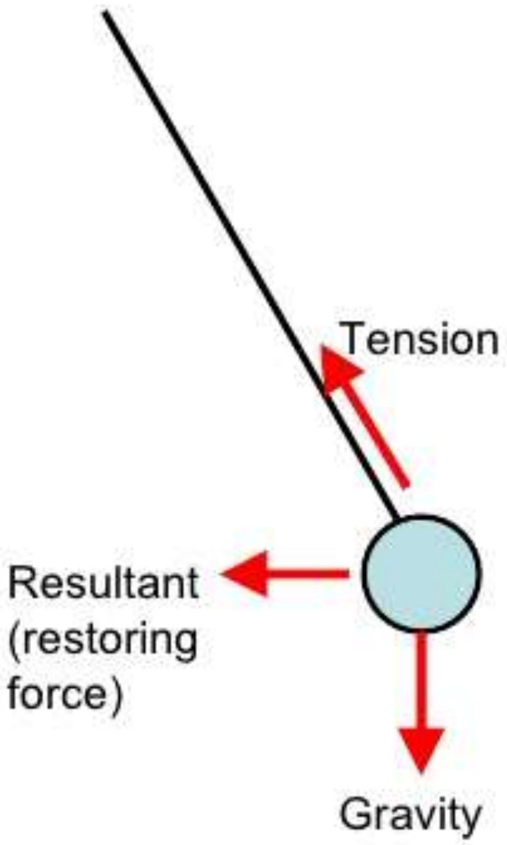




SHM

A system will oscillate if there is a force acting on it that tends to pull it back to its equilibrium position – a restoring force.

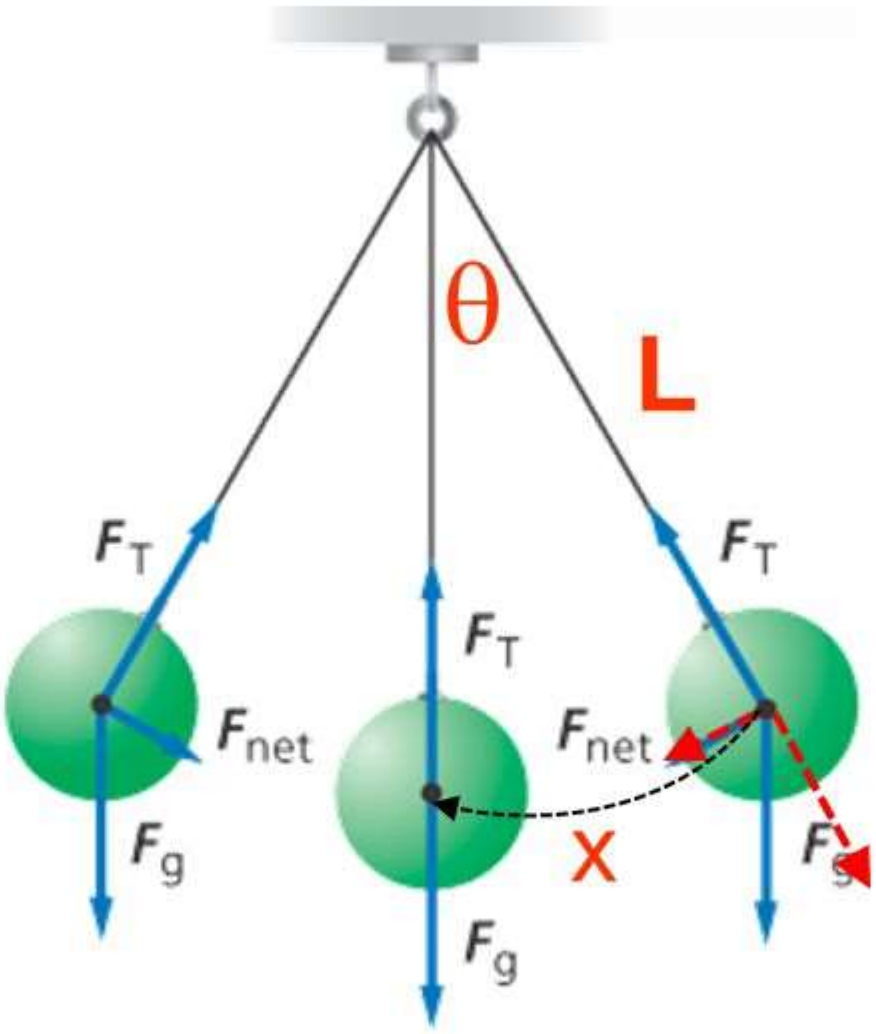
In a swinging pendulum the combination of gravity and the tension in the string that always act to bring the pendulum back to the centre of its swing.



Forces on Pendulum

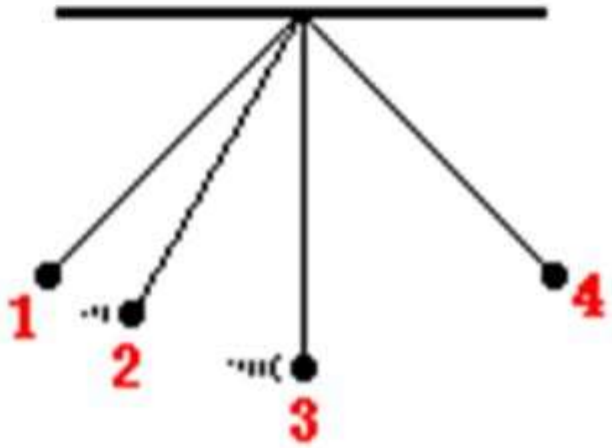
At the **left and right positions**, the net force and acceleration are maximum, and the velocity is zero.

At the **middle** position in the figure, the net force and acceleration are zero, and the velocity is maximum



Example

- As the 2.0-kg pendulum bob in the above diagram swings to and fro, its height and speed change. Use energy equations and the above data to determine the blanks in the above diagram.



Position 1	Position 2	Position 3	Position 4
PE = 6 J	PE = 3 J	PE = 0 J	PE = 6 J
KE = 0 J	KE = 3 J	KE = 6 J	KE = 0 J
h = 0.306 m	h = 0.153 m	h = 0 m	h = 0.306 m
v = 0 m/s	v = 1.73 m/s	v = 2.45 m/s	v = 0 m/s

Pendulums

$$mg\sin\theta = \text{Restoring Force}$$

$$mg\sin\theta = kx$$

$$\theta = \frac{s}{R} = \frac{s}{L}$$

$$s = \theta L = Amplitude$$

$$mg\sin\theta = k\theta L$$

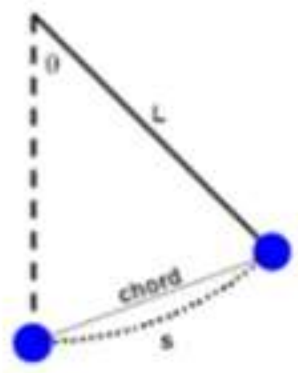
$$\sin\theta \cong \theta, if\ \theta = small$$

$$mg = kl$$

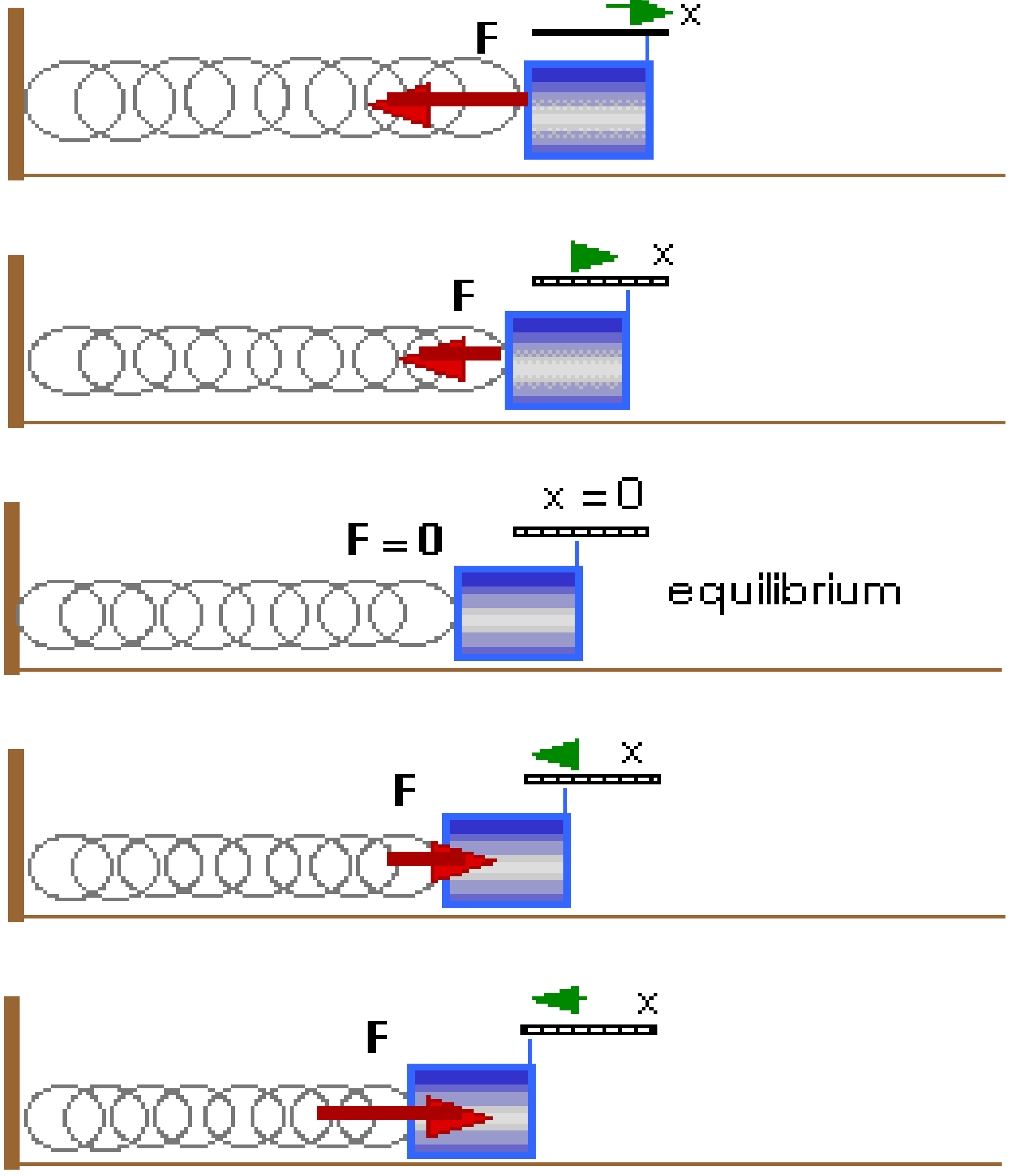
$$\frac{m}{k} = \frac{l}{g}$$

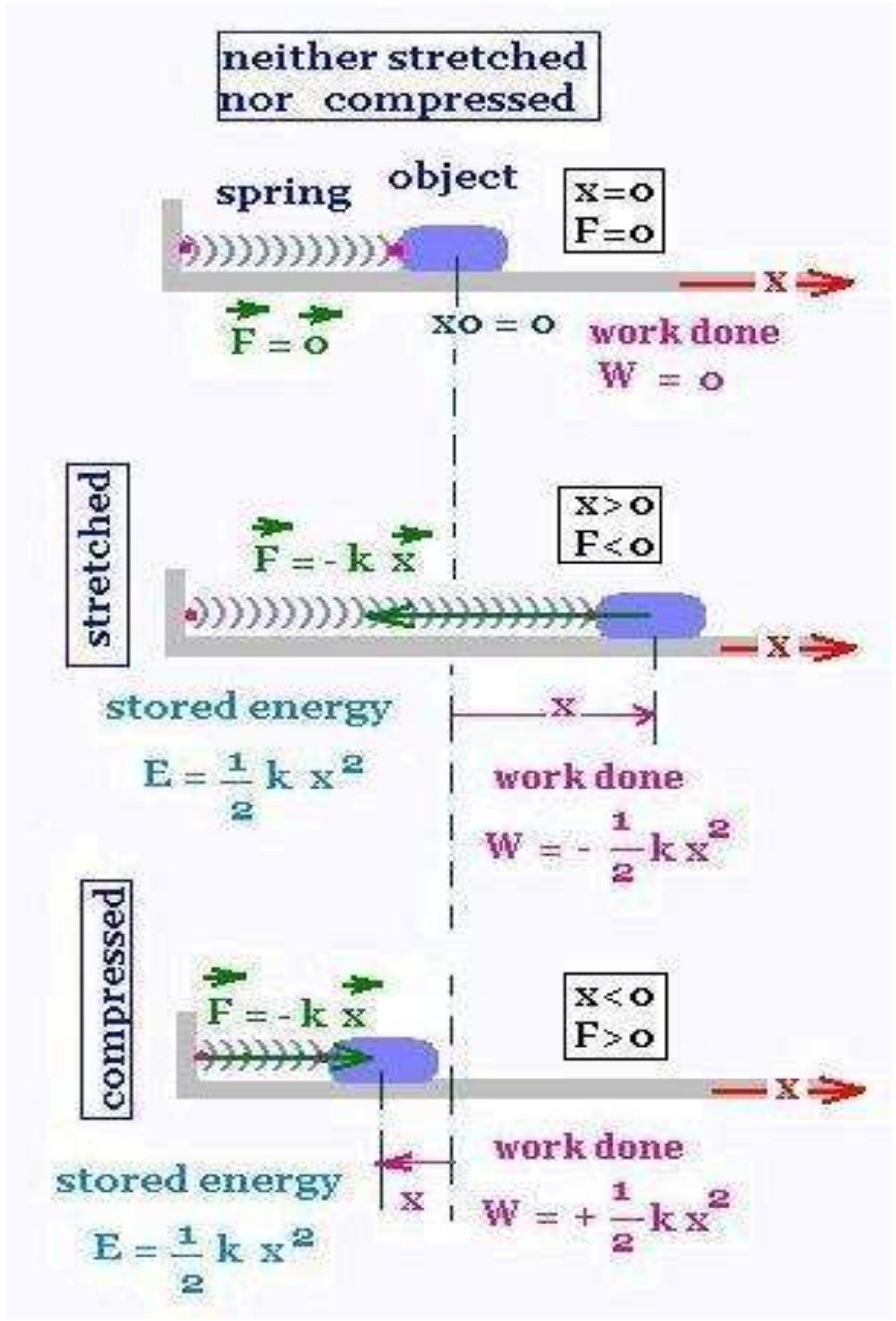
$$T_{spring} = 2\pi\sqrt{\frac{m}{k}}$$

What is x? It is the amplitude! In the picture to the left, it represents the chord from where it was released to the bottom of the swing (equilibrium position).



$$T_{pendulum} = 2\pi\sqrt{\frac{l}{g}}$$


F
x
F
x
F = 0
x = 0
equilibrium
F
x
F
x

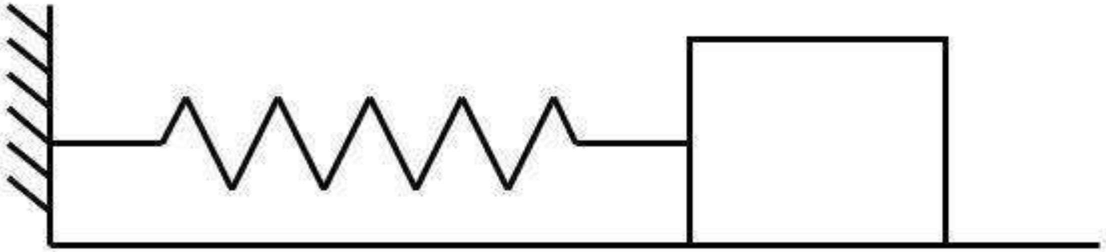

neither stretched nor compressed
spring
object
x=o
F=o
F = o
xo = o
work done
W = o
stretched
F = - k x
x>o
F<o
stored energy
E = 1/2 k x²
x
work done
W = - 1/2 k x²
compressed
F = - k x
x<o
F>o
stored energy
E = 1/2 k x²
x
work done
W = + 1/2 k x²

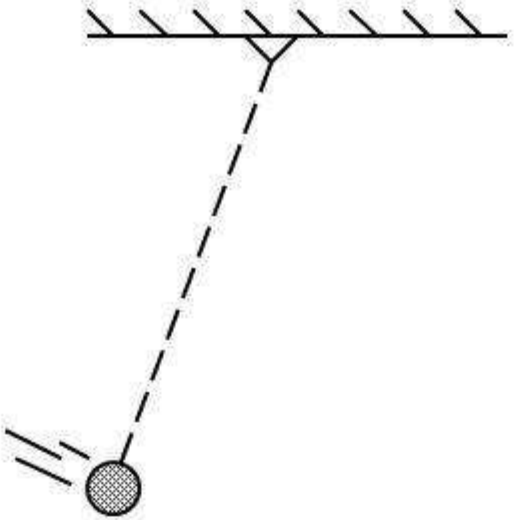
restoring force: acts to move an object back to equilibrium

simple harmonic motion (SHM): $F_{restore} \propto \Delta x$

As displacement increases, so does $F_{restore}$.

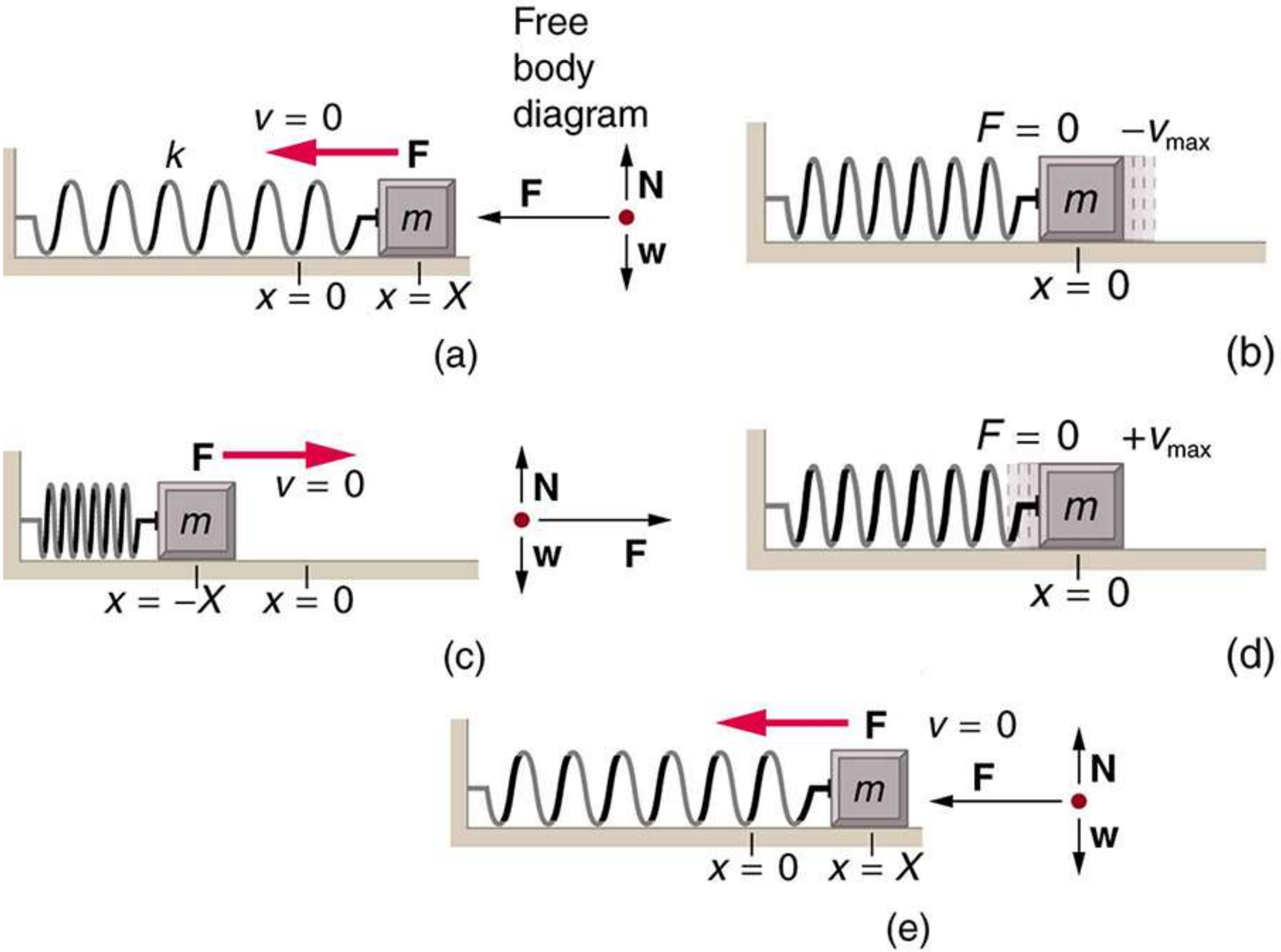
And when $\Delta x = 0$… $F_{restore} = 0$.





For a mass-spring system, Hooke's law applies:

$$F_{restore} = F_{elas} = k\,\Delta x$$



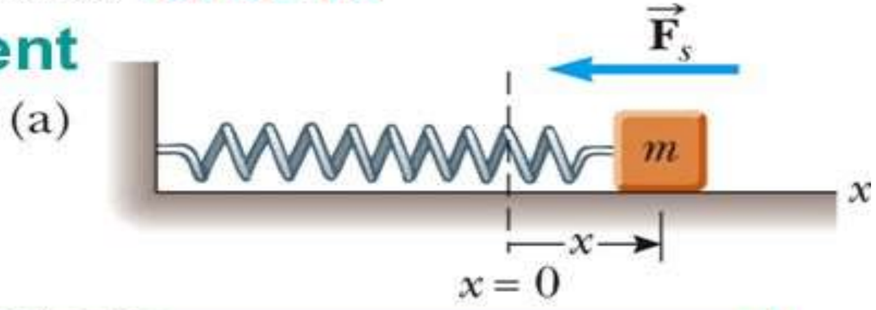
Free
body
diagram
v = 0
k
F
m
F
N
w
x = 0
x = X
(a)
F = 0
−v max
m
N
w
x = 0
(b)
F
v = 0
m
N
w
F
x = −X
x = 0
(c)
F = 0
+v max
m
N
w
x = 0
(d)
F
v = 0
m
F
N
w
x = 0
x = X
(e)

The force law for simple harmonic motion

- From the Newton's Second Law:

$$F = ma = -m\omega^2 x$$

- For simple harmonic motion, the force is proportional to the displacement



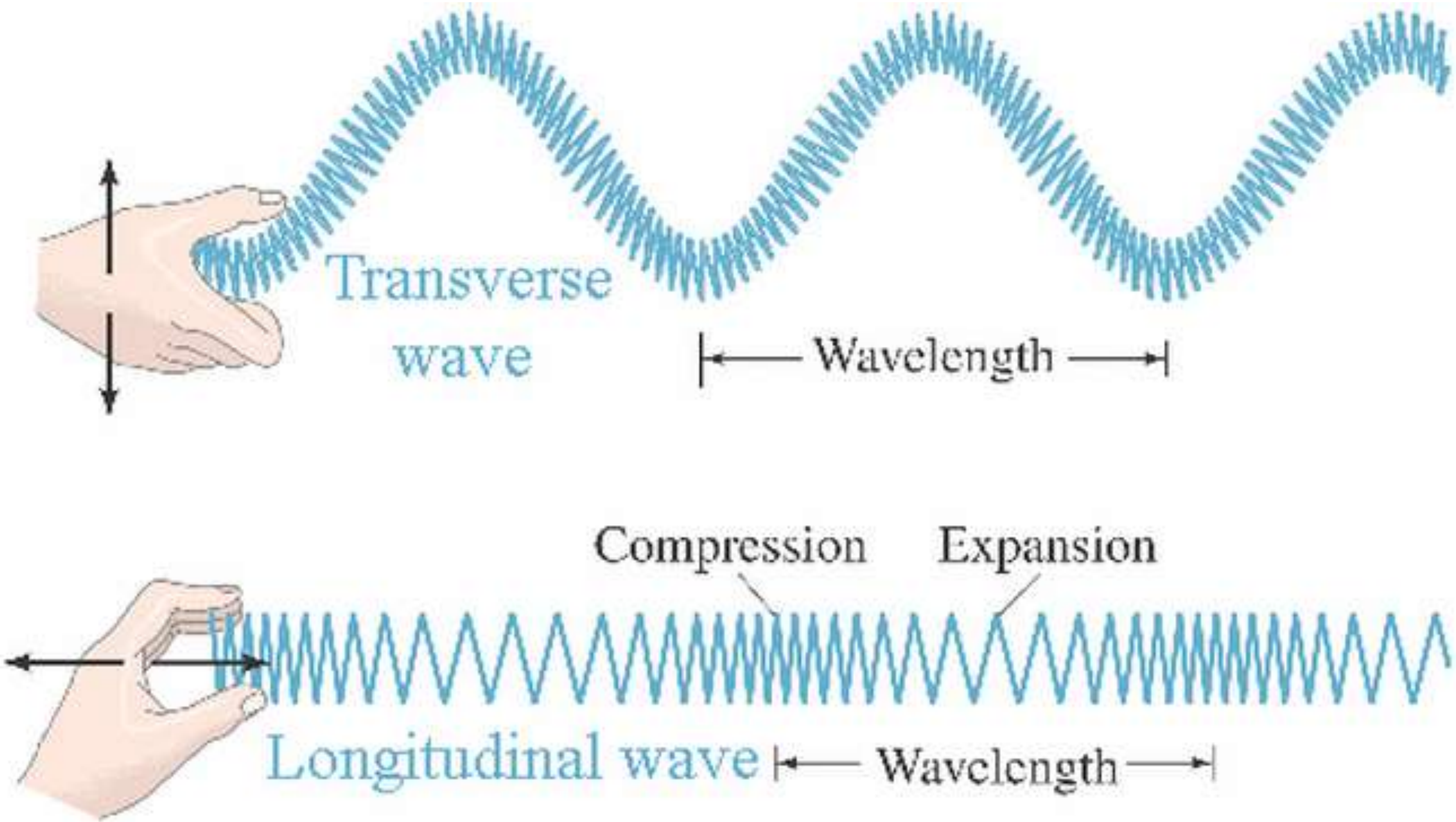
- Hooke's law:

$$F = -kx$$

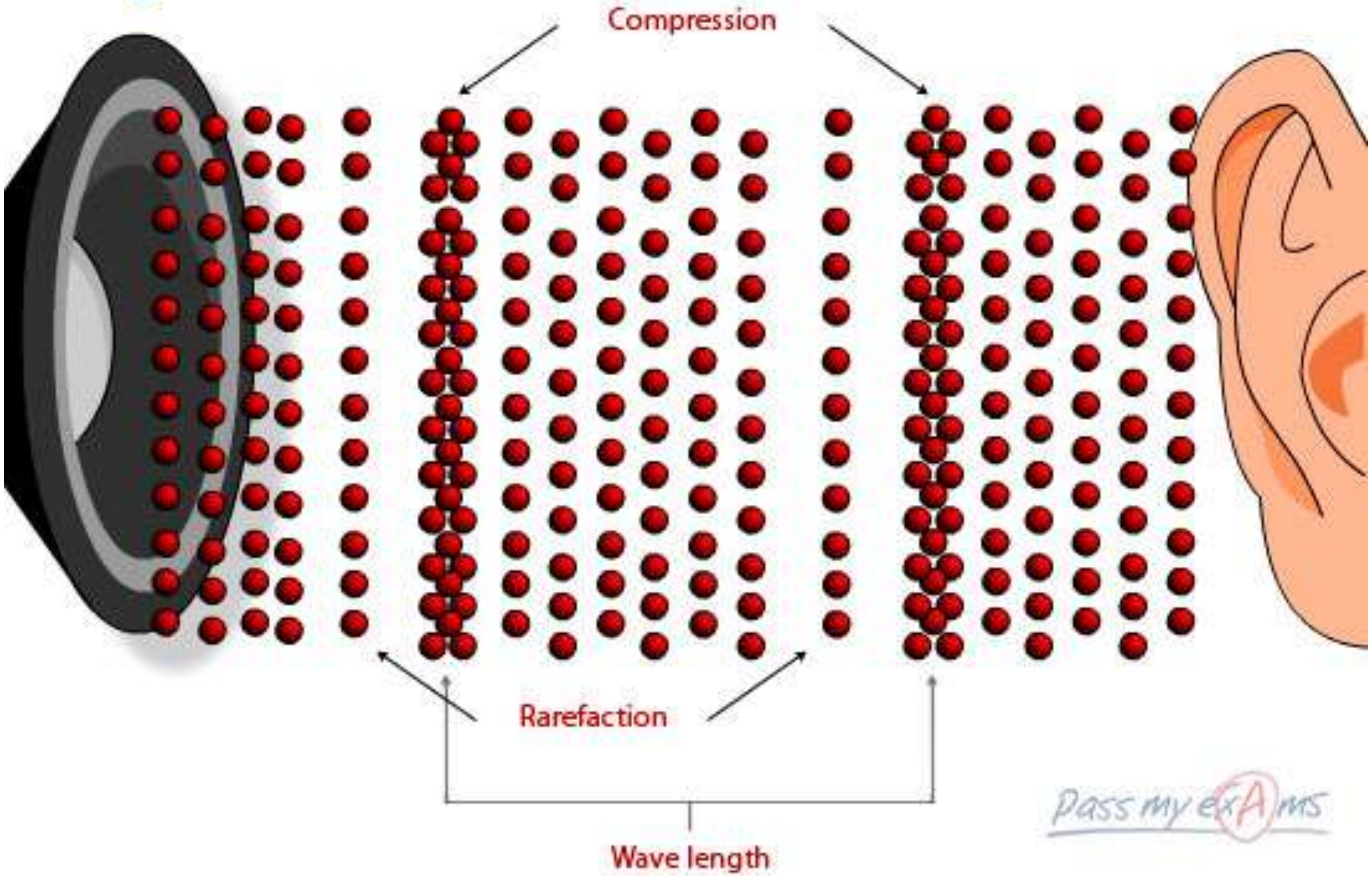
$$k = m\omega^2$$

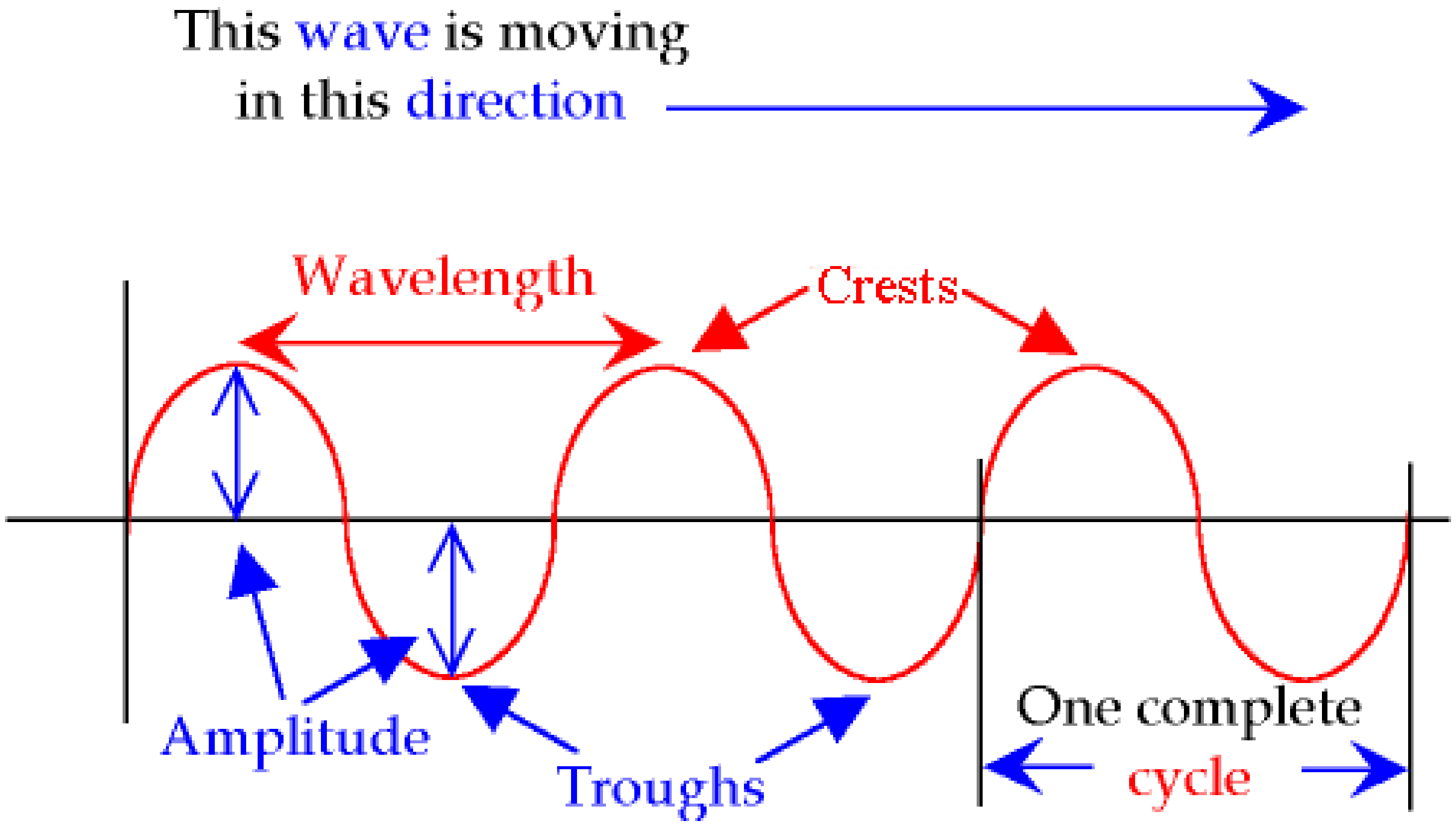
$$\omega = \sqrt{\frac{k}{m}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

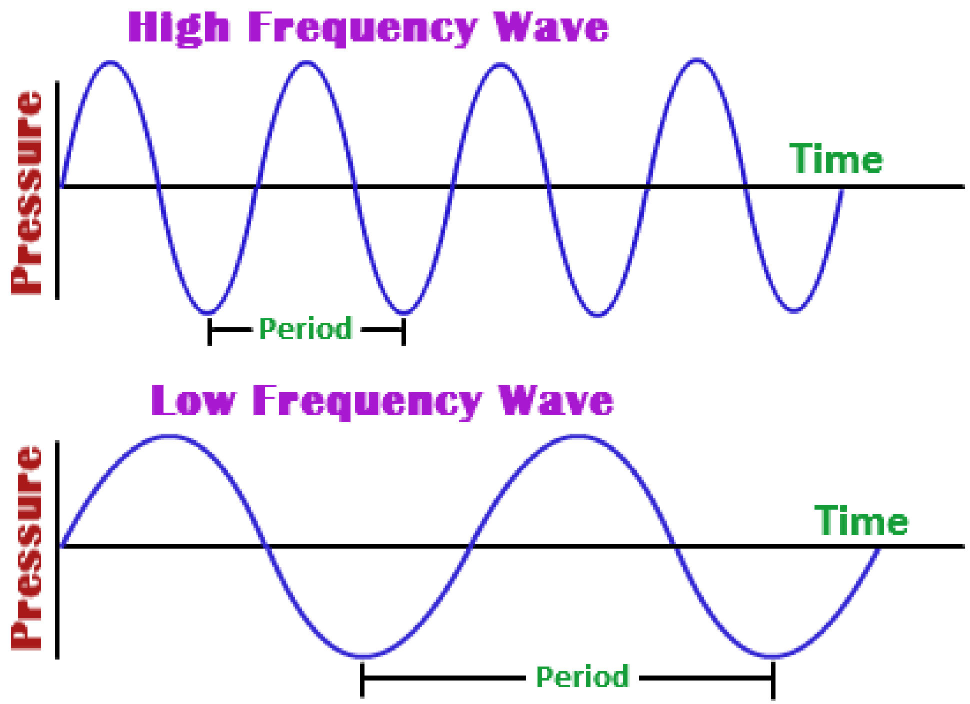

Energy
Waves only transfer energy

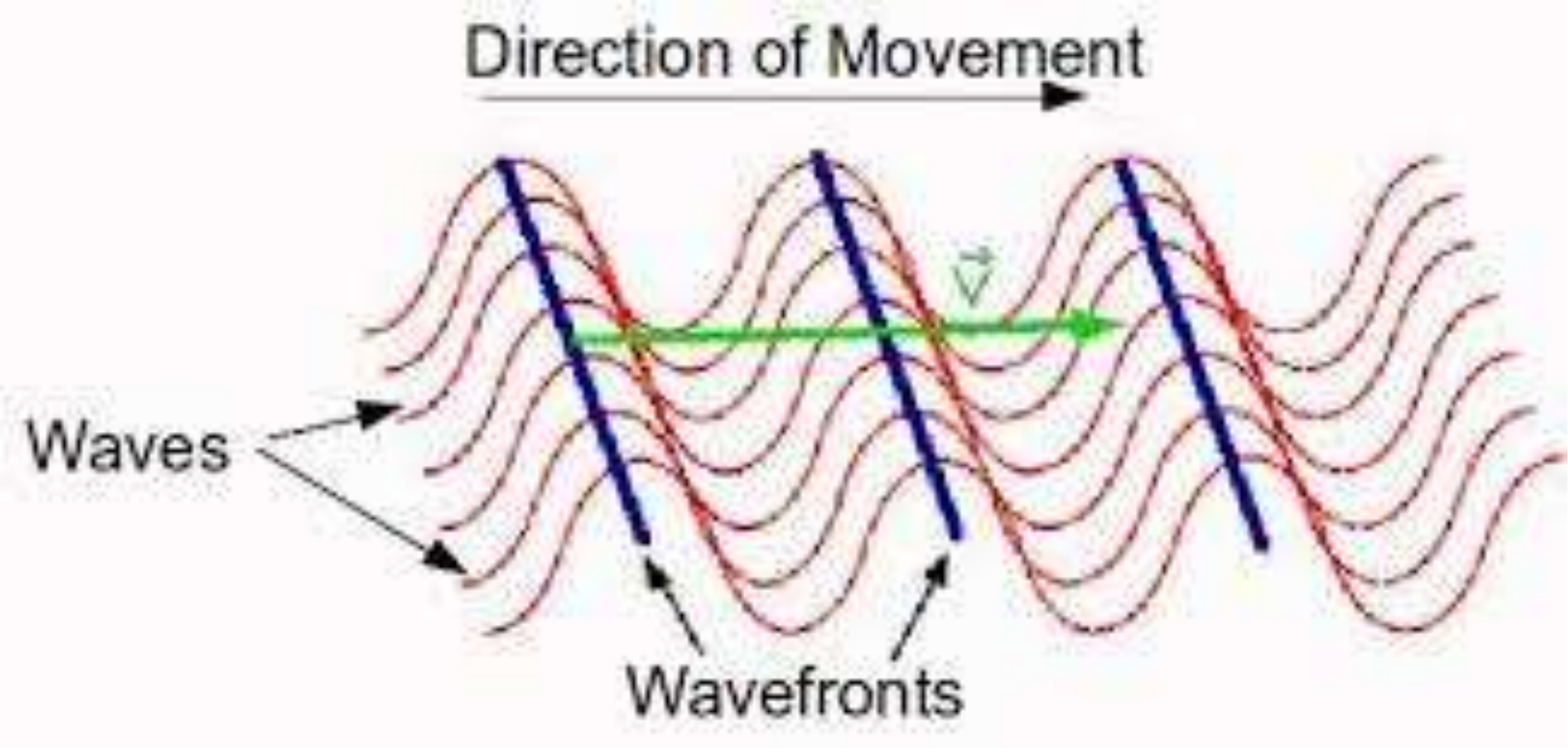

Transverse
wave
Wavelength
Compression
Expansion
Longitudinal wave
Wavelength

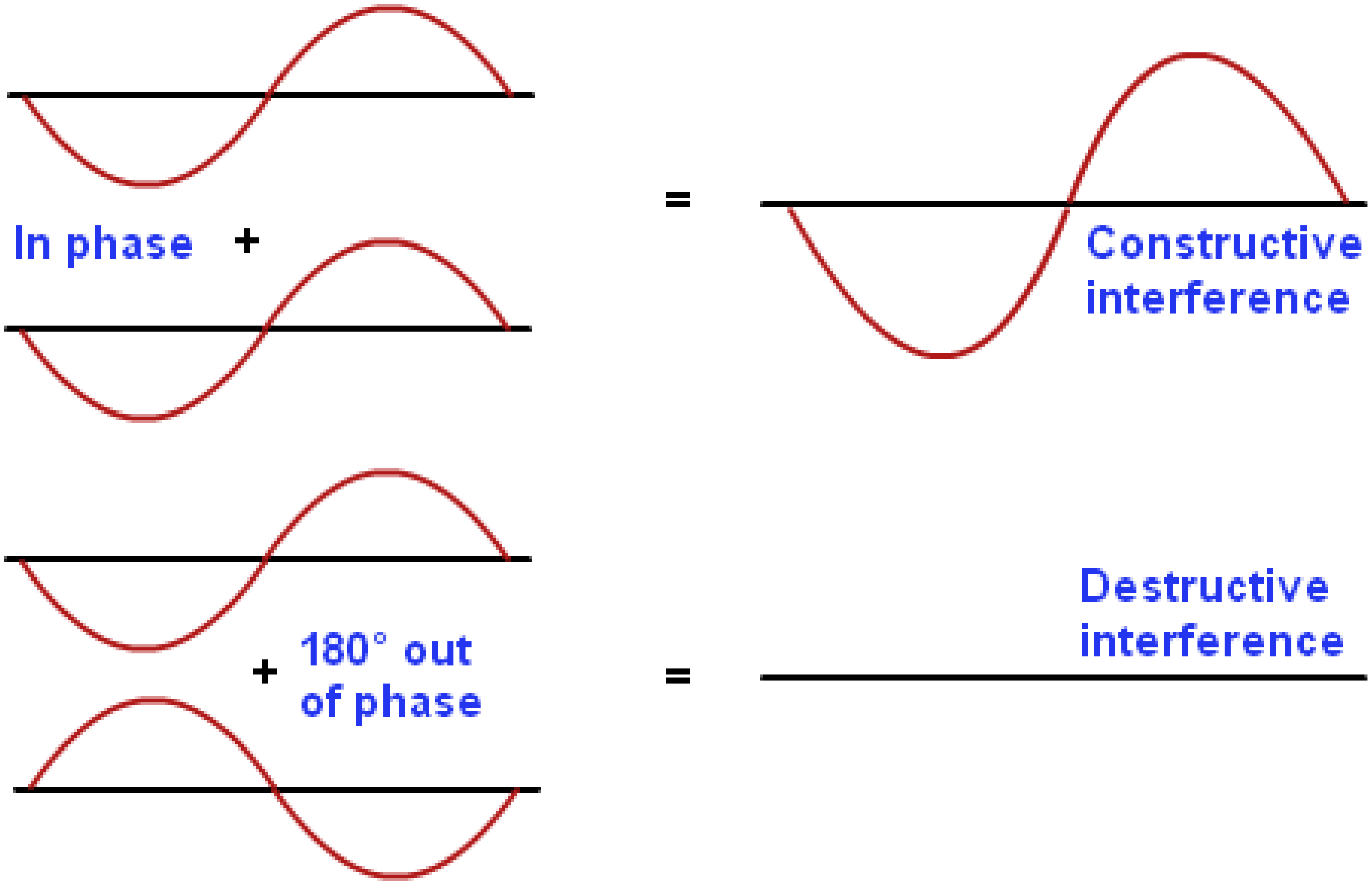
Longitudinal Waves




This wave is moving
in this direction
Wavelength
Crests
Amplitude
Troughs
One complete
cycle


High Frequency Wave
Pressure
Time
Period
Low Frequency Wave
Pressure
Time
Period


Direction of Movement
v
Waves
Wavefronts


In phase
+
=
Constructive interference
+
180° out of phase
=
Destructive interference

The Wave Equation

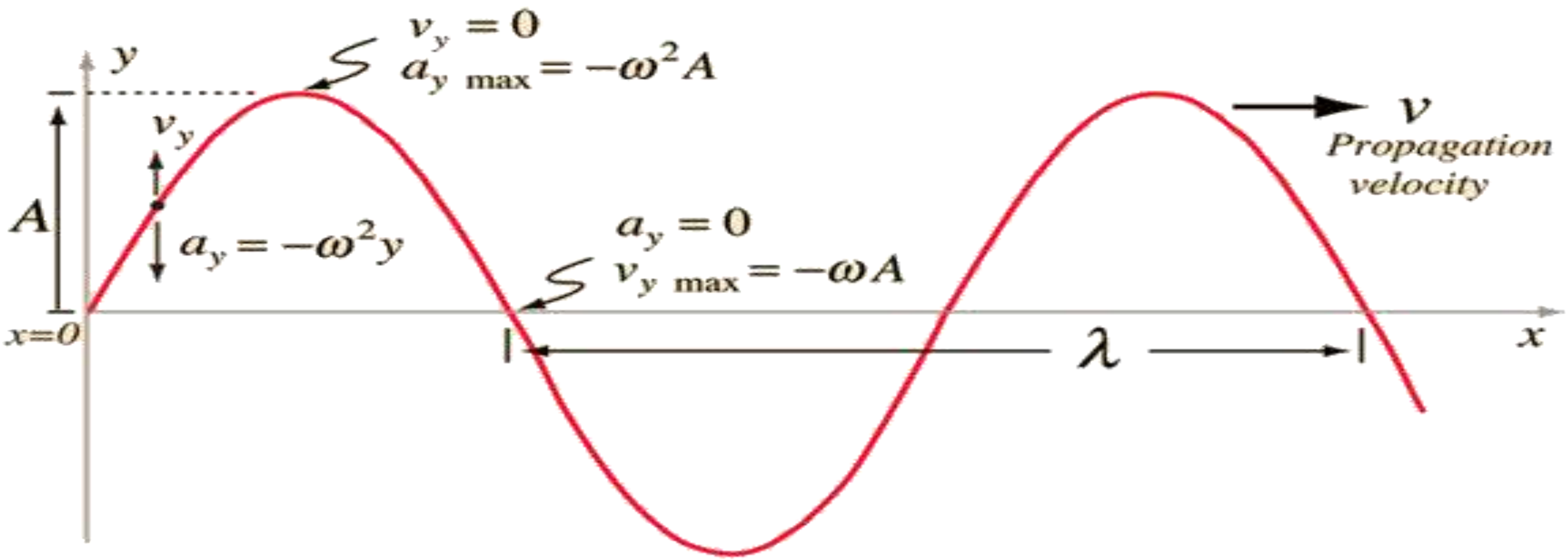
wave speed =	frequency	x	wavelength
(metres per second)	(hertz)		(metre)
m/s	Hz		m

Also written as $\underline{\mathbf{v = f\lambda}}$

Sample Problem # 2

The period of a wave from the radio is 8.3×10^7. If the speed of the wave in the air was 3.5×10^{-6} m/s, what is its wavelength?

Answer: $\lambda = 2.9 \times 10^2$ m



Description of the transverse motion.

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

$$v = f\lambda$$

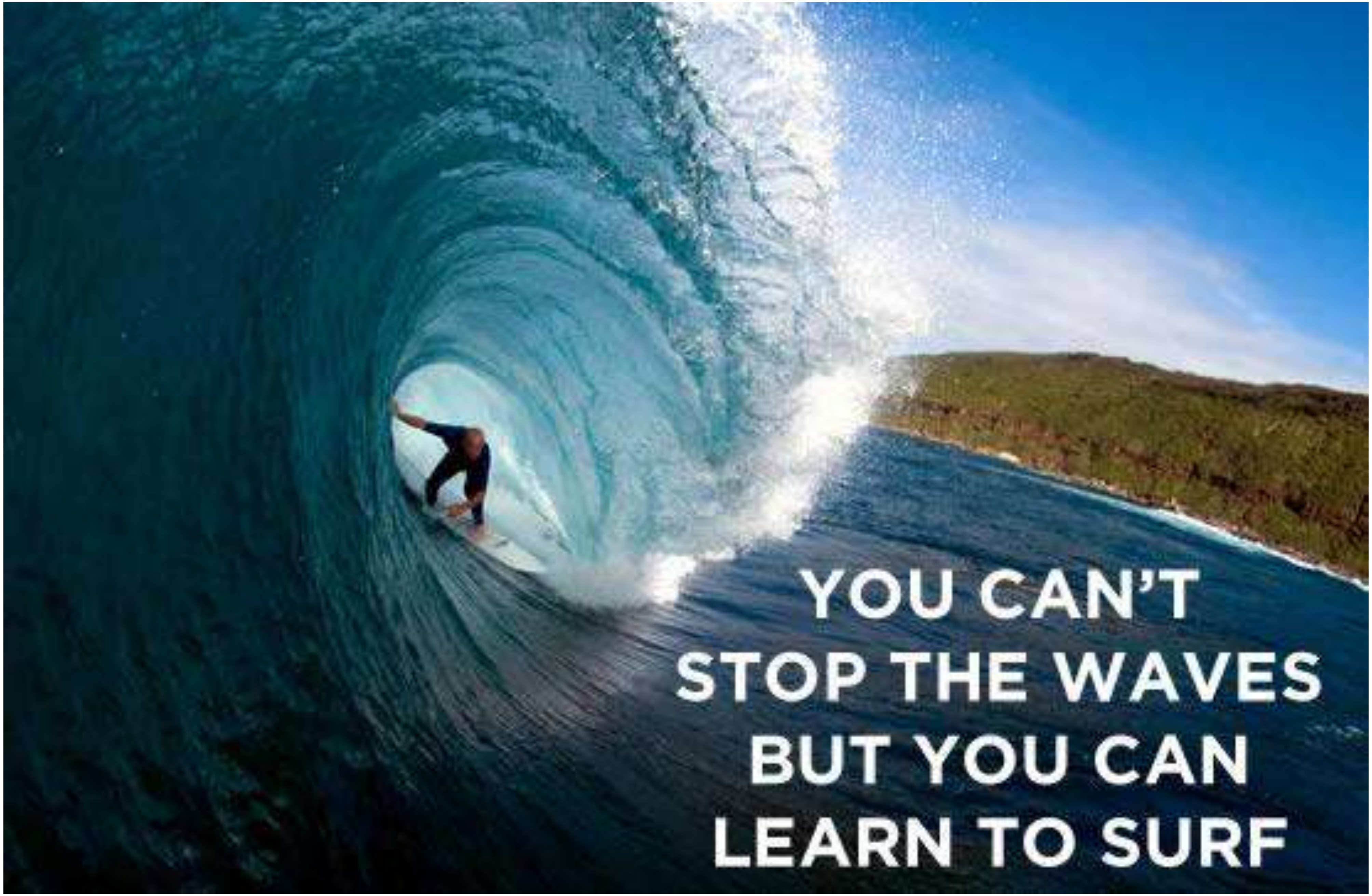
$$y(x,t) = A\sin\frac{2\pi}{\lambda}(x - vt)$$

$$v_y(x,t) = \frac{dy}{dt} = \omega A\cos\frac{2\pi}{\lambda}(x - vt)$$

$$a_y(x,t) = \frac{d^2y}{dt^2} = -\omega^2 y = -\omega^2 A\sin\frac{2\pi}{\lambda}(x - vt)$$

Traveling wave $S(x,t) = A\sin(kx - \omega t)$

Standing wave $S(x,t) = A\sin(kx)\sin(\omega t)$


YOU CAN'T
STOP THE WAVES
BUT YOU CAN
LEARN TO SURF