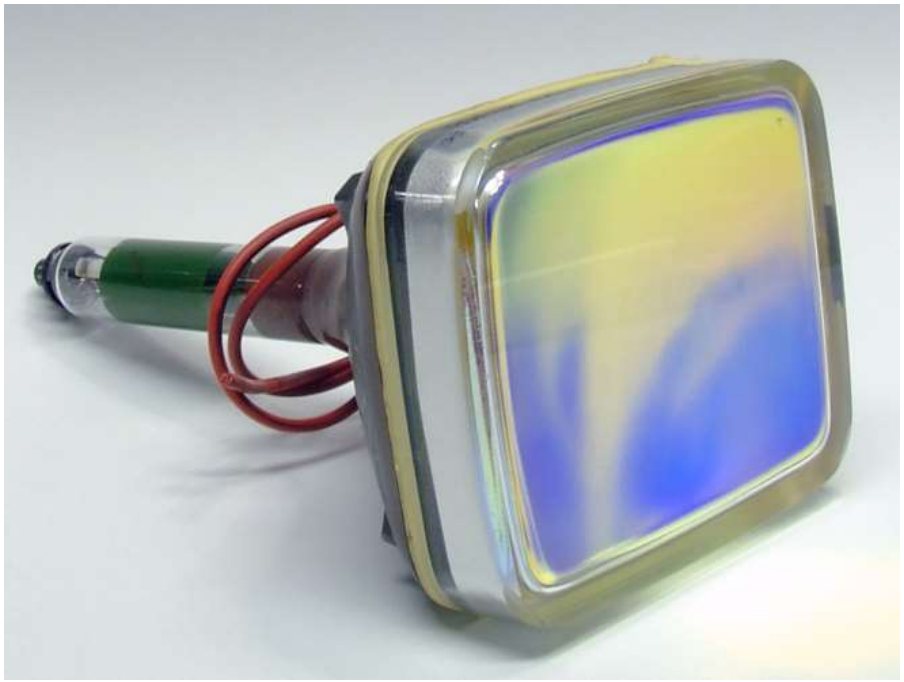
CRT = Cathode Ray Tube



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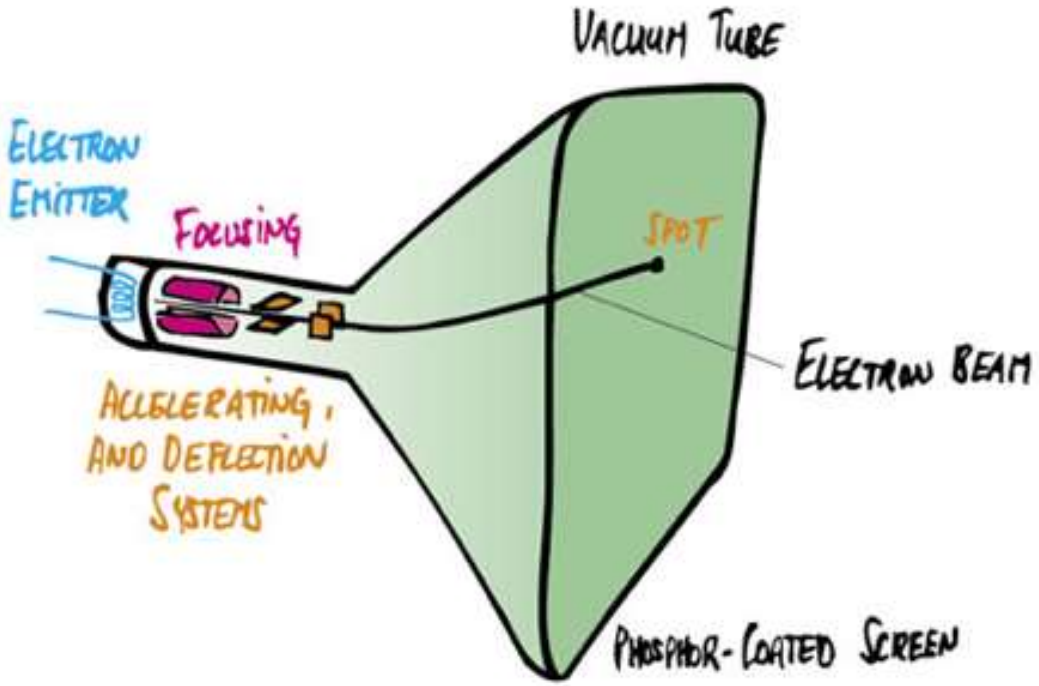
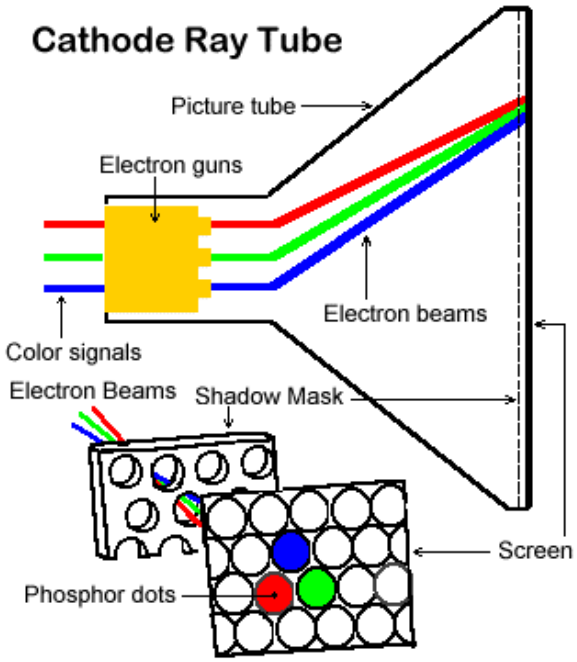
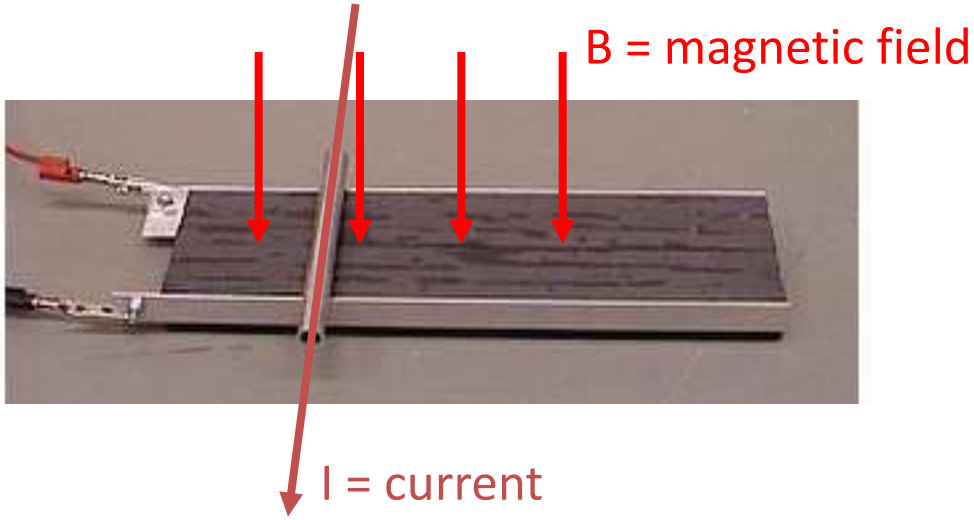




Black and White **Color**

Ampere motor demo



Clicker

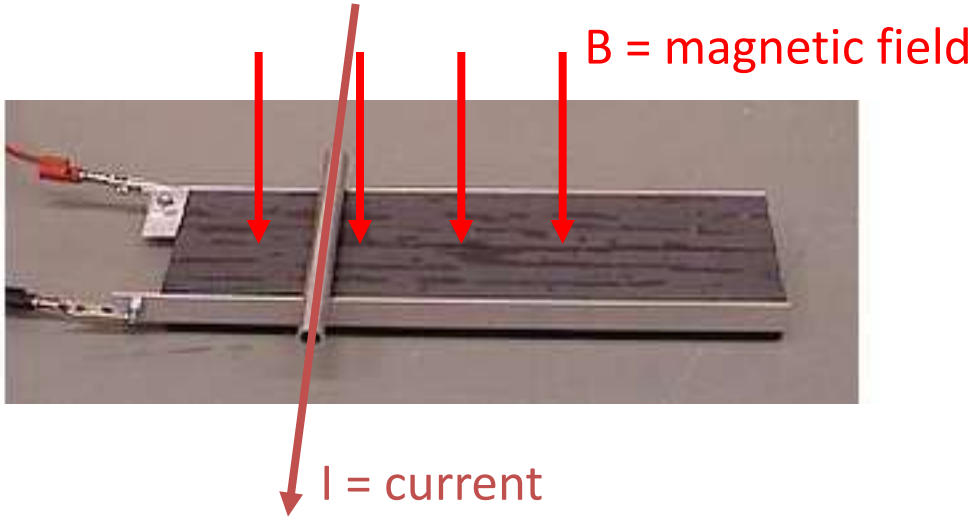
If the metal cylinder is reversed, the force on the cylinder will:

A) Reverse direction

B) Stay in the same direction

C) Go to zero

Ampere motor demo



Clicker

If the metal cylinder is reversed, the force on the cylinder will:

A) Reverse direction

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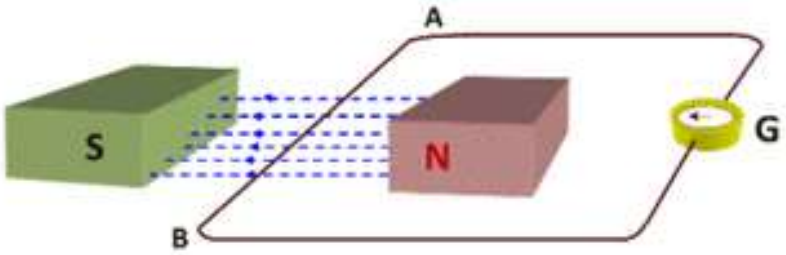
C) Go to zero

Electric generators

- Moving charges feel magnetic force
- Moving charges generate magnetic fields
- Electric motors
- Magnetic induction and electric generators

Induction of current in moving wire (animation)



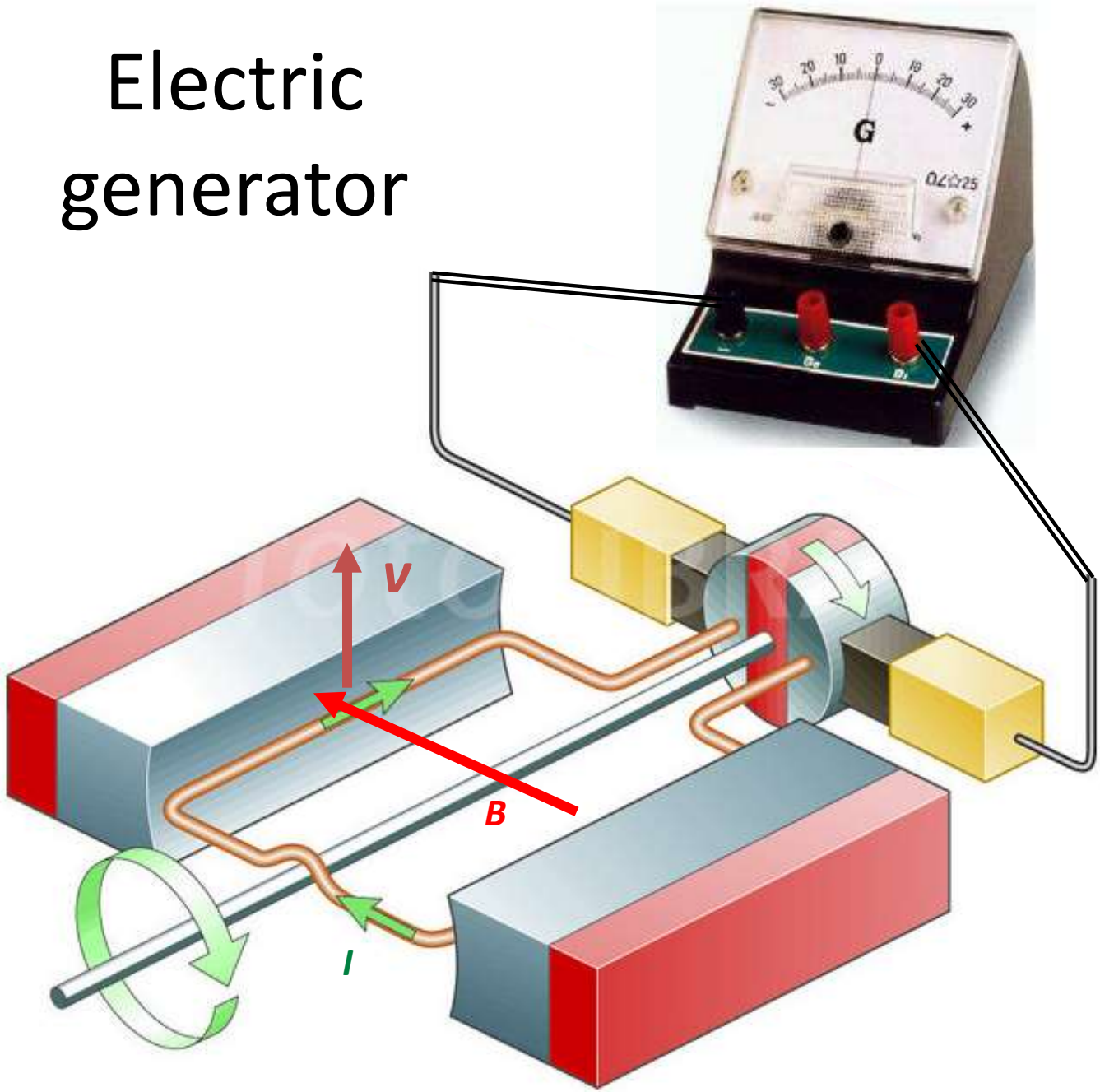
If charge in a wire is moving *perpendicular* to a magnetic field, then the force on the charge is along the wire.

This force does work, and work per unit charge is voltage.

Therefore, any change in the magnetic environment of the wire will cause a voltage (and current) to be "induced" in the wire.

Discovered by Michael Faraday!
(mathematically described by James Maxwell)

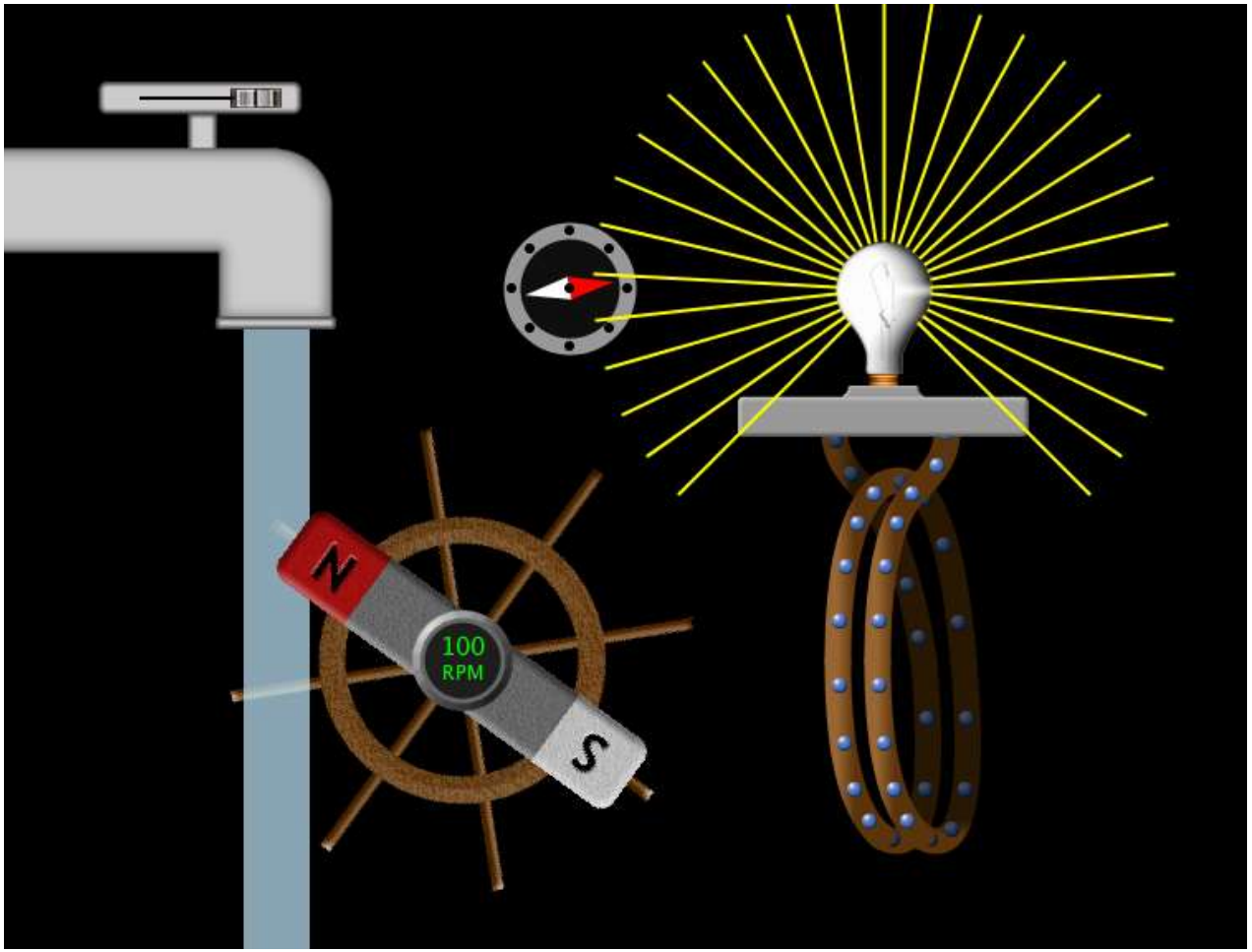
Electric generator



If the movement of the wire is in the form of a rotating coil, then the two sides of the coil move in opposite directions.

Since the rotation produces different directions of motion at different points on the circle of rotation, the voltage generated is sinusoidal – produces an alternating current (AC).

Simulation: Generator



https://phet.colorado.edu/en/simulation/legacy/faraday

Efficiency of motors and generators

Energy conversions:

Electrical $\Rightarrow$ Mechanical: Motor

Mechanical $\Rightarrow$ Electrical: Generator

$$\text{Max Efficiency} = \frac{T_{in} - T_{out}}{T_{in}}$$

(Temperatures measured in K)

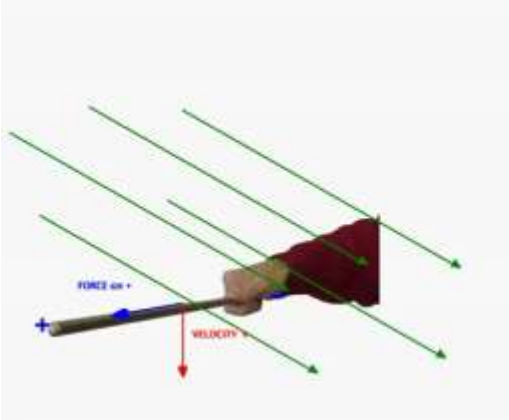
Does it apply?

No!

NOT A THERMAL ENGINE!

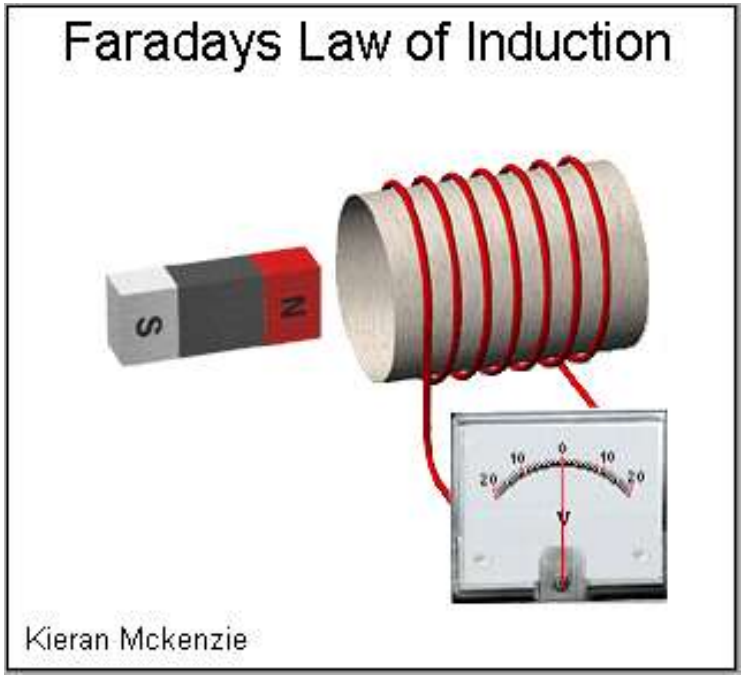
Types of magnetic induction

- Induction of current in a moving wire



- Induction by moving magnet and stationary wire
- Induction with nothing moving!

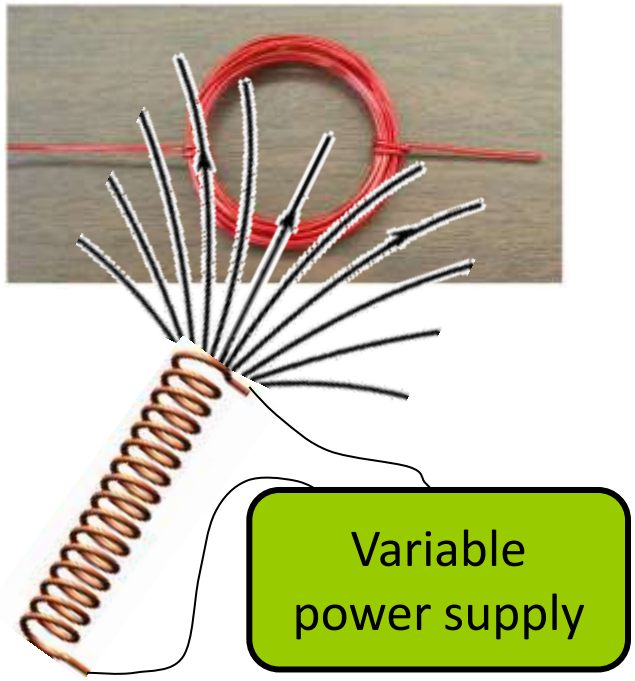
Types of magnetic induction



Moving wire, stationary magnet

Stationary wire, moving magnet

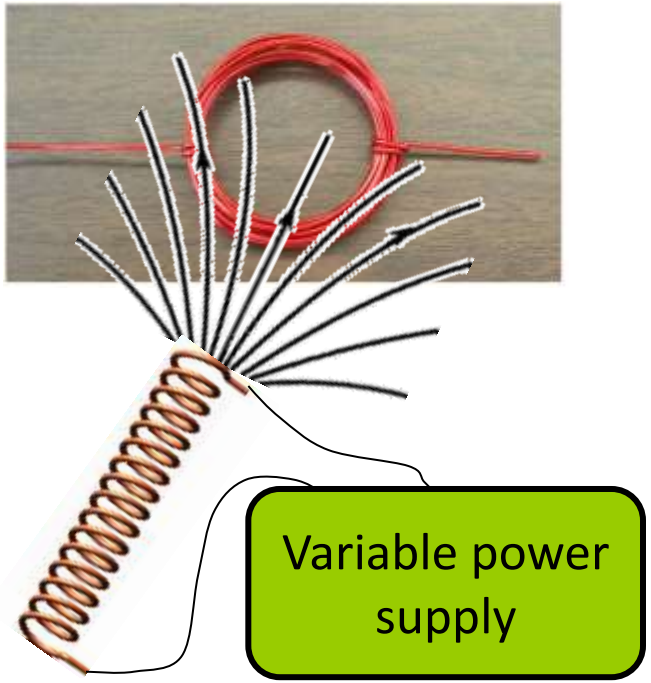
Types of magnetic induction



Stationary wire,
stationary magnet!

Faraday principle

- Induced voltage depends only on the rate of change of the magnetic flux through the loop
- Changing magnetic fields generate circulating electric fields



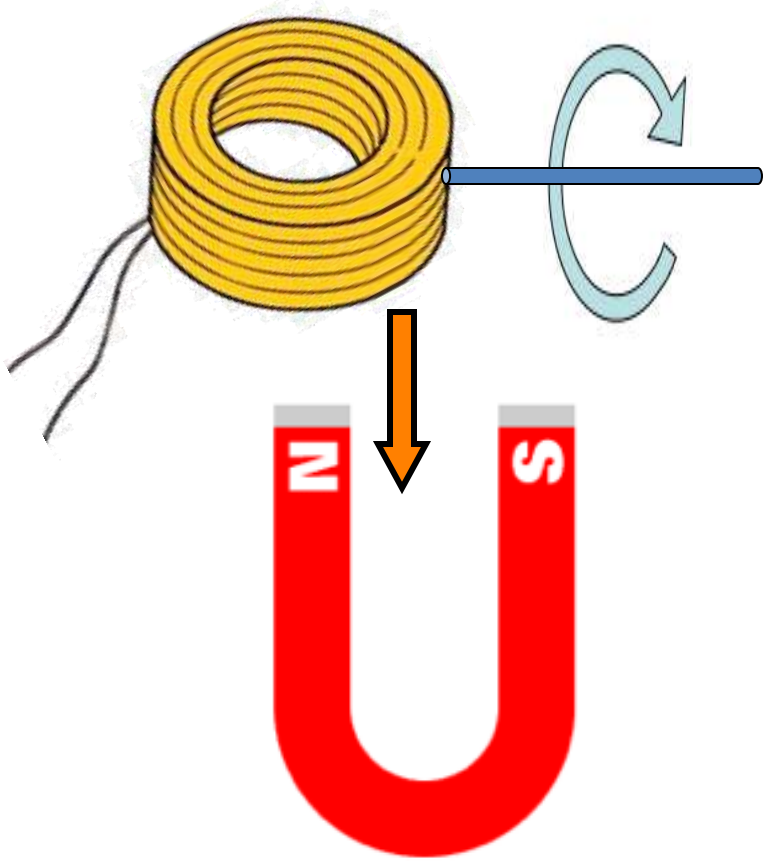
Faraday Coils

If the coil is flipped upside down before lowering onto the magnet, the current meter deflection will:

A) Reverse direction

B) Stay in the same direction

C) Go to zero



Faraday Coils

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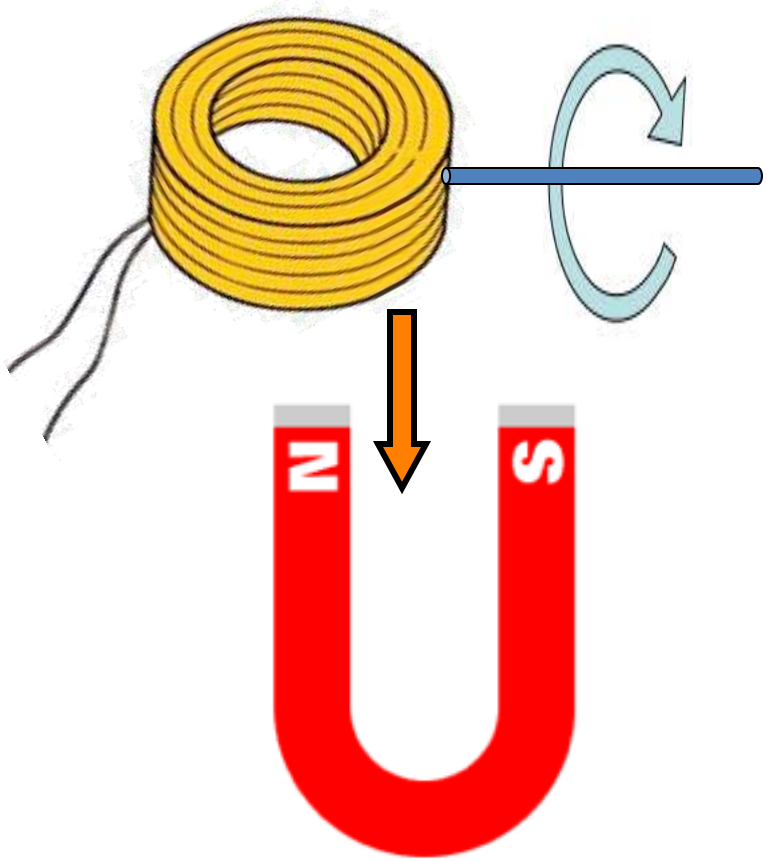


Faraday principle

Changing magnetic fields generate circulating electric fields

Maxwell principle

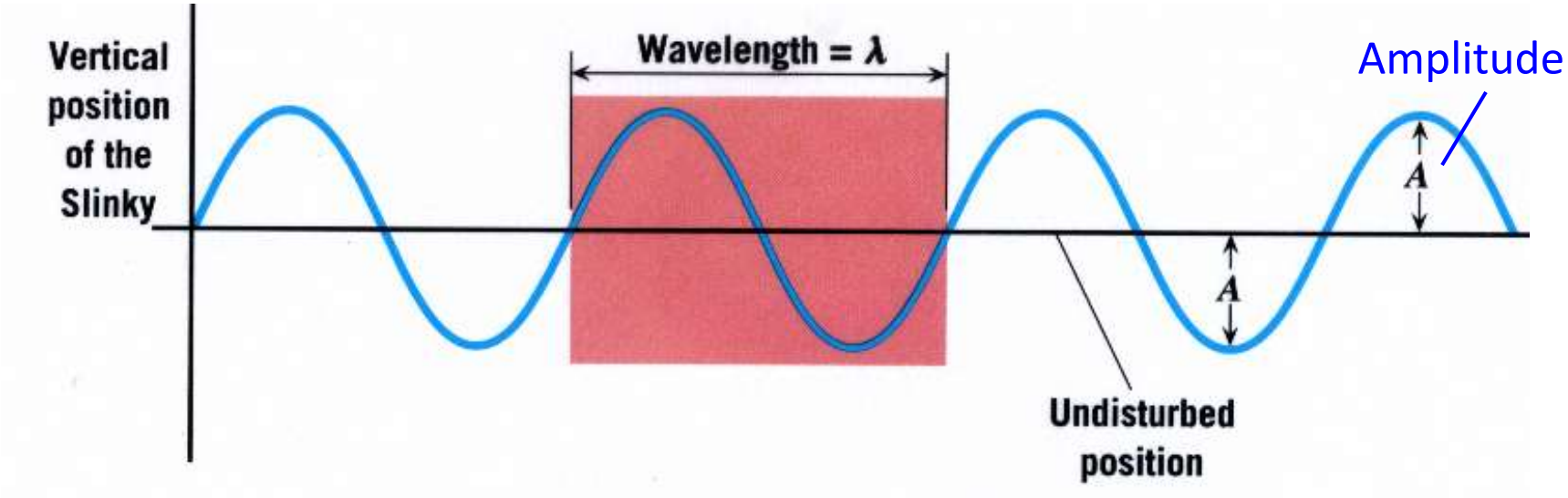
Changing electric fields generate circulating magnetic fields

Electromagnetic waves!

Chapter 9:
Waves and Light

- Waves:
  - What is a wave?
    - Examples of waves: Sound
  - Is light a wave?
    - YES!
  - Properties of waves
    - Frequency and wavelength
    - Interference
    - Diffraction

Definitions

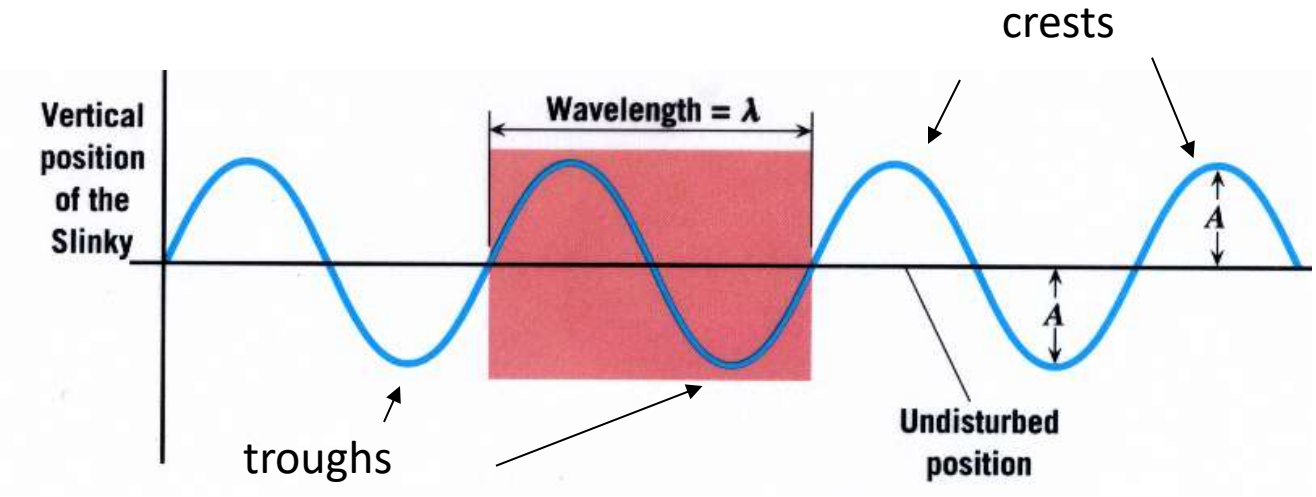


Wavelength: Distance from crest to crest

Frequency: Number of complete oscillations per second

Amplitude: Height (strength) of the wave

Wavelength and frequency



Wavelength is proportional to inverse of frequency

To be more precise:

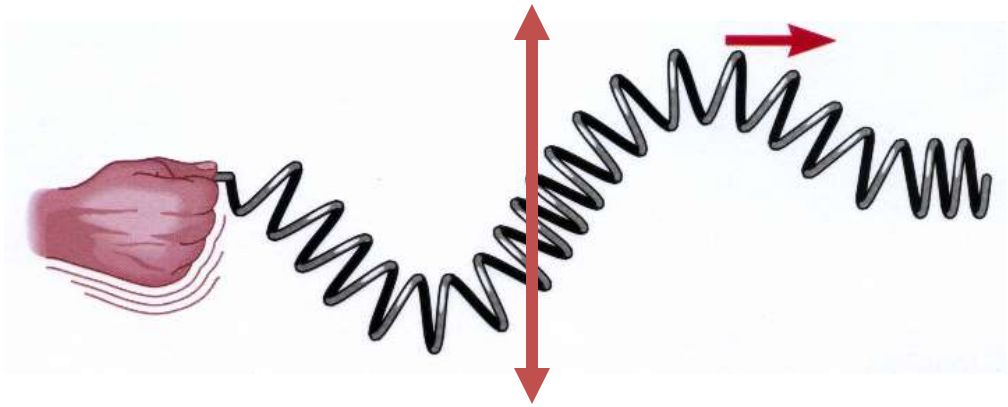
(Speed of the wave) = (Wavelength) x (Frequency)

Depends on tension in the string

Transverse and Longitudinal Waves

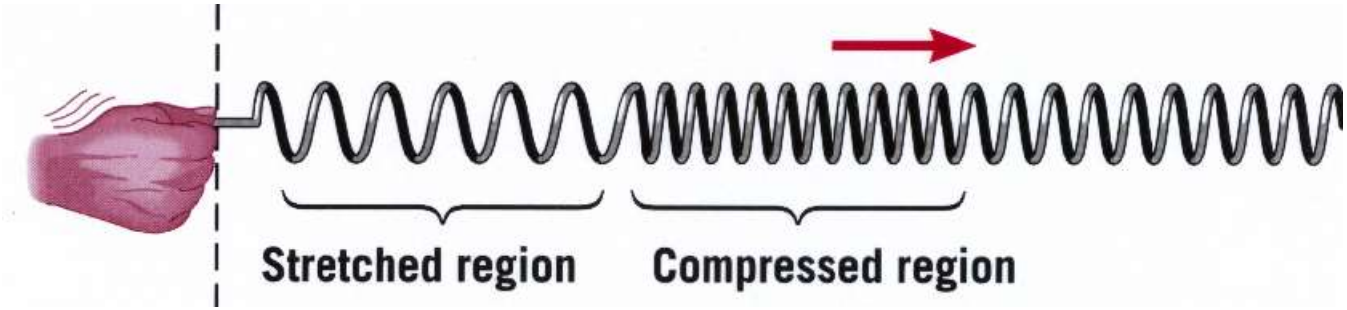
Motion of medium

Motion of wave



"transverse wave"

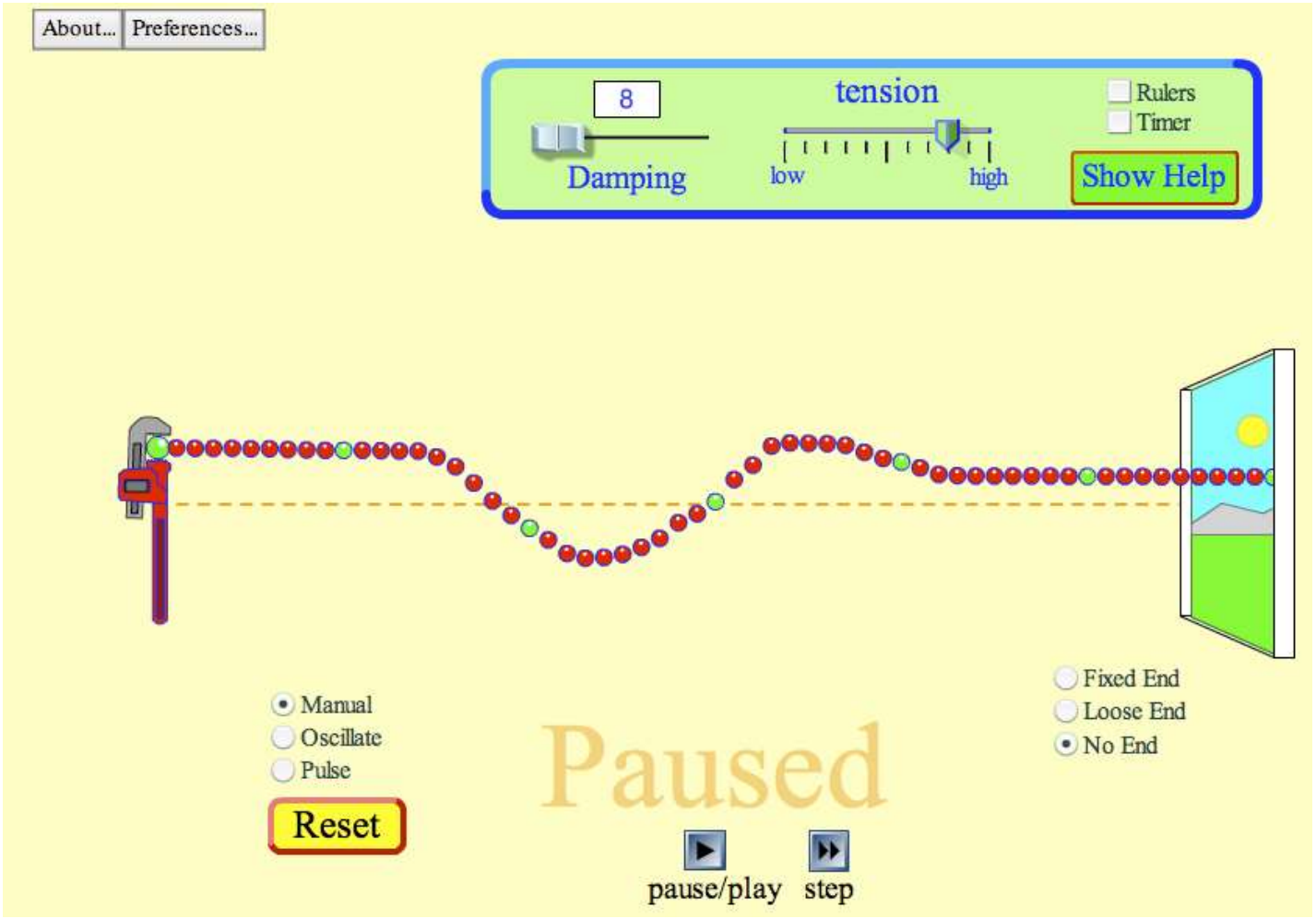
Motion of wave



Motion of medium

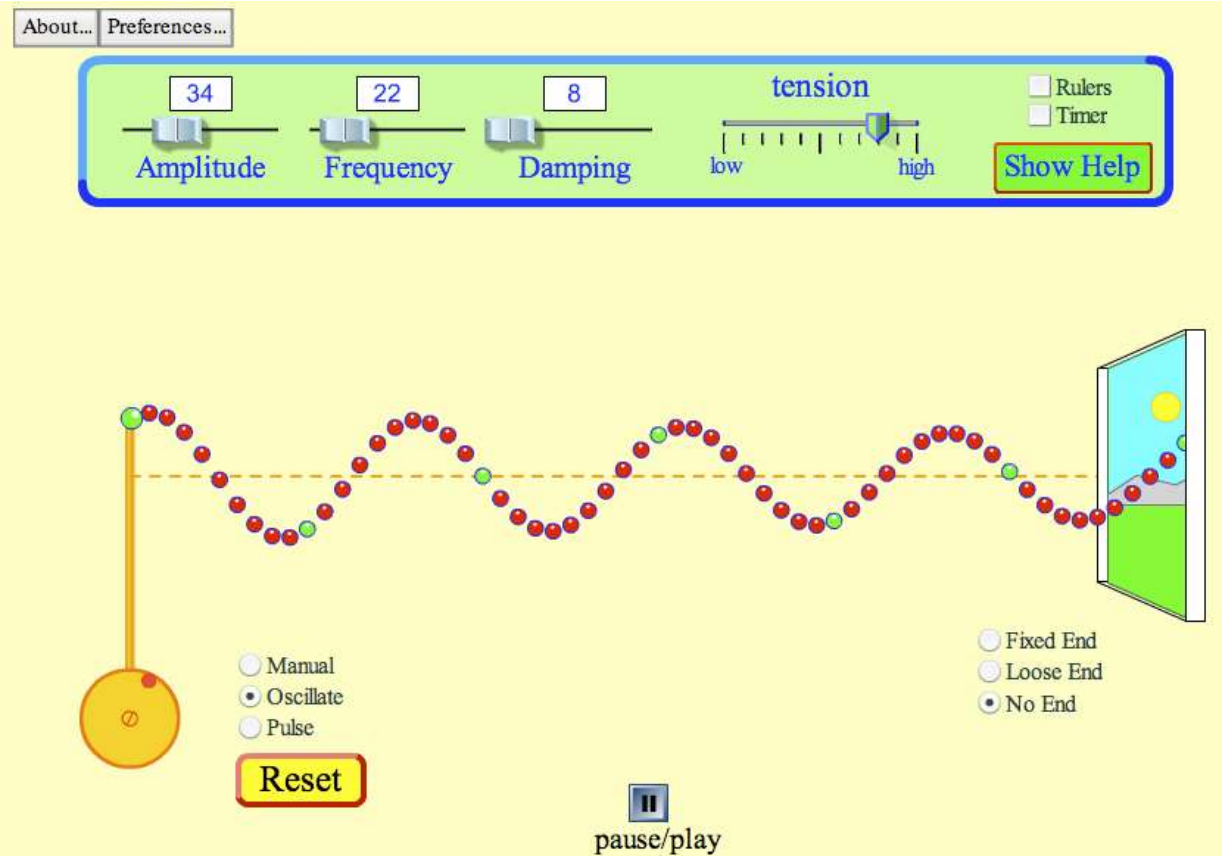
"longitudinal wave"

PHET demonstration: [Waves on a string demo]:



PHET demonstration: [Waves on a string demo]:

Oscillatory waves



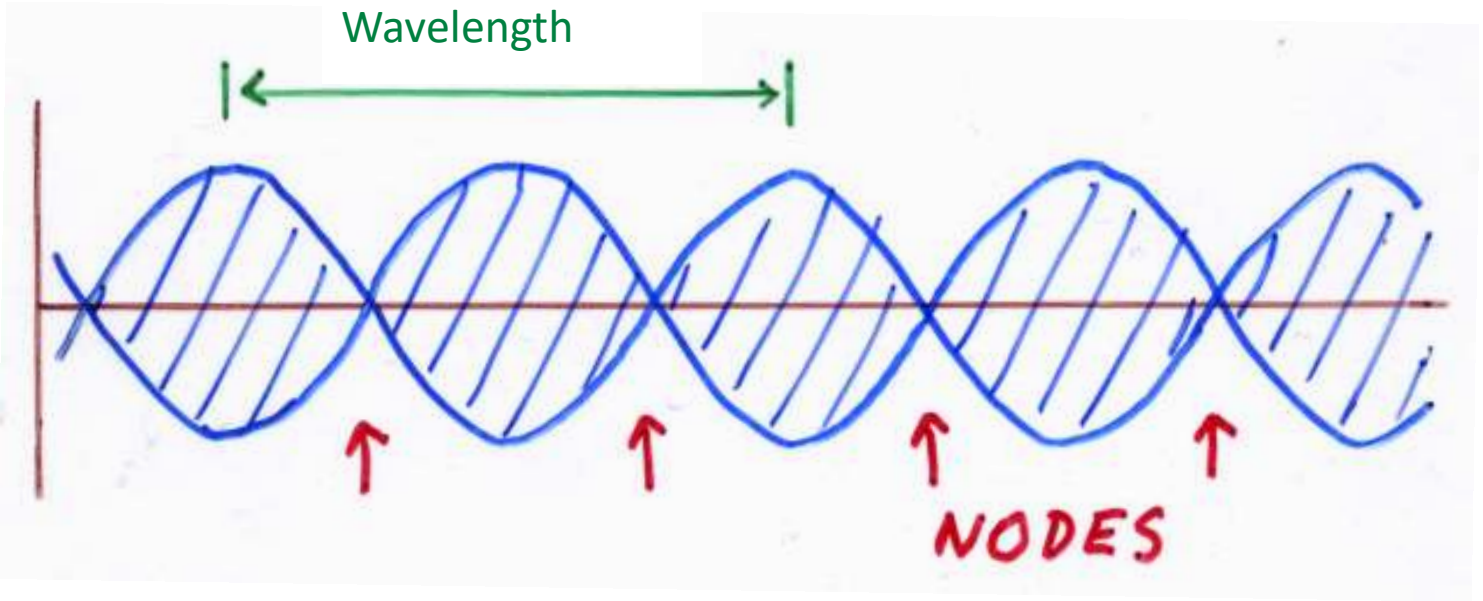
Demos: Transverse Waves

With a slinky:

Demos: Longitudinal Waves

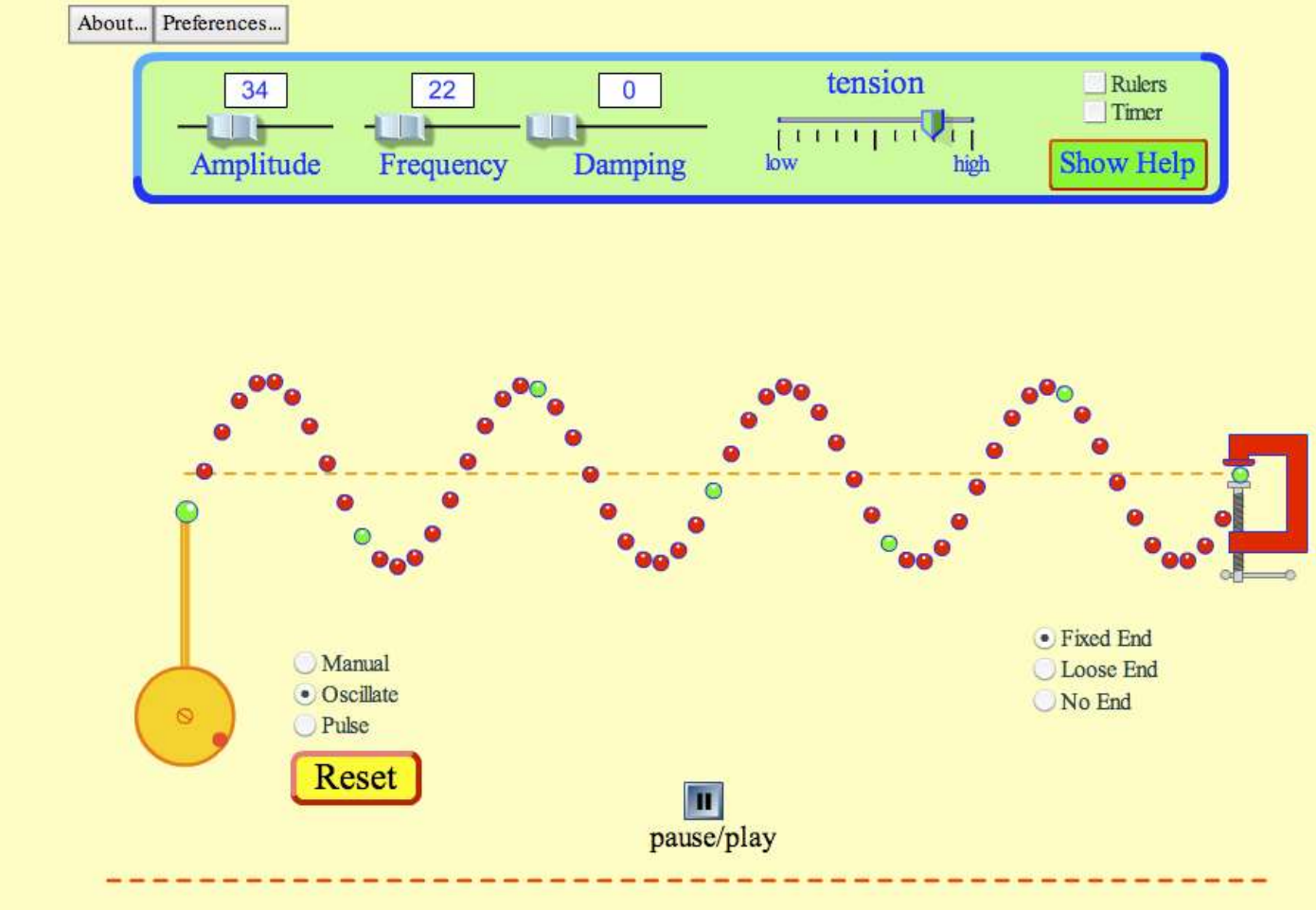
With a slinky:

Standing waves



- A standing wave is combination of two waves moving in <u>opposite directions</u>, each having the same amplitude and frequency.
- It is a result of interference of the two waves:
  - waves are superimposed, and are either added together or cancelled out.
- The standing wave modes arise from the combination of reflection and interference such that the reflected waves interfere with the incident waves.

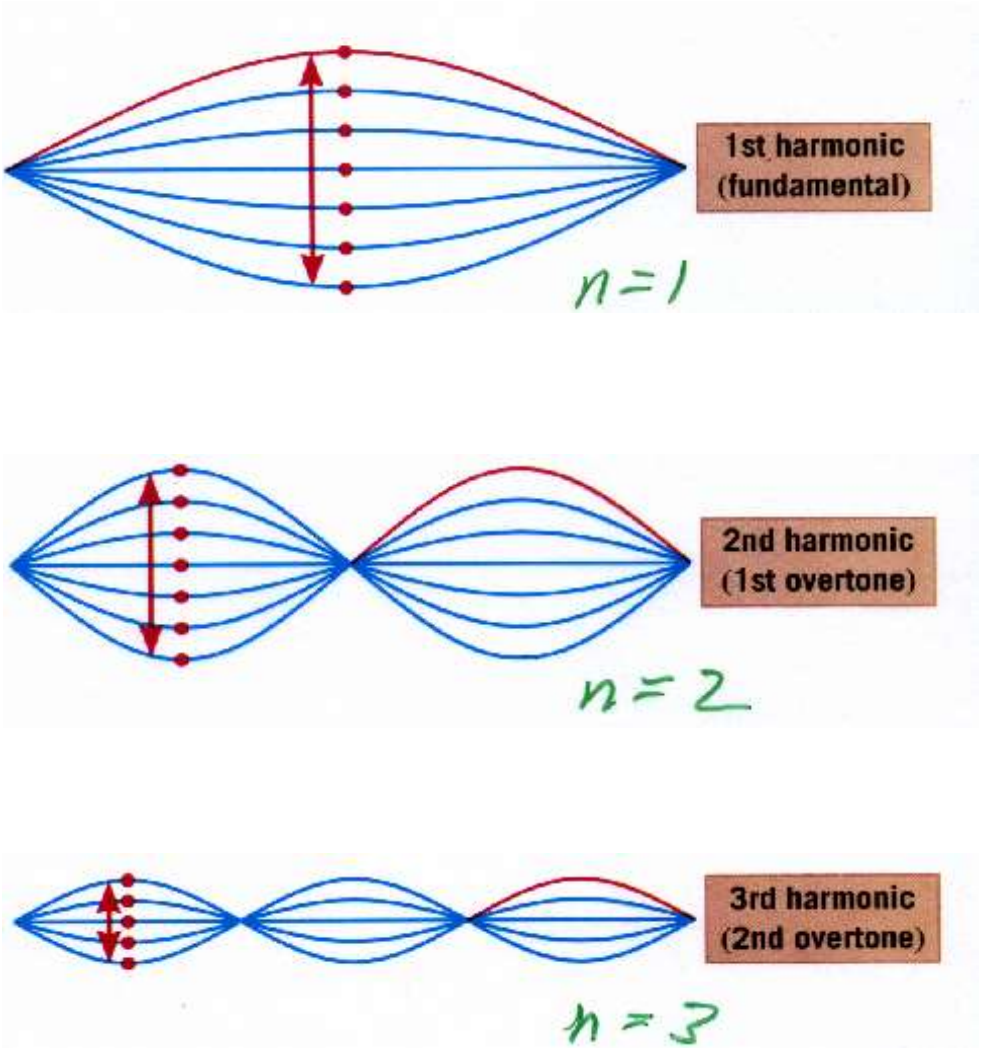
PHET demonstration: Standing Waves:



Demo: Standing Waves

Standing waves

Stringed instruments



Higher frequency

Clicker

I pluck a string on a guitar, then tighten the string and pluck again. What happens to the motion of the guitar string? (Not the sound waves in air…)

A) The wavelength increases

B) The wavelength decreases

C) The frequency increases

D) The frequency decreases

E) The frequency and wavelength both change

Clicker

I pluck a string on a guitar, then tighten the string and pluck again. What happens to the motion of the guitar string? (Not the sound waves in air…)

A) The wavelength increases

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D) The frequency decreases

E) The frequency and wavelength both change

Clicker

I pluck a string on a guitar. Which is true?

A) The string wavelength and the sound-wave wavelength are the same

B) The string frequency and sound-wave frequency are the same

C) Both of the above

D) Neither of the above

Clicker

I pluck a string on a guitar. Which is true?

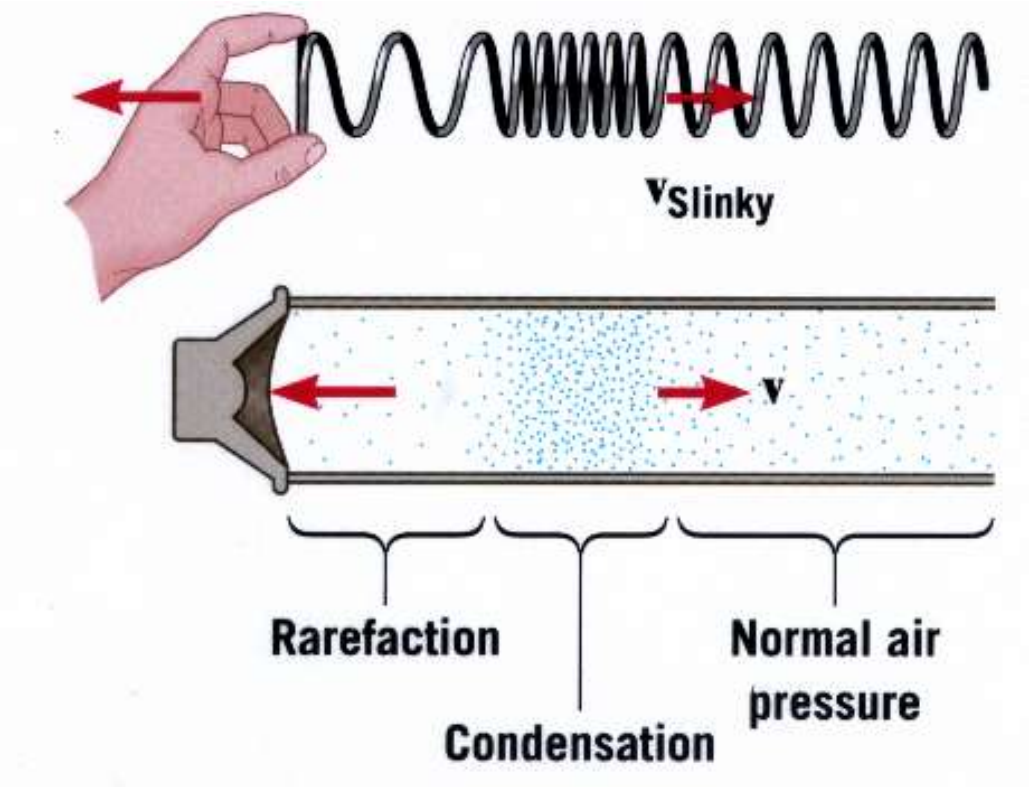
A) The string wavelength and the sound-wave wavelength are the same

B) The string frequency and sound-wave frequency are the same

C) Both of the above

D) Neither of the above

Sound waves



"longitudinal wave"

Sound waves:

- Medium = air
- Waves = density variations
- Do air molecules move with the wave?

Speed of sound in air

Speed of sound = 1100 ft/s = 340 m/s

5 second rule for lightning/thunder

Middle A = 440 Hz (1 Hz = 1 cycle/s)

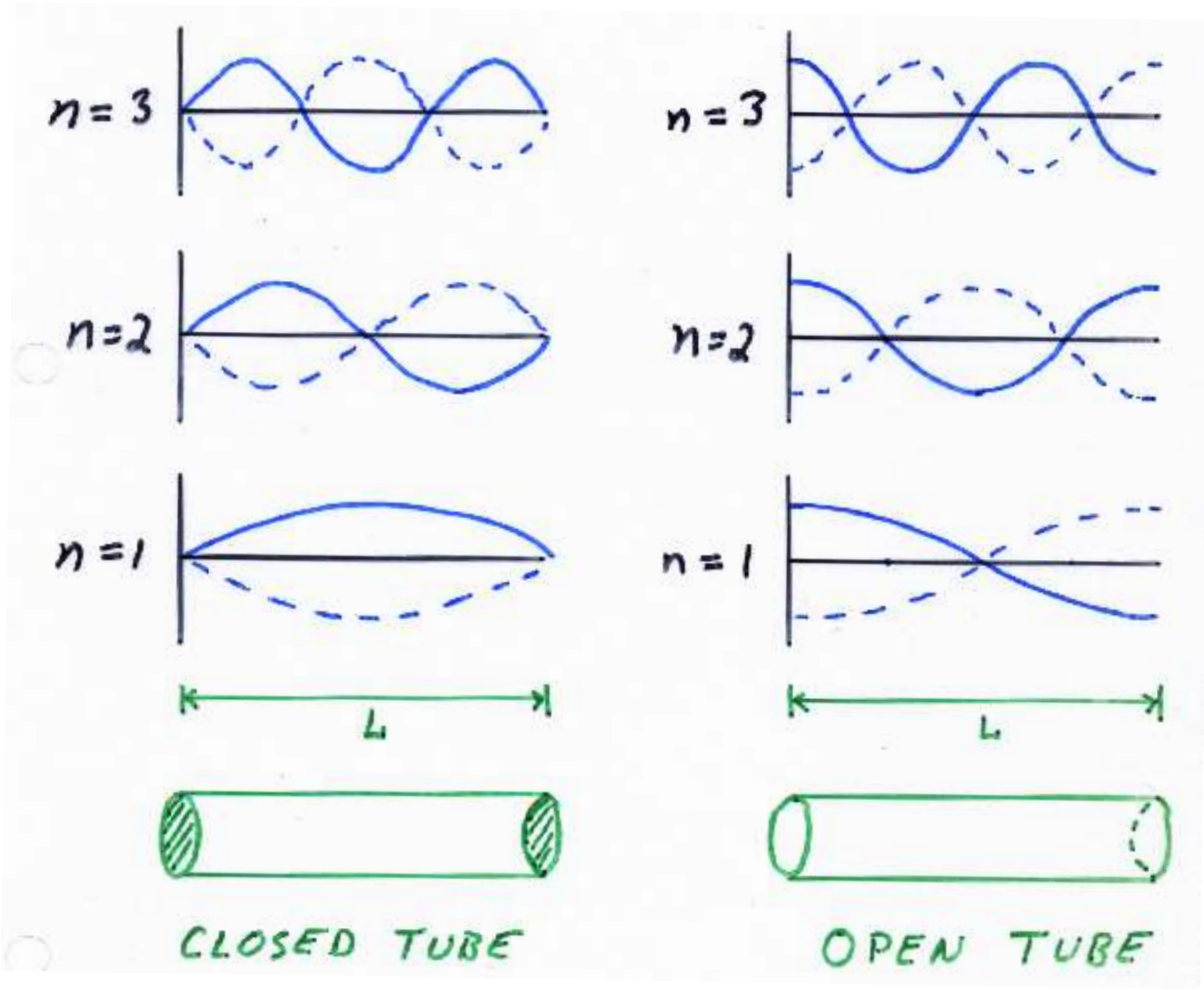
What is its wavelength?

(Speed of the wave) = (Wavelength) x (Frequency)

0.77 m = 2.5 ft

Demo: Sound Waves

Sound: Open and closed tubes



Demos:

- Whistles etc.
- Flame tube

Clicker

If we turn up the frequency of the sound in the flame tube, what happens?

A) The wavelength increases

B) The wavelength decreases

C) The wavelength stays the same

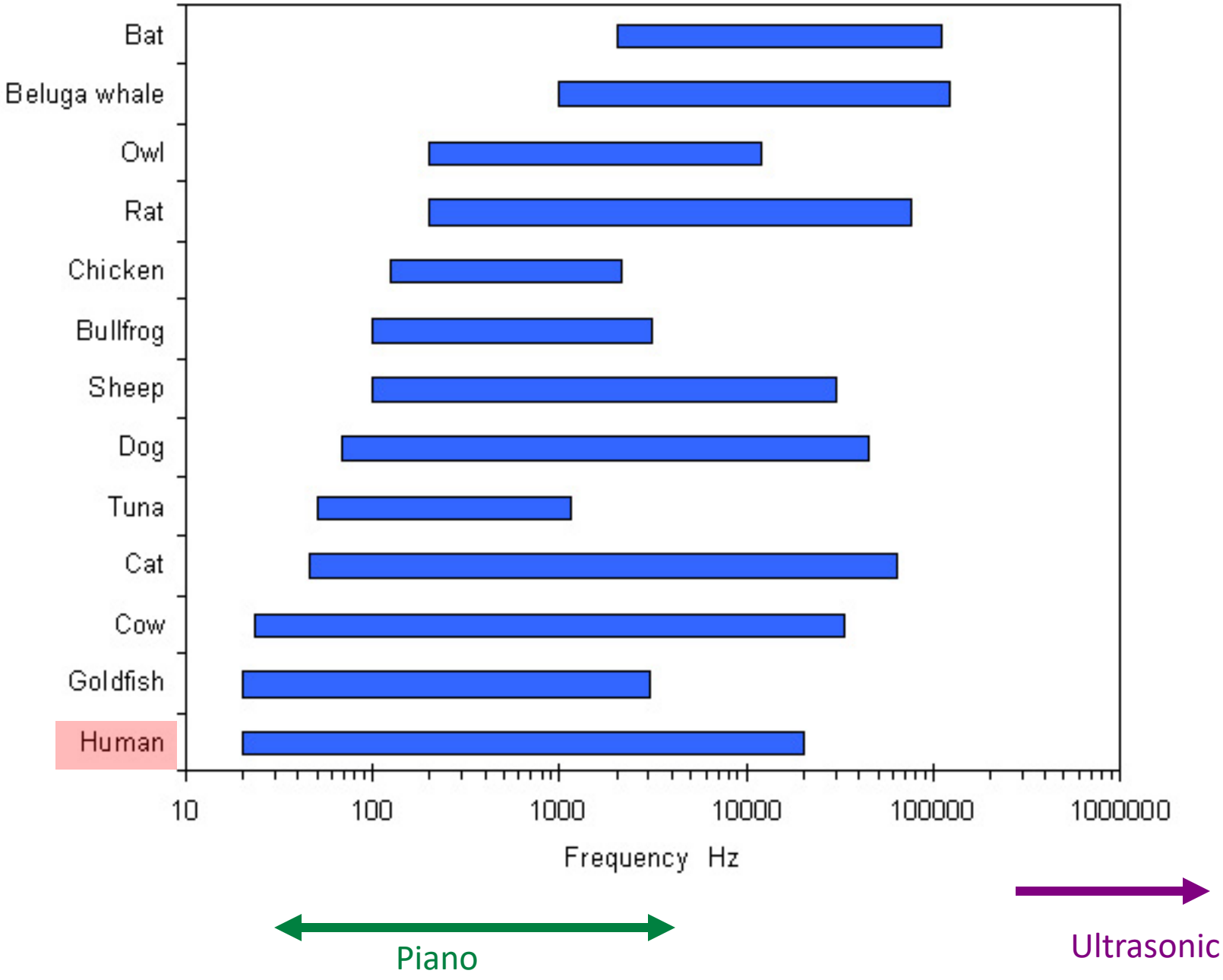
Clicker

If we turn up the frequency of the sound in the flame tube, what happens?

A) The wavelength increases

B) The wavelength decreases

C) The wavelength stays the same


Bat
Beluga whale
Owl
Rat
Chicken
Bullfrog
Sheep
Dog
Tuna
Cat
Cow
Goldfish
Human
10
100
1000
10000
100000
1000000
Frequency Hz
Piano
Ultrasonic

Medical Ultrasound

Older technology

Newer technology