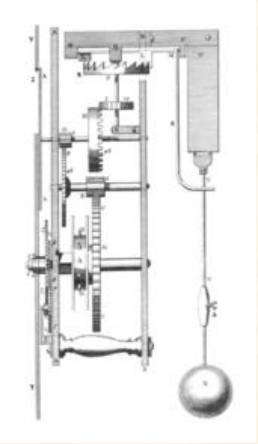
Vibrations and Waves

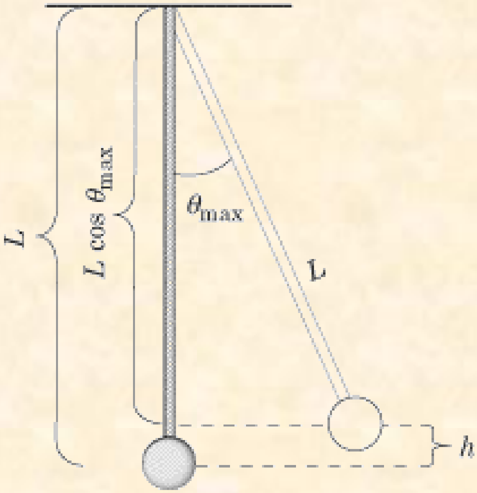
Waves

- **Waves**
  - rhythmic disturbances that carry energy through matter or space
- **Medium**
  - material through which a wave transfers energy
  - solid, liquid, gas, or combination
  - electromagnetic waves don't need a medium (e.g. visible light)

Waves Description

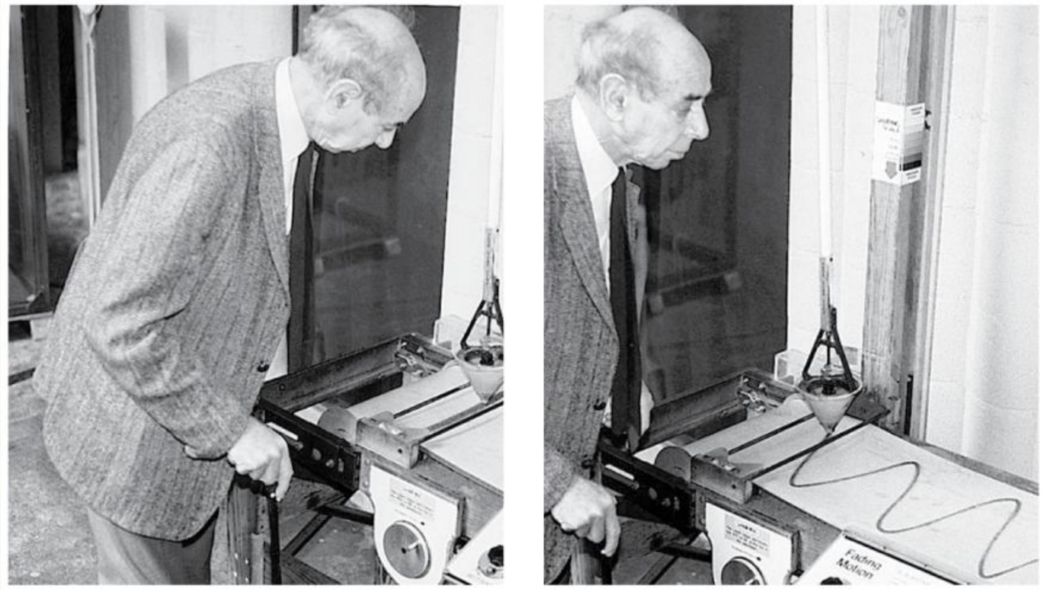


- Cycle – One full oscillation. Where the wave begins to repeat itself.
- Period – The time taken to complete a full cycle in an oscillating system



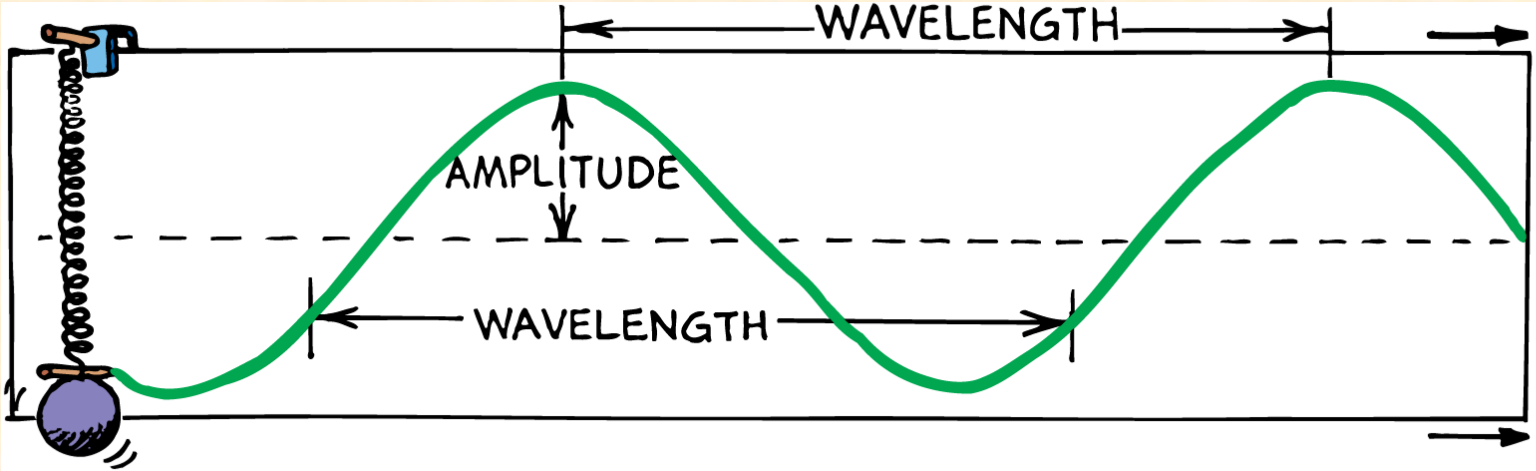
Waves Description

- Simple Harmonic Motion -The back-and-forth vibratory motion—called oscillatory motion of a swinging pendulum.
- A sine curve is a pictorial representation of a wave.



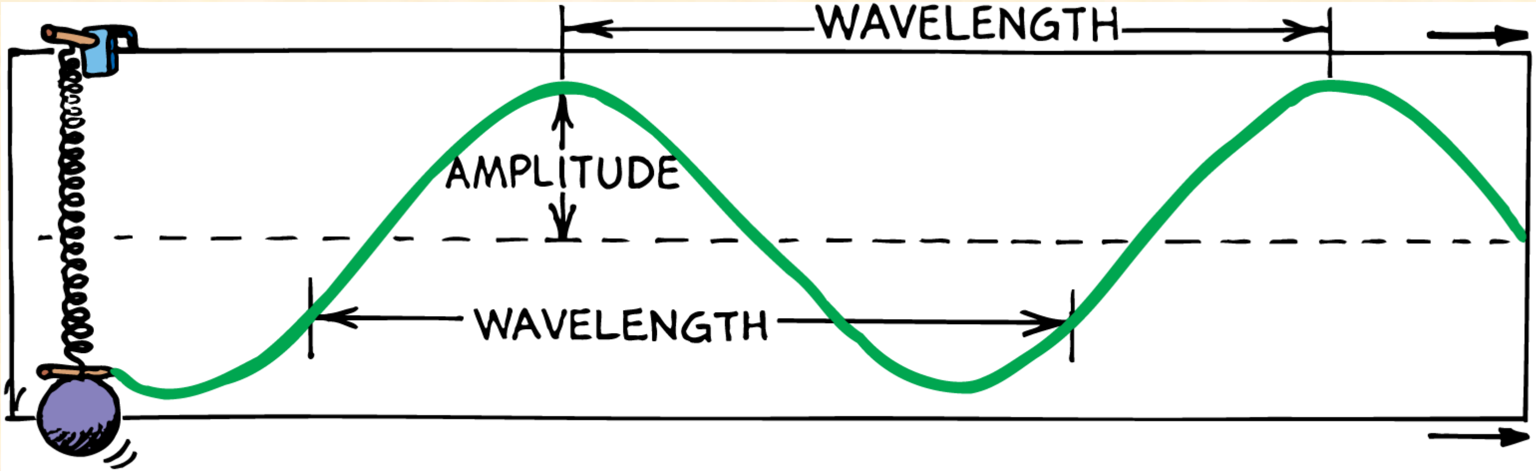
Waves Description

- A weight attached to a spring undergoes simple harmonic motion.
- A marking pen attached to the bob traces a sine curve on a sheet of paper that is moving horizontally at constant speed.
- A sine curve is a pictorial representation of a wave.



Waves Description

- Crest - The high points on a wave.
- Troughs - The low points on a wave.
- Amplitude - distance from the midpoint to the crest (or trough) of the wave.
  - maximum displacement from equilibrium.

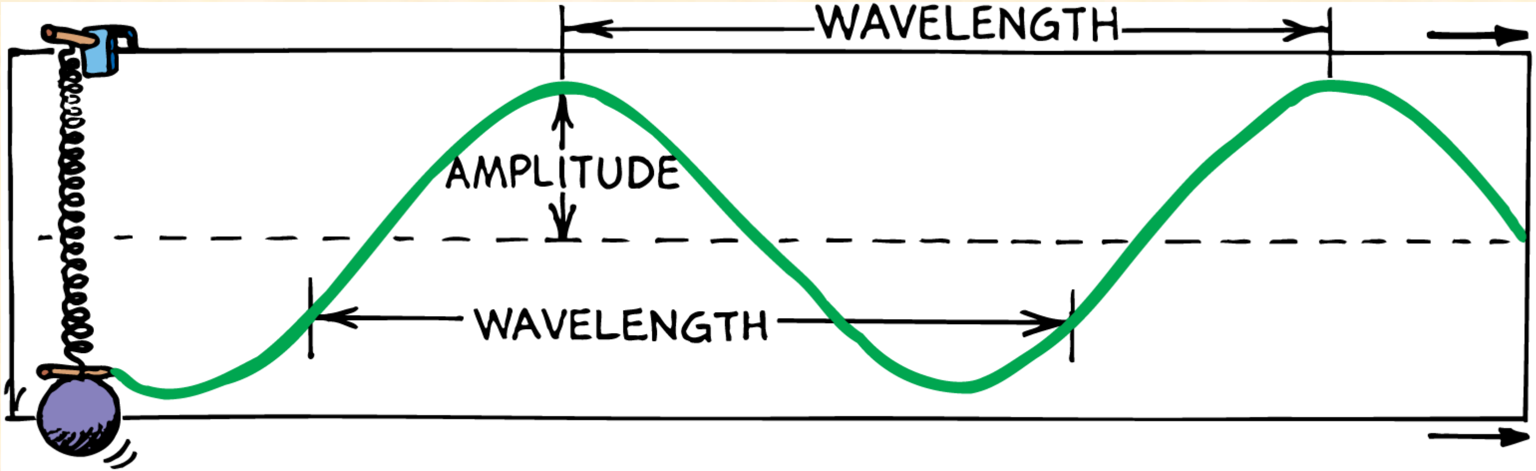


Waves Description

Wavelength - the distance from the top of one crest to the top of the next one.

Frequency - The number of vibrations an object makes in a unit of time (usually one second).

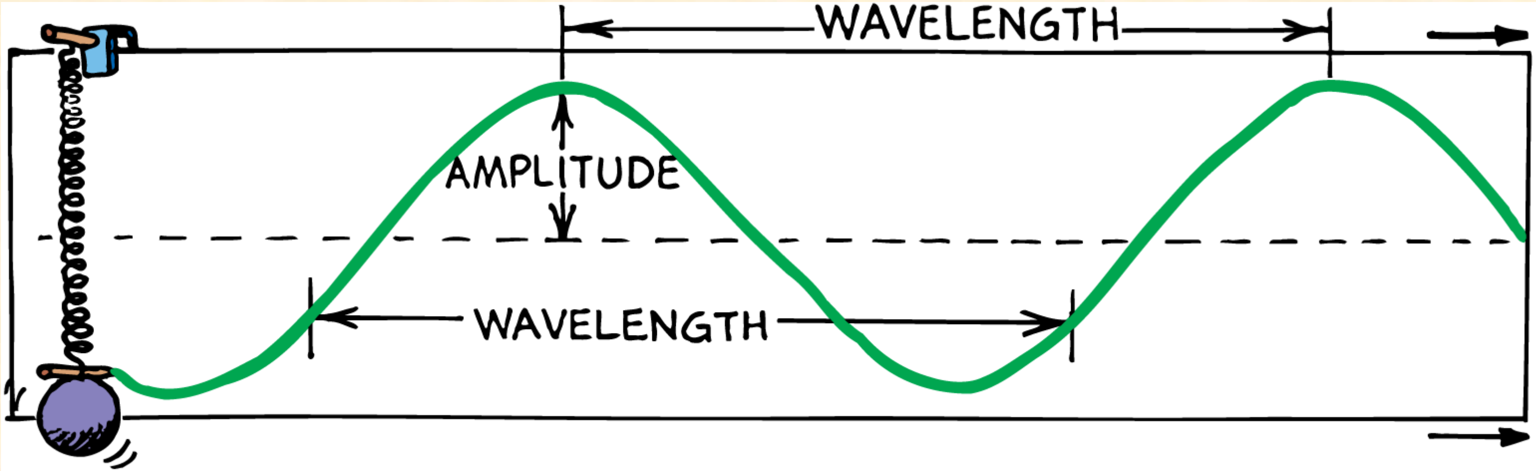
- Frequency is measured in hertz (1hz = 1 cycle per sec).



Waves Description

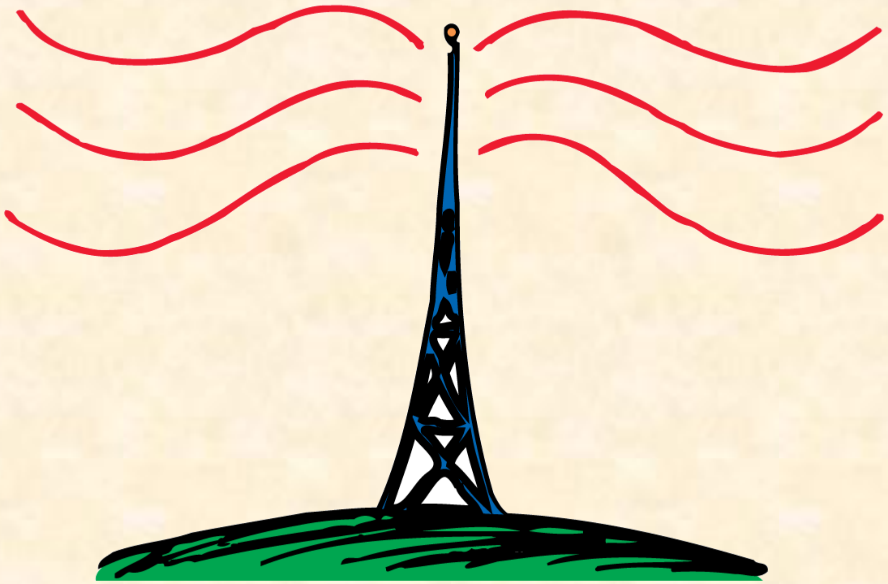
Frequency -

- The unit of frequency is called the **hertz** (Hz).
- A frequency of one cycle per second is 1 hertz, two cycles per second is 2 hertz, and so on.



Waves Description

- Electrons in the antenna of an AM radio station at 960 kHz vibrate 960,000 times each second, producing 960-kHz radio waves.



Waves Description

- Period and frequency are inversely related.
  - Period is how long it takes to complete one cycle
  - Frequency is how many cycles occur during a given time

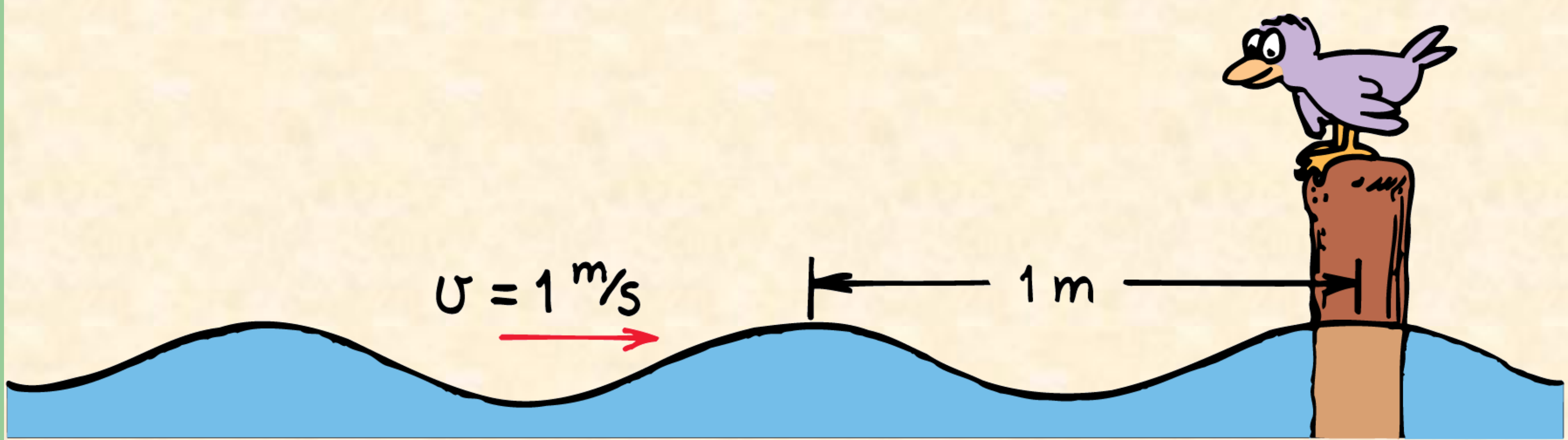
$$\text{frequency} = \frac{1}{\text{period}} \quad \text{or period} = \frac{1}{\text{frequency}}$$

Waves Motion

- When energy is transferred by a wave from a vibrating source to a distant receiver, no matter is transferred between the two points.
- Each part of the string moves up and down and the disturbance moves horizontally along the length of the string.
- The disturbance moves, not parts of the string itself.

Waves Speed

- The speed of a wave depends on the medium through which the wave moves.
- If the wavelength is 1 meter, and one wavelength per second passes the pole, then the speed of the wave is 1 m/s.

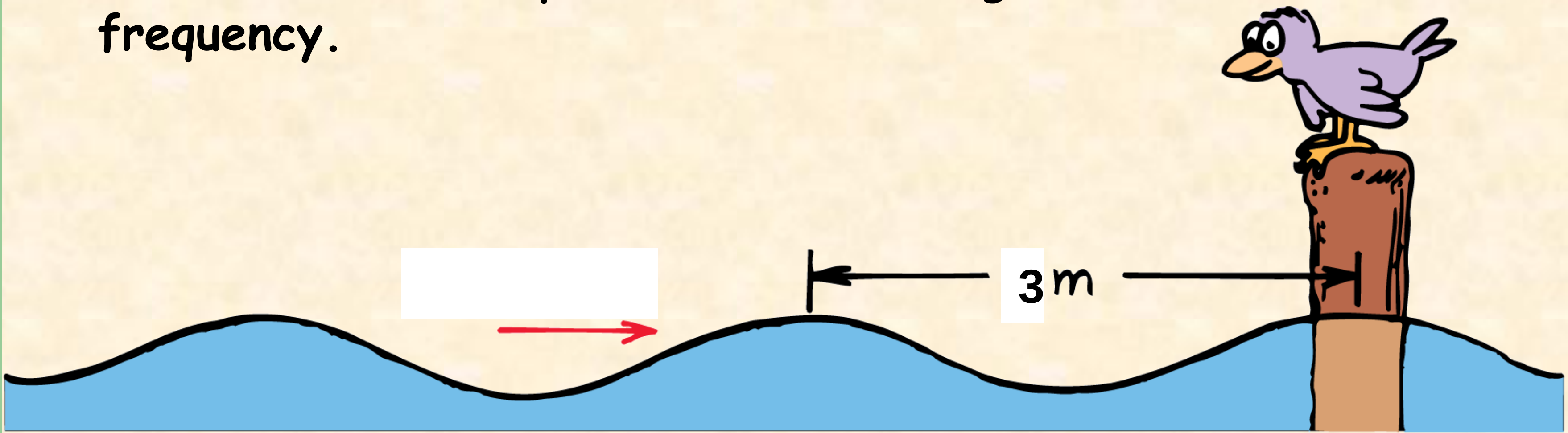


Waves Speed

- If the wavelength is 3 meters and if two crests pass a stationary point each second, then 3 meters × 2 waves pass by in 1 second.
- The waves therefore move at 6 meters per second.

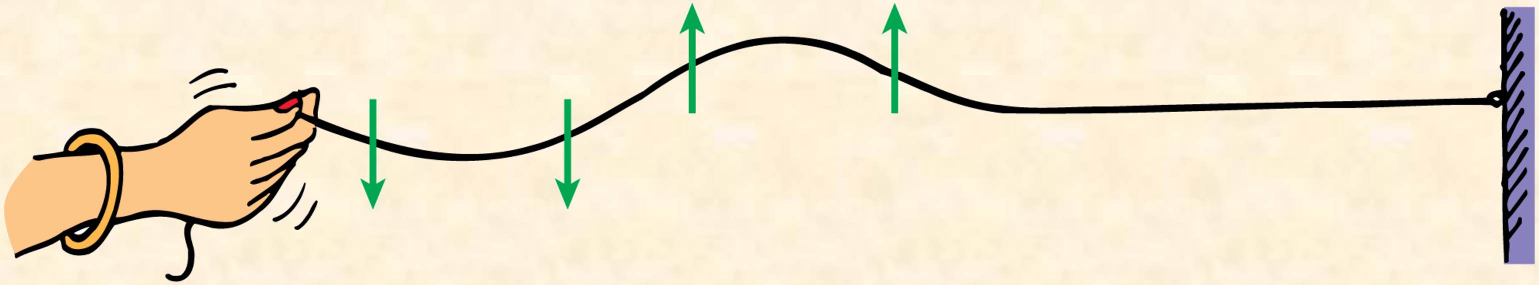
$$v = \lambda f$$

- where v is wave speed, λ is wavelength, and f is wave frequency.



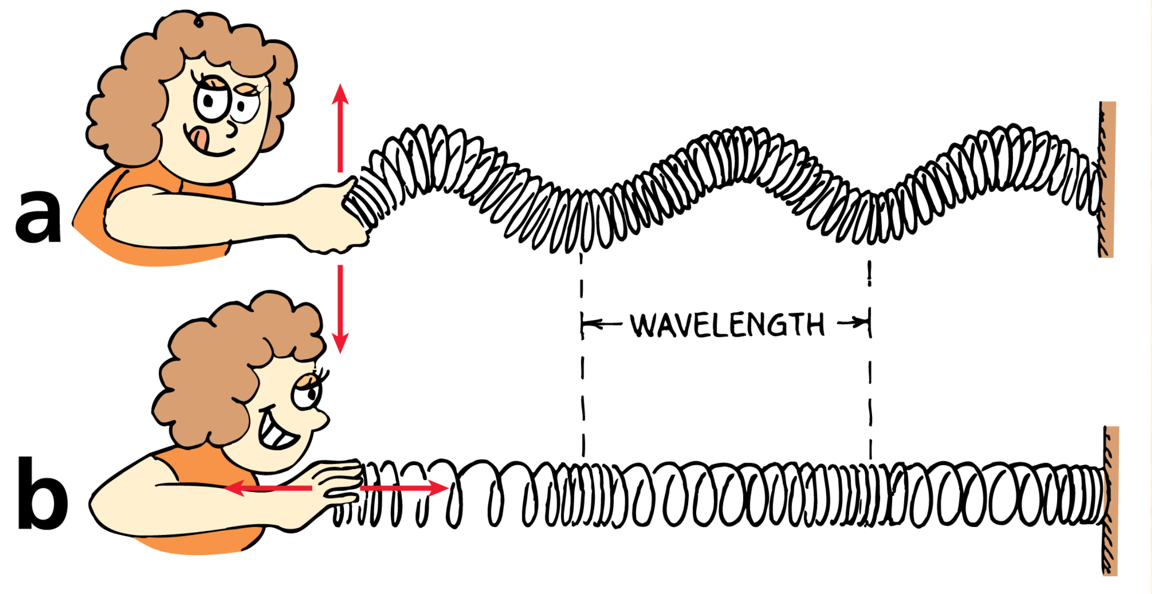
Transverse Waves

- Transverse wave – occurs when the motion of the medium is at right angles to the direction in which a wave travels.



Longitudinal Waves

- **Longitudinal wave** -When the particles oscillate parallel to or *along* the direction of the wave.



D. Measuring Waves

- EX: Find the velocity of a wave in a wave pool if its wavelength is 3.2 m and its frequency is 0.60 Hz.

Known:	Work:
v = ? λ = 3.2 m f = 0.60 Hz	$v = \lambda \times f$ v = (3.2 m)(0.60 Hz) **v = 1.92 m/s**

D. Measuring Waves

- EX: An earthquake produces a wave that has a wavelength of 417 m and travels at 5000 m/s. What is its frequency?

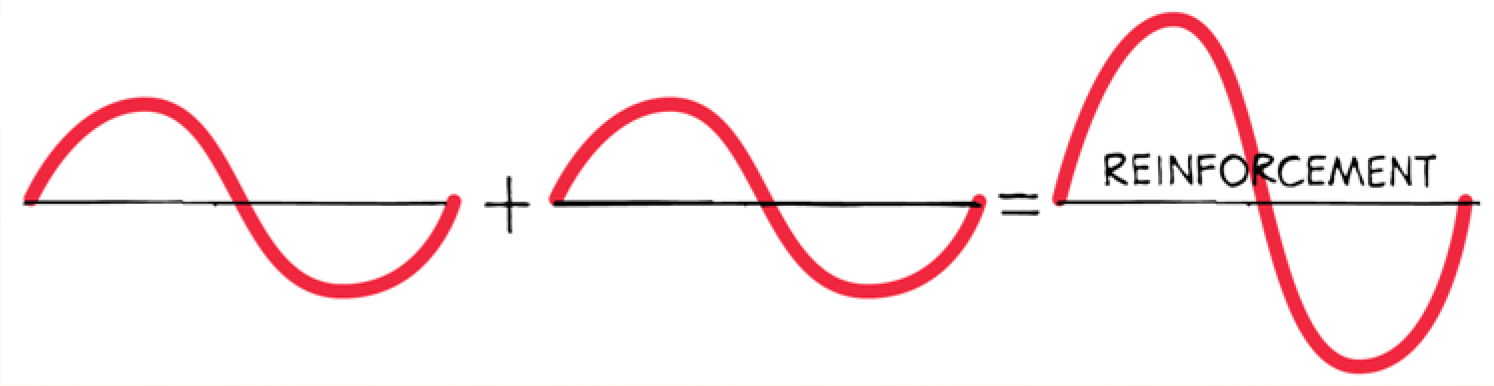
Known:	Work:
λ = 417 m ***v*** = 5000 m/s ***f*** = ?	***f*** = ***v*** ÷ λ ***f*** = (5000 m/s) ÷ (417 m) ***f* = 12 Hz**

Interference patterns

- Interference patterns occur when waves from different sources arrive at the same point—at the same time.

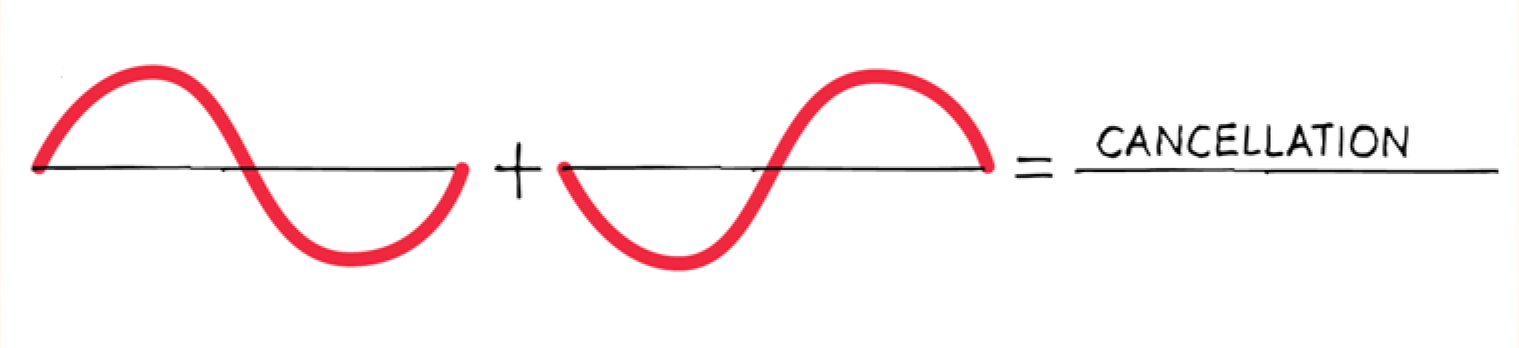
Interference patterns

- In **constructive interference,** the crest of one wave overlaps the crest of another and their individual effects add together.
- The result is a wave of increased amplitude, called reinforcement.

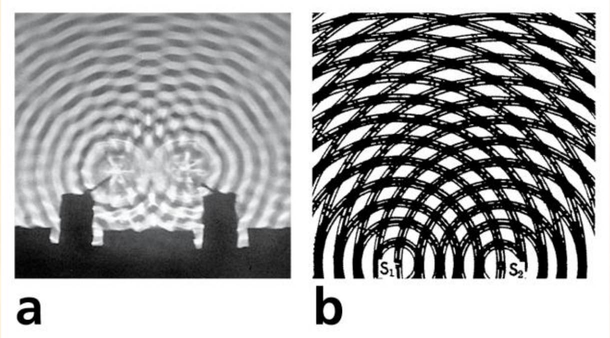


Interference patterns

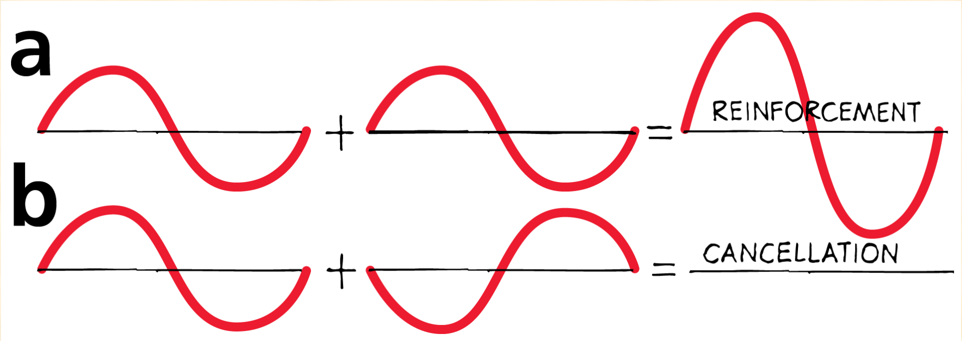
- In **destructive interference**, the crest of one wave overlaps the trough of another and their individual effects are reduced.
- The high part of one wave fills in the low part of another, called cancellation.



Interference patterns

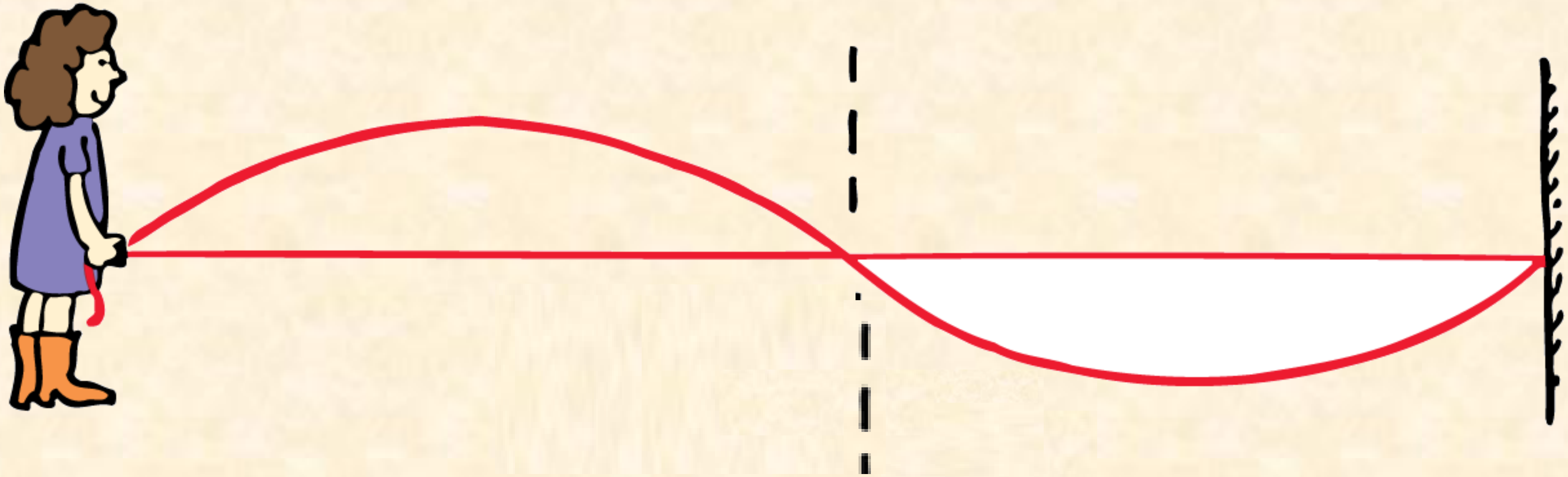


- Wave interference is easiest to see in water as an interference pattern.
- **Out of phase** – Occurs when the crests of one wave overlap the troughs of another to produce regions of zero amplitude.
- **In phase** – Occurs when the crests of one wave overlap the crests of the other, and the troughs overlap as well.



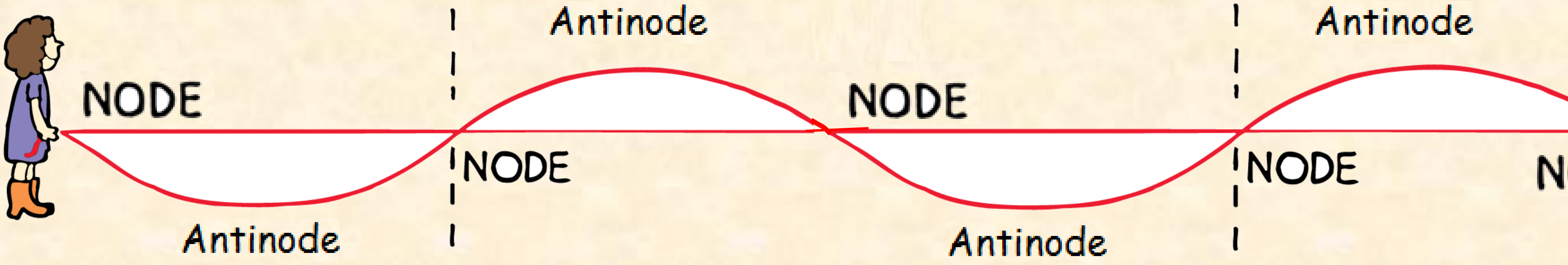
Standing Waves

- **Standing wave** -Forms only if half a wavelength or a multiple of half a wavelength fits exactly into the length of the vibrating medium.



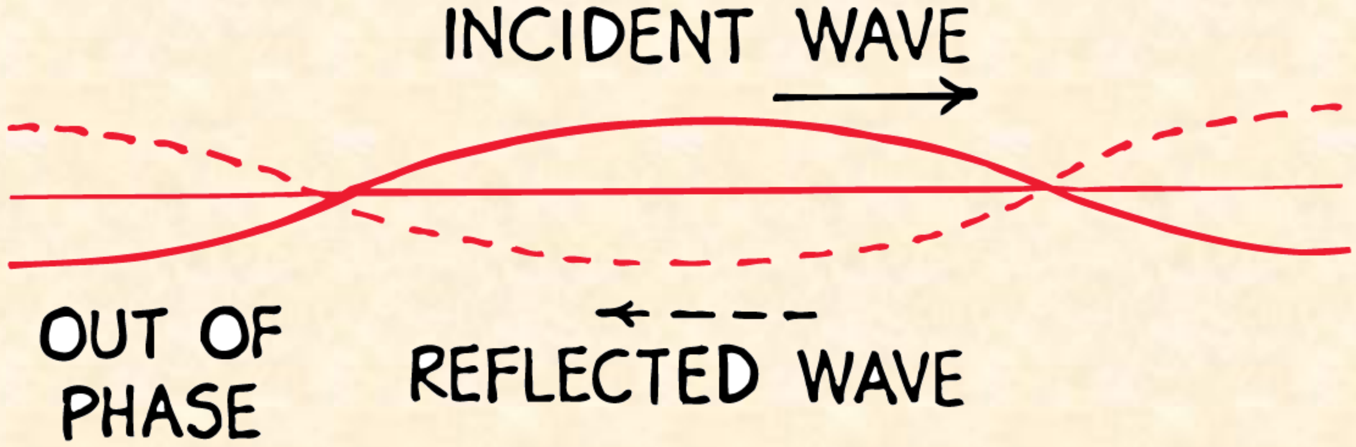
Standing Waves

- **Nodes** - stationary points on a standing wave.
- **Antinodes** - positions on a standing wave with the largest amplitudes are known as
  - Antinodes occur halfway between nodes.



Standing Waves

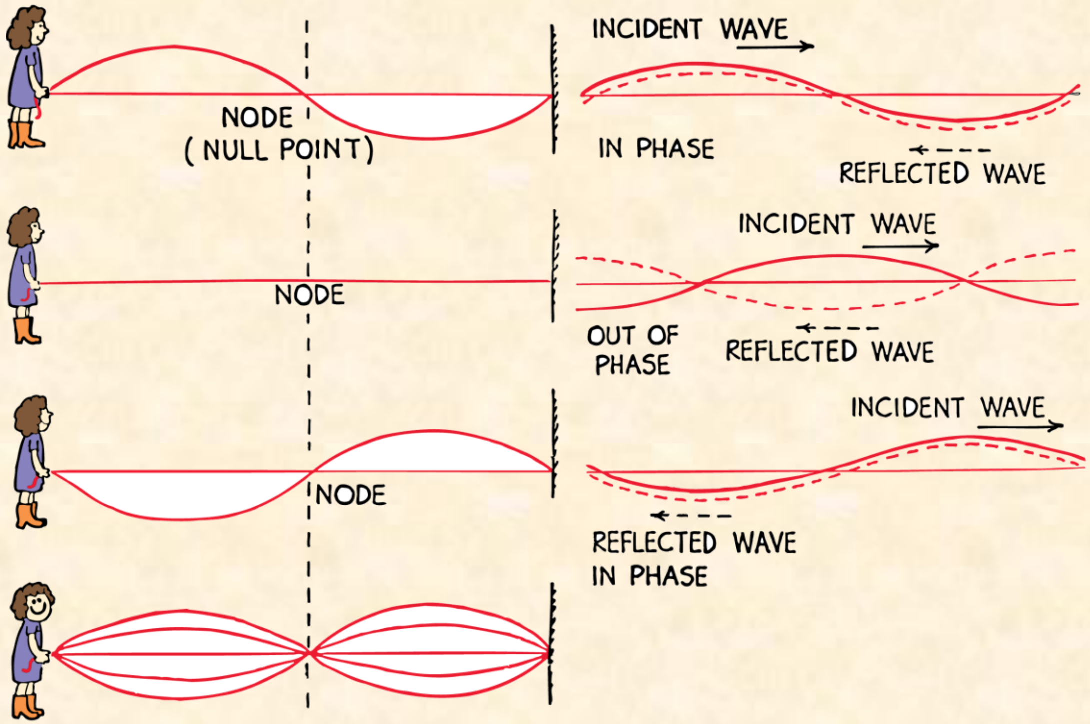
- Incident Wave – wave moving from the source
- Reflected Waves – a wave that strikes a boundary and is "reflected" in the opposite direction it was moving.



Standing Waves

Standing waves –

- Are a result of interference.
- Occurs when two waves of equal amplitude and wavelength pass through each other in opposite directions.
- They are always out of phase at the nodes.



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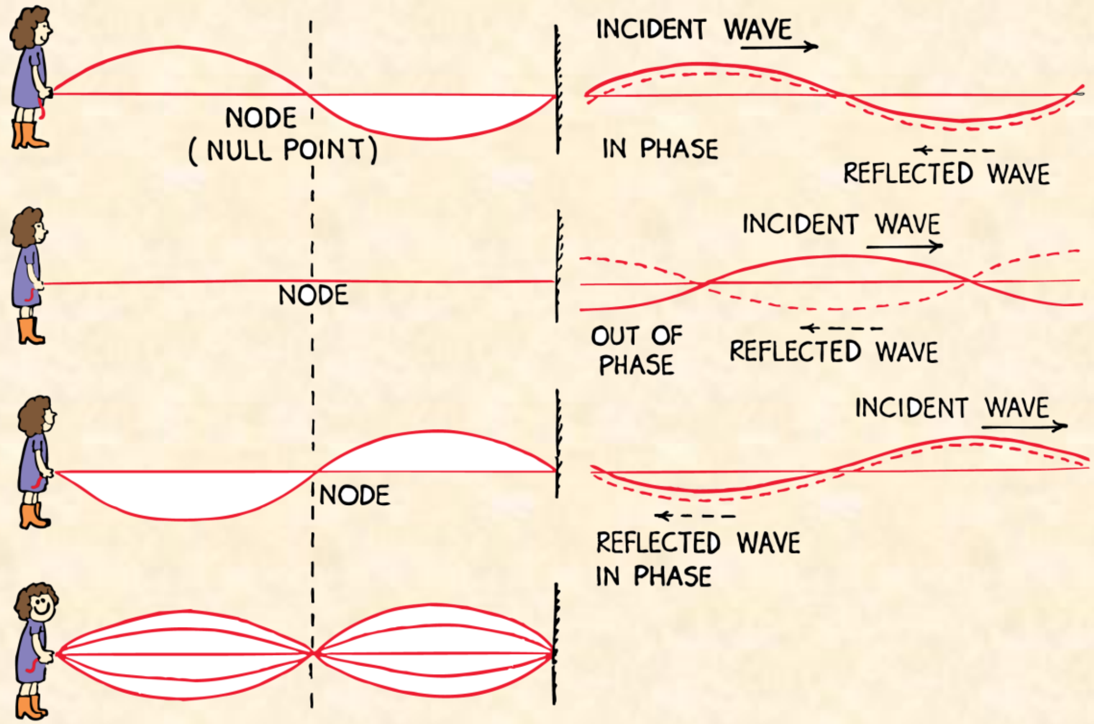


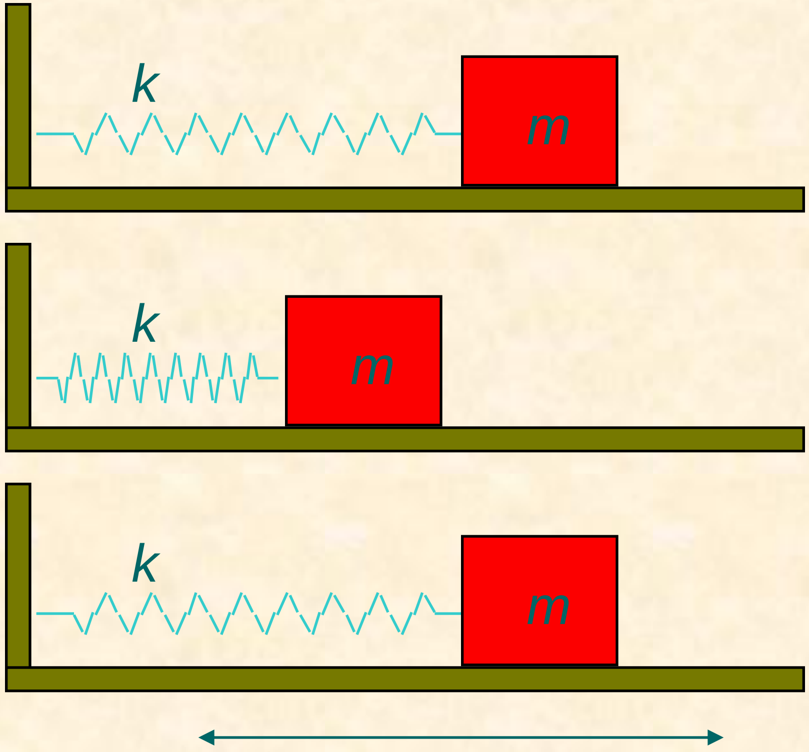
Standing Waves

Standing waves are set up in the strings of musical instruments that are struck.
They are set up in the air in an organ pipe and the air of a soda-pop bottle when air is blown over the top.
Standing waves can be produced in either transverse or longitudinal waves.



Hooke's Law

- We know that if we stretch a spring with a mass on the end and let it go, the mass will oscillate back and forth (if there is no friction).



Hooke's Law

- At any given instant we know that F = ma must be true.
  But in this case F = -kx and F = ma
- So: *-kx = ma*
- *F = - kx (Hooke's Law)*
- Apply some trig and we find that period is proportional to the square root of mass over spring constant.

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

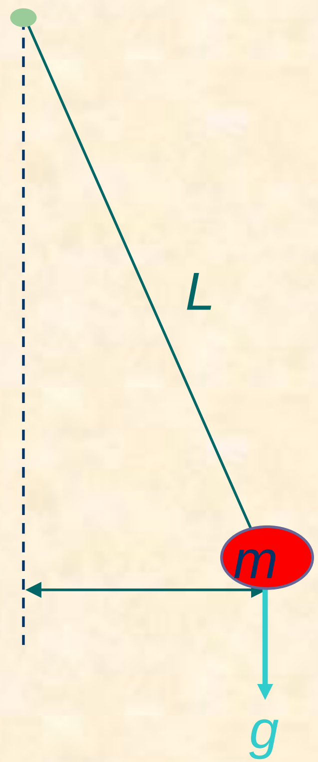
Period of a Pendulum

- Period is proportional to the square root of the length over gravity

- This works when the angle is not too large.

$$T = 2\pi\sqrt{\frac{L}{g}}$$

- The period does not depend on the mass of the object



The Doppler Effect

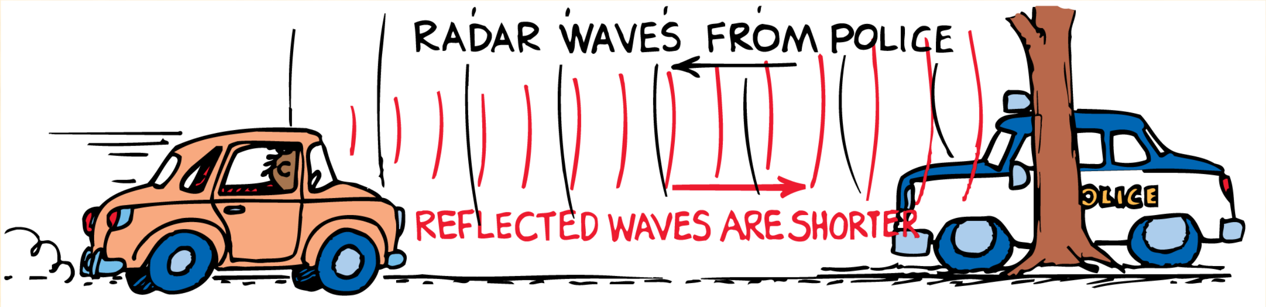
- **Doppler effect** - The apparent change in frequency due to the motion of the source or receiver.
  - The greater the speed of the source, the greater will be the Doppler effect.

The Doppler Effect

- The Doppler effect causes the changing pitch of a siren.
- When an object approaches, the pitch sounds higher than normal because the sound wave crests arrive more frequently.
- When an object moves away, you hear a drop in pitch because the wave crests are arriving less frequently.

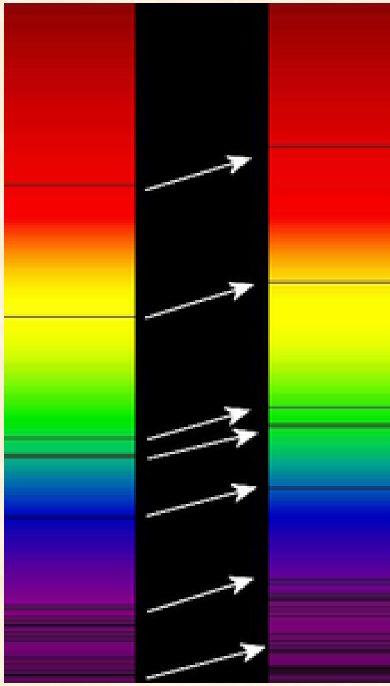
The Doppler Effect

- Police use the Doppler effect of radar waves to measure the speeds of cars on the highway.
- Radar waves are electromagnetic waves.
- Police bounce them off moving cars. A computer built into the radar system compares the frequency of the radar with the frequency of the reflected waves to find the speed of the car.



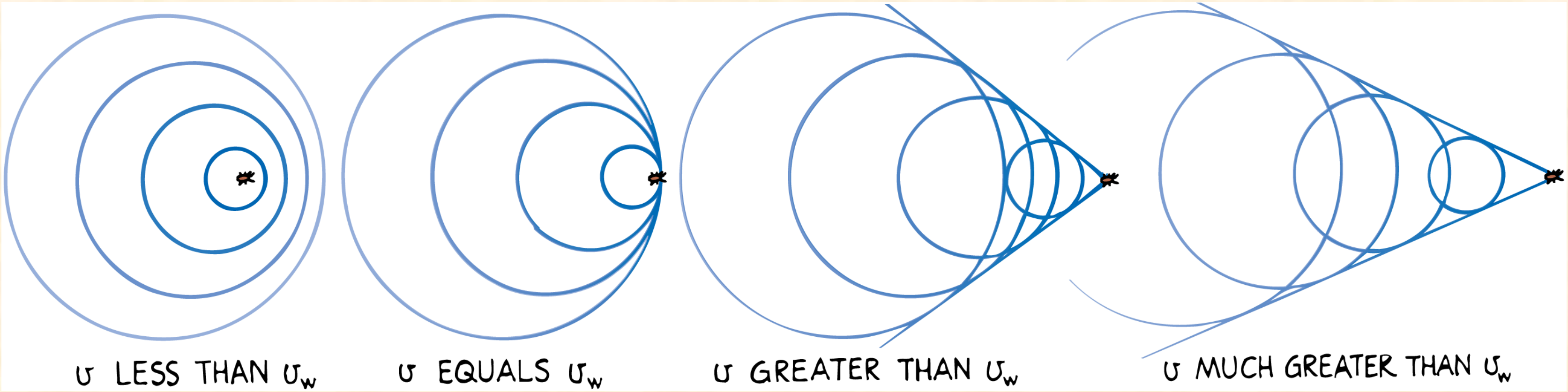
The Doppler Effect & Light

- **Blue shift** – An apparent **increase** in observed frequency in the visible light spectrum. This indicates an object is moving toward the observer.
- **Red shift** – An apparent **decrease** in observed frequency in the visible light spectrum. This indicates an object is moving away the observer.
- Distant galaxies show a red shift in their light. A measurement of this shift enables astronomers to calculate their speeds of recession.



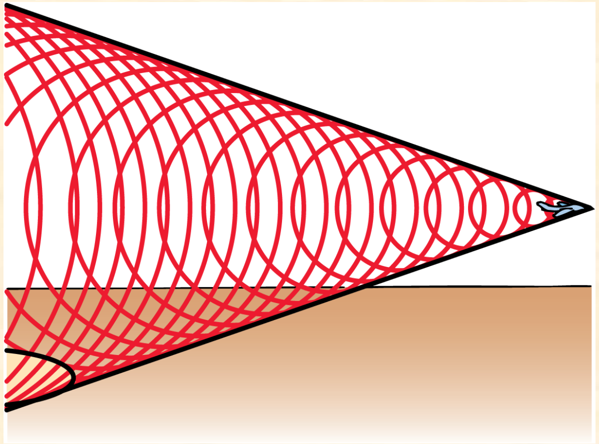
Bow Waves

- **Bow wave -** occurs when a wave source moves faster than the waves it produces.
  - When the plane travels faster than sound, it is *supersonic.*
  - A supersonic airplane flies into smooth, undisturbed air because no sound wave can propagate out in front of it.



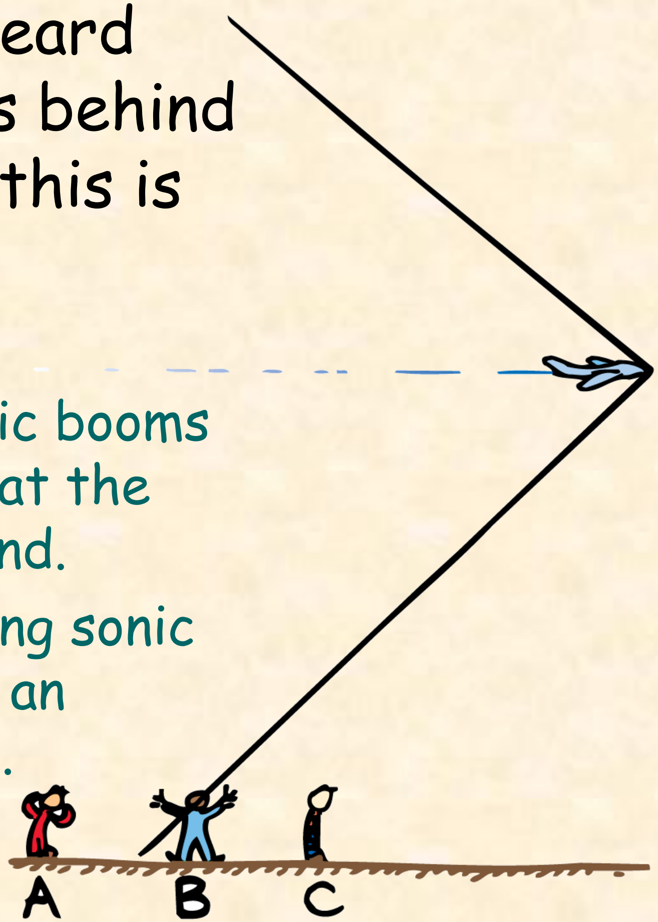
Shock Waves

- **Shock wave -** occurs when an object moves faster than the speed of sound.
  - It is a three-dimensional wave that consists of overlapping spheres that form a cone.
  - The conical shock wave generated by a supersonic craft spreads until it reaches the ground.



Shock Waves

- **Sonic boom -** The sharp crack heard when the shock wave that sweeps behind an object reaches the listeners (this is most often associated with a jet aircrafts).
  - A common misconception is that sonic booms are produced only at the moment that the aircraft surpasses the speed of sound.
  - In fact, a shock wave and its resulting sonic boom are swept continuously behind an aircraft traveling faster than sound.



Other Shock Waves

- A supersonic bullet passing overhead produces a crack, which is a small sonic boom.
- When a lion tamer cracks a circus whip, the cracking sound is actually a sonic boom produced by the tip of the whip.
- Snap a towel and the end can exceed the speed of sound and produce a mini sonic boom.
- The bullet, whip, and towel are not in themselves sound sources. When they travel at supersonic speeds, sound is generated as waves of air at the sides of the moving objects.