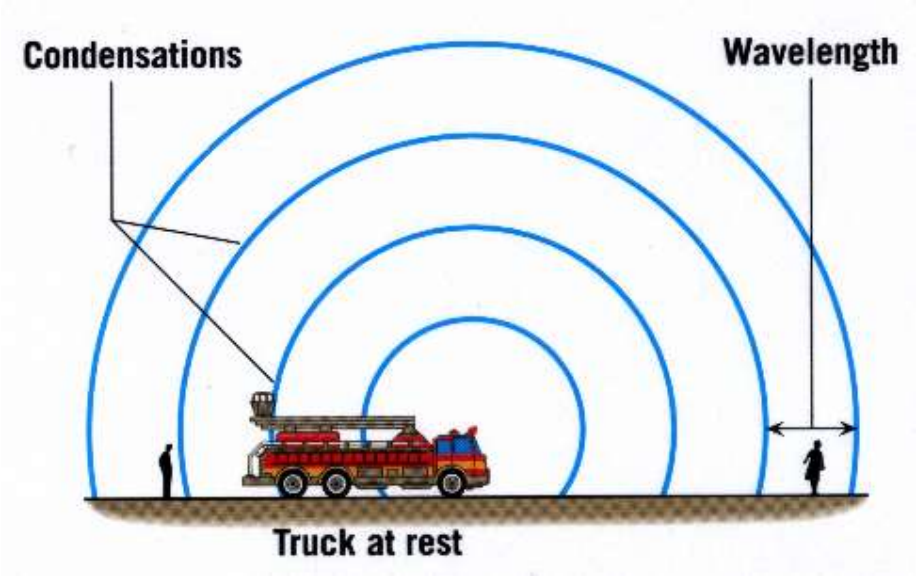
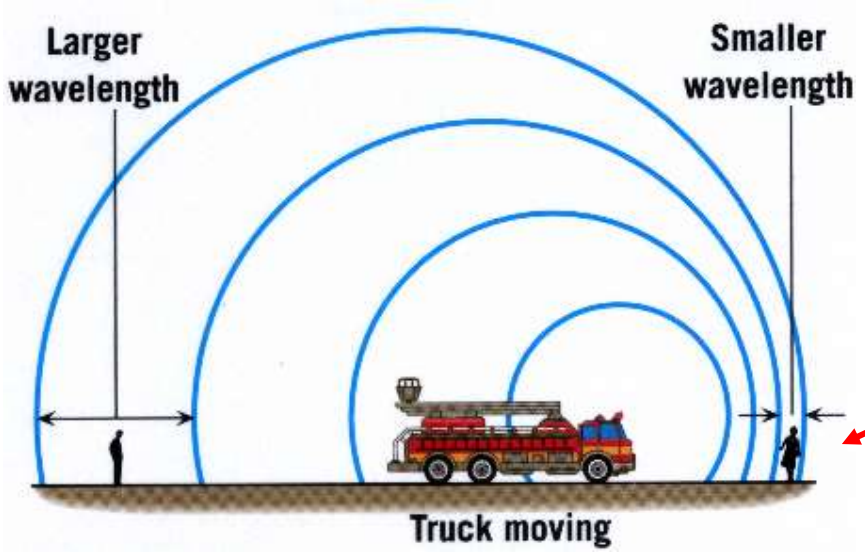
Sound: Doppler effect





- An increase (or decrease) in the frequency of sound (or light, or other waves) as the source and observer move toward (or away from) each other.
- The effect causes, for example:
  - the sudden change in pitch noticeable in a passing sirens
  - the redshift seen by astronomers

Person hears higher pitch

Demo: Doppler Effect

Clicker

When swinging the “Doppler ball,” what does the person doing the swinging hear?

A) Ooh-eeh-ooh-eeh-…

B) Eeh-ooh-eeh-ooh-…

C) A constant tone

Clicker

When swinging the “Doppler ball,” what does the person doing the swinging hear?

A) Ooh-eeh-ooh-eeh-…

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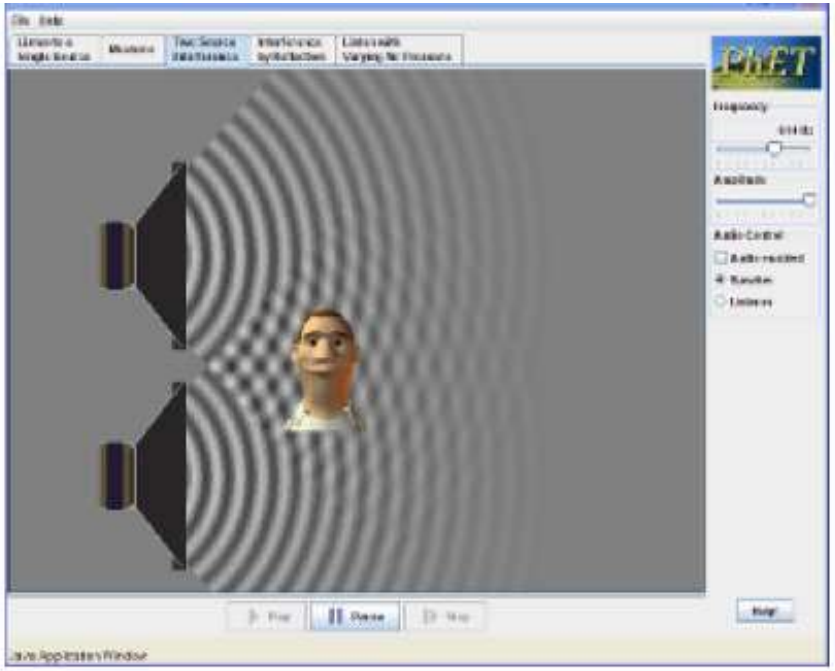
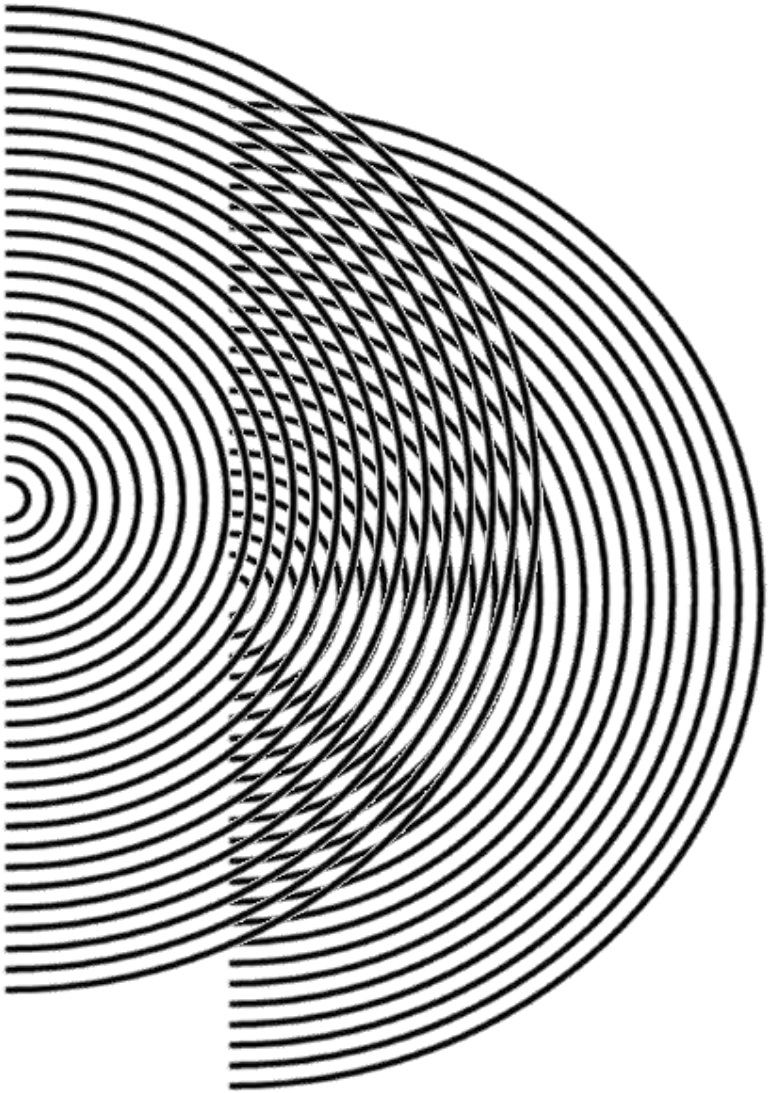
More than one source

- What happens when there is more than one source?
  - Interference!

- PHET: Interference
  - Water waves
  - Sound waves
  - Light waves



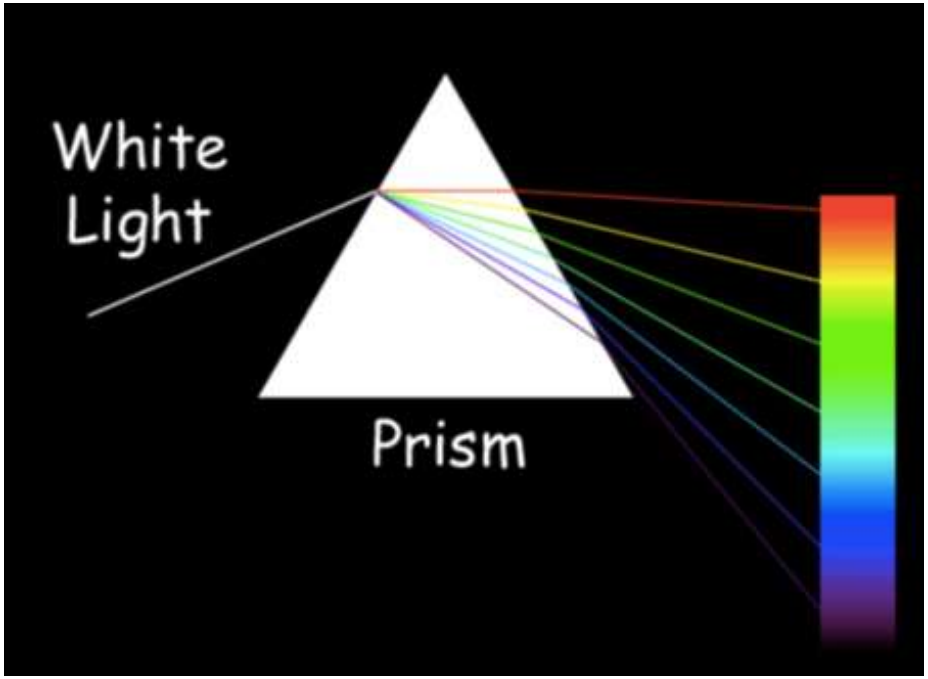
Interference



Areas of constructive (where crest meets crest and trough meets trough) and destructive (where crest meets trough) interference

Demo: Interference

Light



Newton, circa 1670:

- Experiments, color spectrum

Light: Particles or waves?

If waves:

- What is the medium?
- What is "shaking"?

} Electric and magnetic fields!

- What variable is associated with wavelength & frequency?
  - Color ?
- Do light waves interfere?
  - Yes !

Electromagnetism: Review

Faraday

Changing magnetic fields generate circulating electric fields

Maxwell

Changing electric fields generate circulating magnetic fields

Electromagnetic waves!

Electromagnetism: Review

Faraday

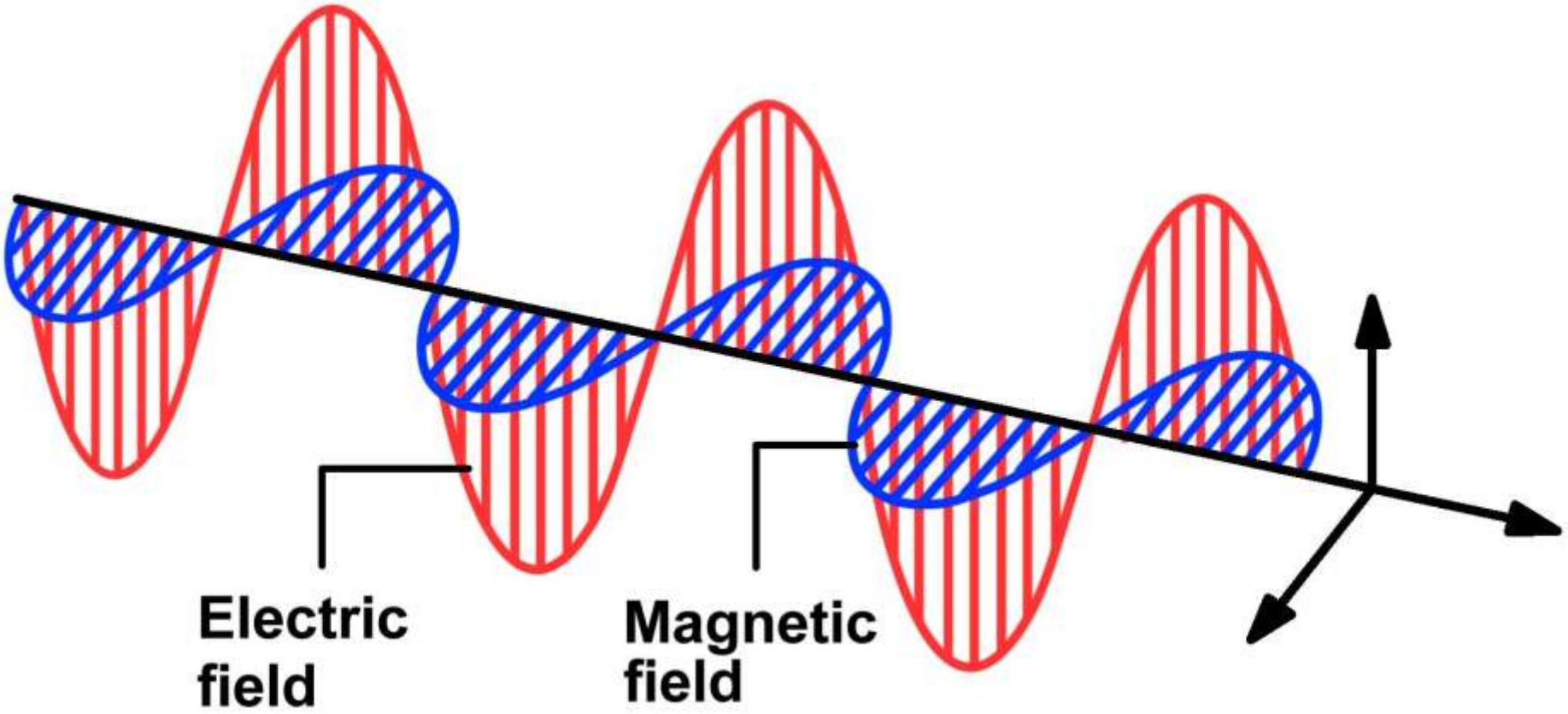
Changing magnetic field
generate circulating
fiel

ting
fields

NO NEED FOR ELECTRIC CHARGES!
Changing Electric Field → Magnetic Field
Changing Magnetic Field → Electric Field
And so on… **LIGHT**

Electromagnetic waves!

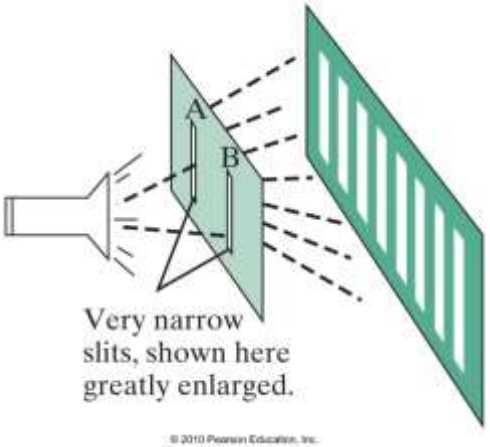
Light is Electromagnetic Wave

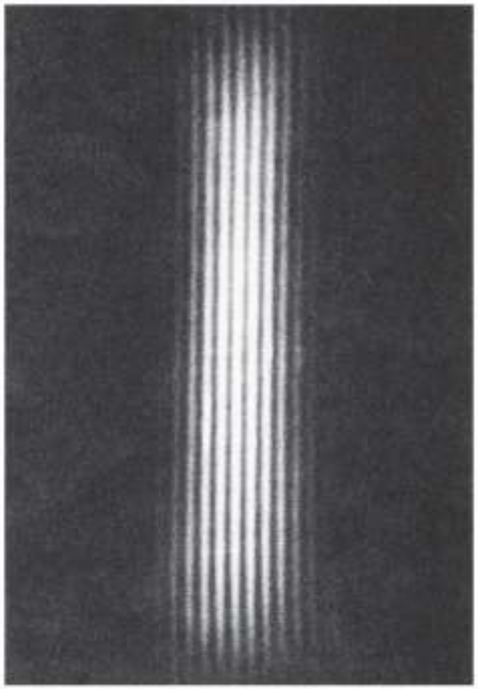


Double-Slit Experiment

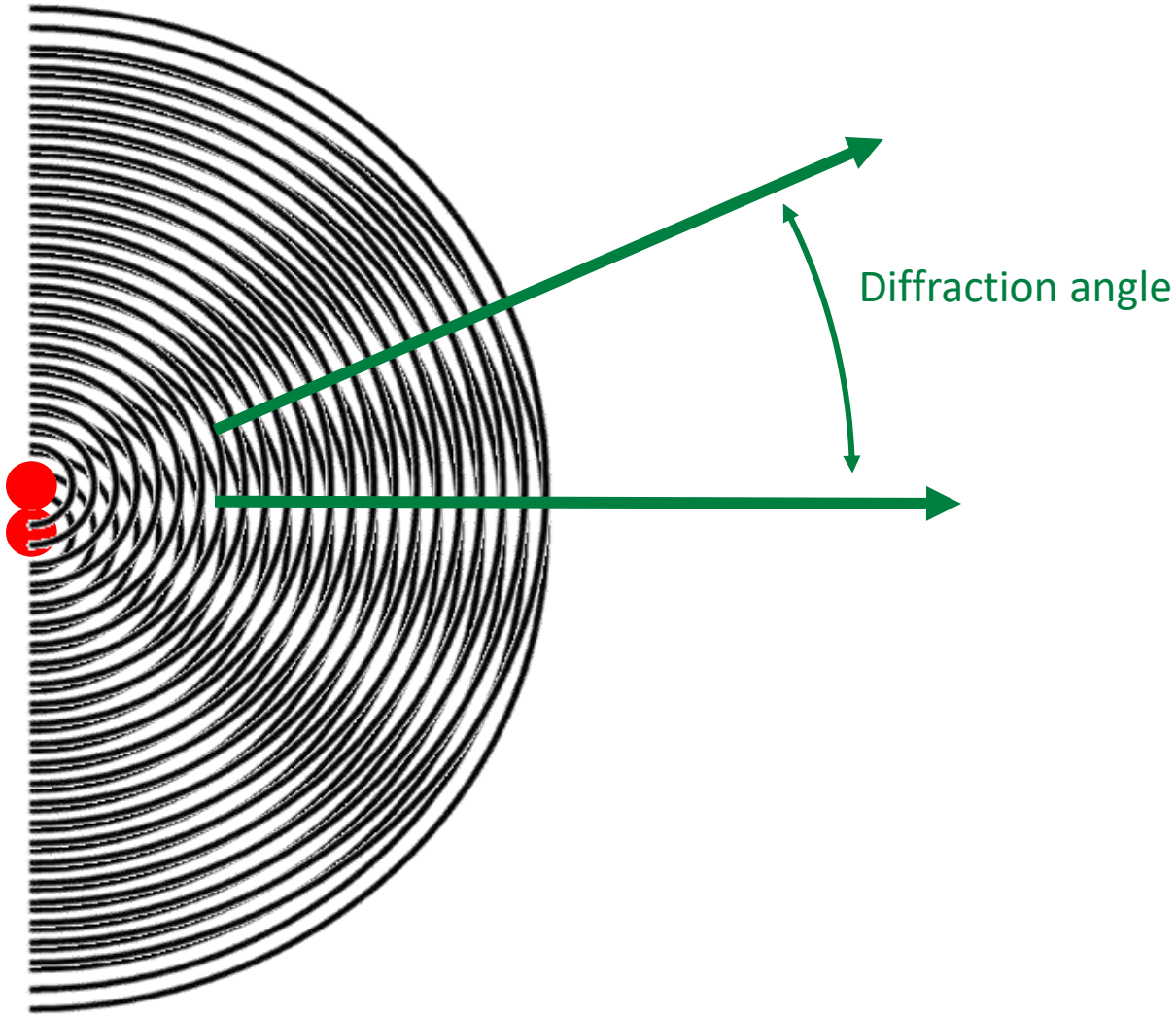
- We can observe double-slit interference effects for light by constructing very narrow slits and using relatively large distances between the slits and the observation screen.
  - First observed by Thomas Young in 1801

- **This experiment demonstrates the wave properties of light!**

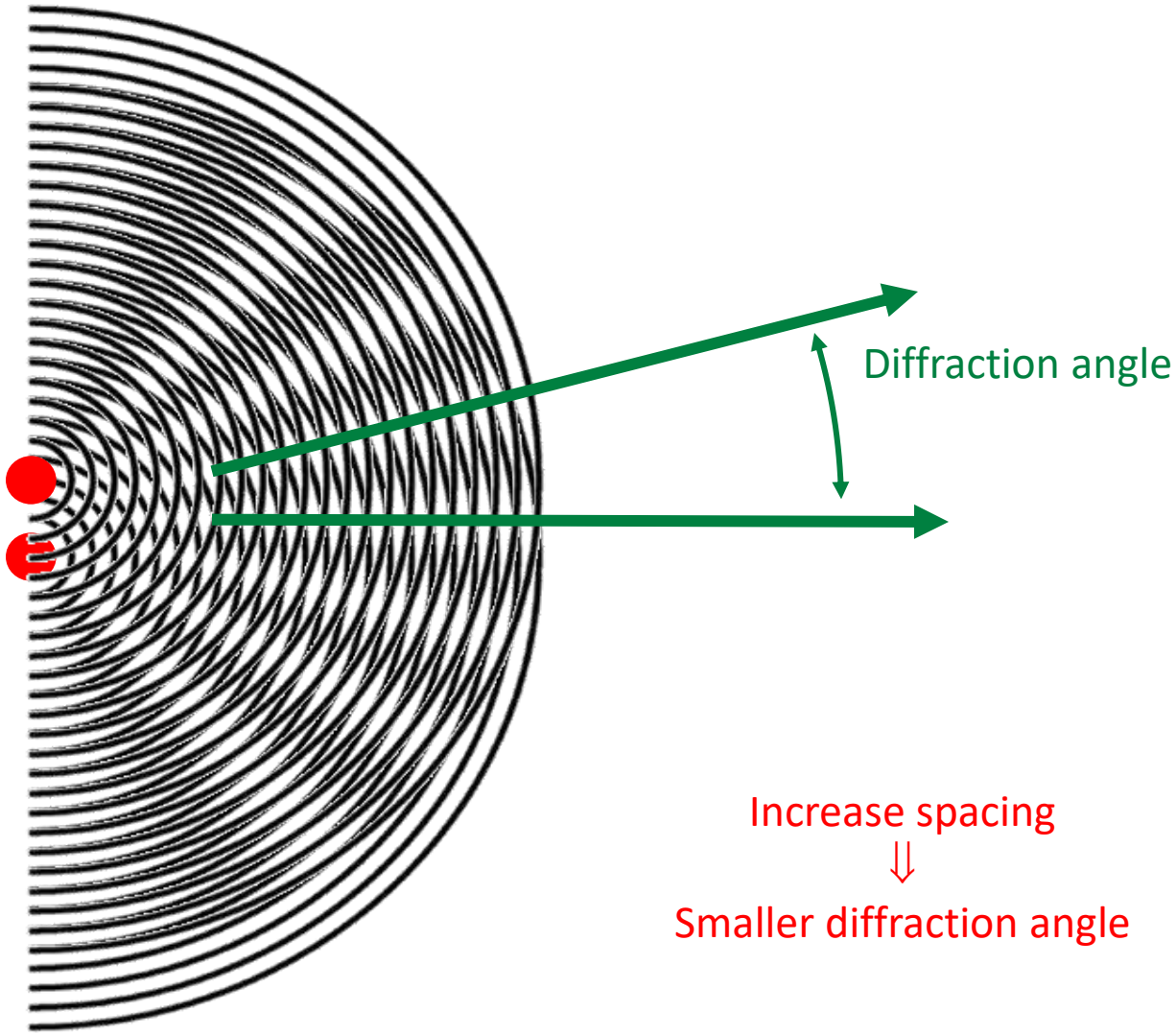




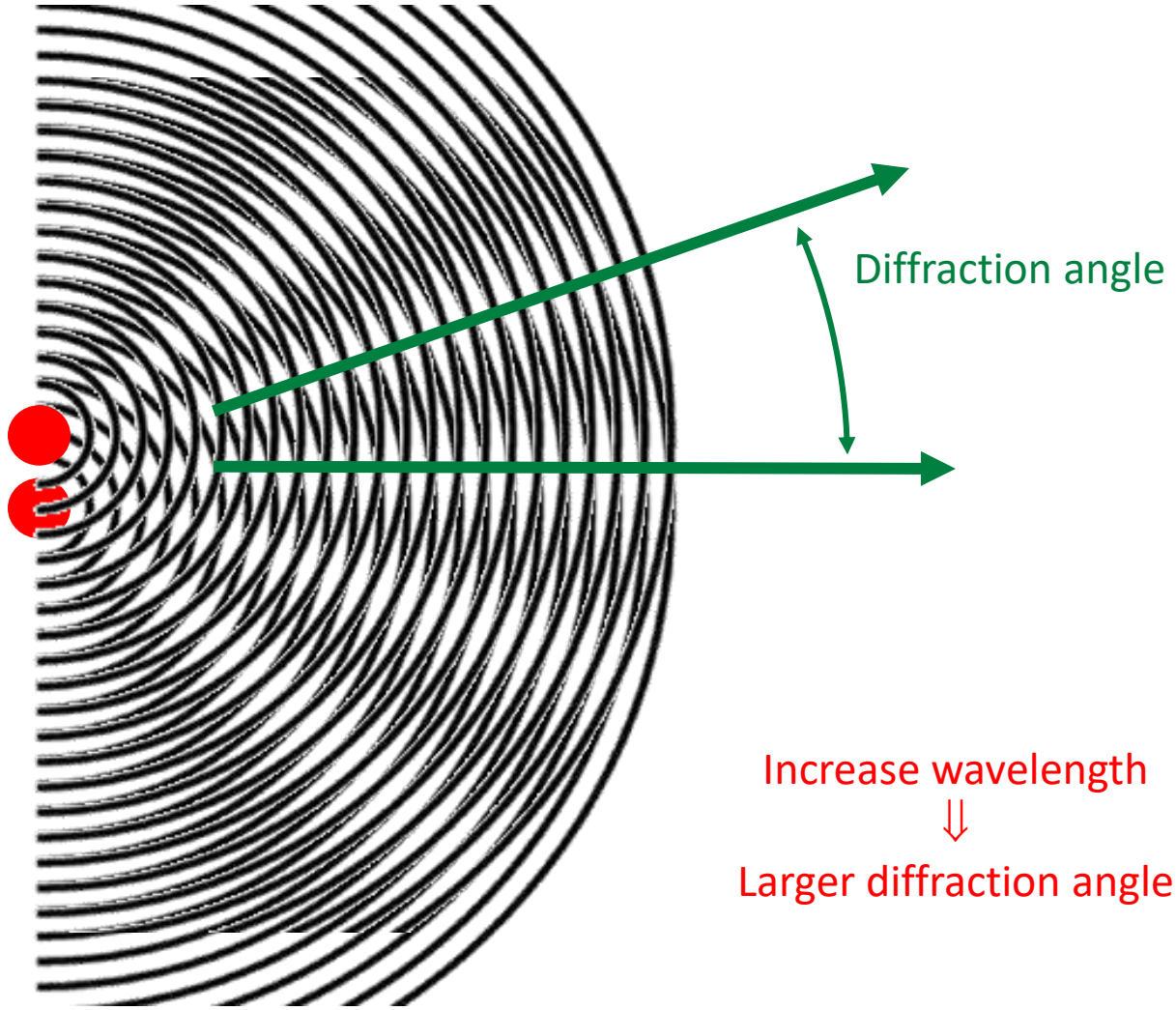
Interference: Diffraction Pattern



Interference: Diffraction Pattern



Interference: Diffraction Pattern



Diffraction

$$\text{Diffraction angle} \propto \frac{\text{Wavelength}}{\text{Spacing}}$$

Demo: Diffraction with Light

Diffraction angle

$$\text{Diffraction angle} \propto \frac{\text{Wavelength}}{\text{Spacing}}$$

Wavelength
- Red laser: 650 nm
- Green laser: 532 nm
- Blue-violet laser: 405 nm

Spacing
- CD: 1600 nm
- DVD: 740 nm
- Blu-Ray: 320 nm

CD

DVD

Blu-ray

Clicker

In the context of the physics of waves, “interference” occurs when

A) One wave dominates another one

B) One radio station intrudes on another one at a nearby frequency

C) The crests of two or more waves either add to make a stronger signal, or cancel to make a weaker one

D) One wave blocks so that another wave can complete a forward pass

E) One wave tells another wave how to run its life

Clicker

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Frequency and wavelength

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

Speed of sound = 1100 ft/s = 340 m/s (in air)

Speed of light = 3×10^8 m/s (in vacuum)

Speed of waves on a string (guitar, piano) depends on material and tension

Clicker Question

In a two-slit interference experiment, I replace a red laser with a green laser. As a result, the angle of the first interference minimum

A. increases.
B. stays the same.
C. decreases.
D. that depends....

Clicker Question

In a two-slit interference experiment, I replace a red laser with a green laser. As a result, the angle of the first interference minimum

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D. that depends....

$$\text{Diffraction angle} \propto \frac{\text{Wavelength}}{\text{Spacing}}$$

Clicker Question

In a two-slit interference experiment, I move the two slits closer together. As a result, the angle of the first interference minimum

A. increases.
B. decreases.
C. stays the same.
D. insufficient information.

Clicker Question

In a two-slit interference experiment, I move the two slits closer together. As a result, the angle of the first interference minimum

A. increases.
B. decreases.
C. stays the same.
D. insufficient information.

$$\text{Diffraction angle} \propto \frac{\text{Wavelength}}{\text{Spacing}}$$

Clicker Question

In a two-slit interference experiment, I somehow increase the wave propagation velocity, but adjust the frequency such that the wavelength stays the same. As a result, the angle of the first interference minimum

A. increases.
B. stays the same.
C. decreases

Clicker Question

In a two-slit interference experiment, I somehow increase the wave propagation velocity, but adjust the frequency such that the wavelength stays the same. As a result, the angle of the first interference minimum

A. increases.
B. stays the same.
C. decreases

$$\text{Diffraction angle} \propto \frac{\text{Wavelength}}{\text{Spacing}}$$

Clicker Question

In a two-slit interference experiment, I insert the double slit into water, where the light propagation velocity is slower than in air. As a result, the angle of the first interference minimum (compared to in air)

A. increases.
B. stays the same.
C. decreases.

Clicker Question

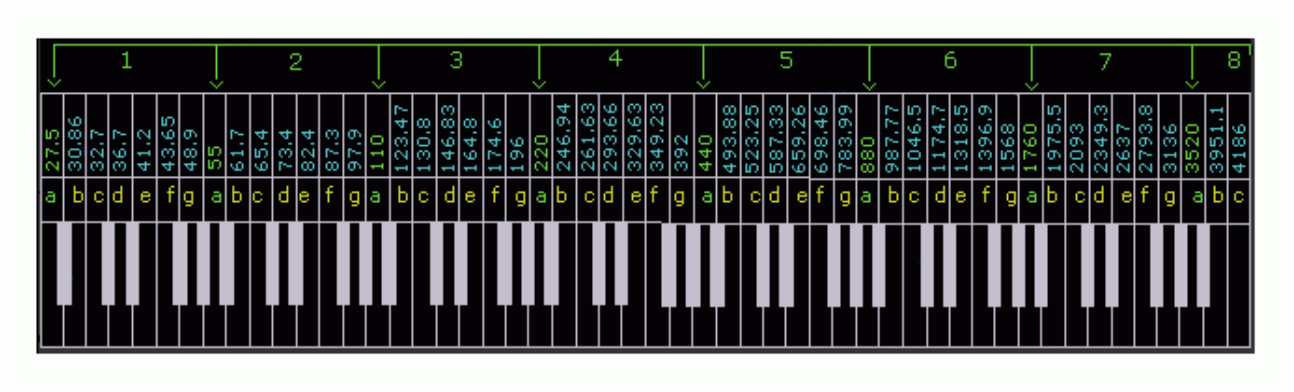
In a two-slit interference experiment, I insert the double slit into water, where the light propagation velocity is slower than in air. As a result, the angle of the first interference minimum (compared to in air)

A. increases.
B. stays the same.
C. decreases.

$$\text{Wavelength} \propto \frac{\text{Propagation velocity}}{\text{Frequency}}$$

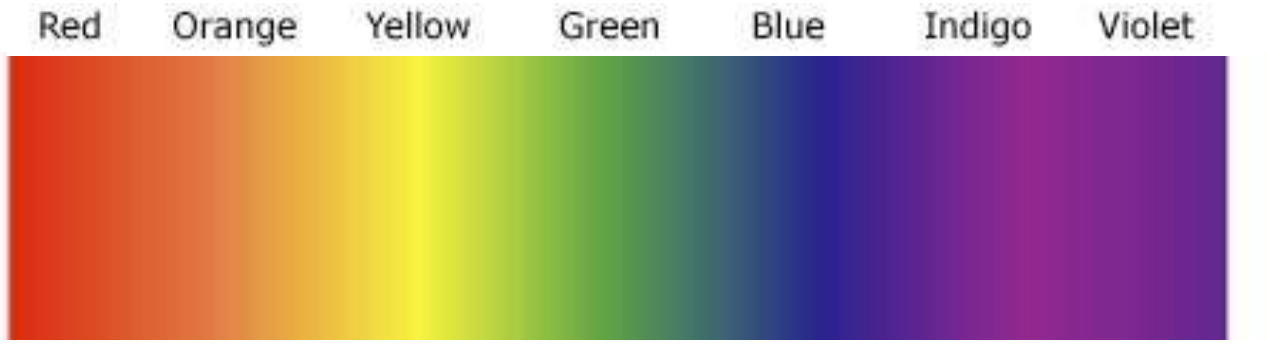
$$\text{Diffraction angle} \propto \frac{\text{Wavelength}}{\text{Spacing}}$$

Sound and light



Infrasound

Ultrasound

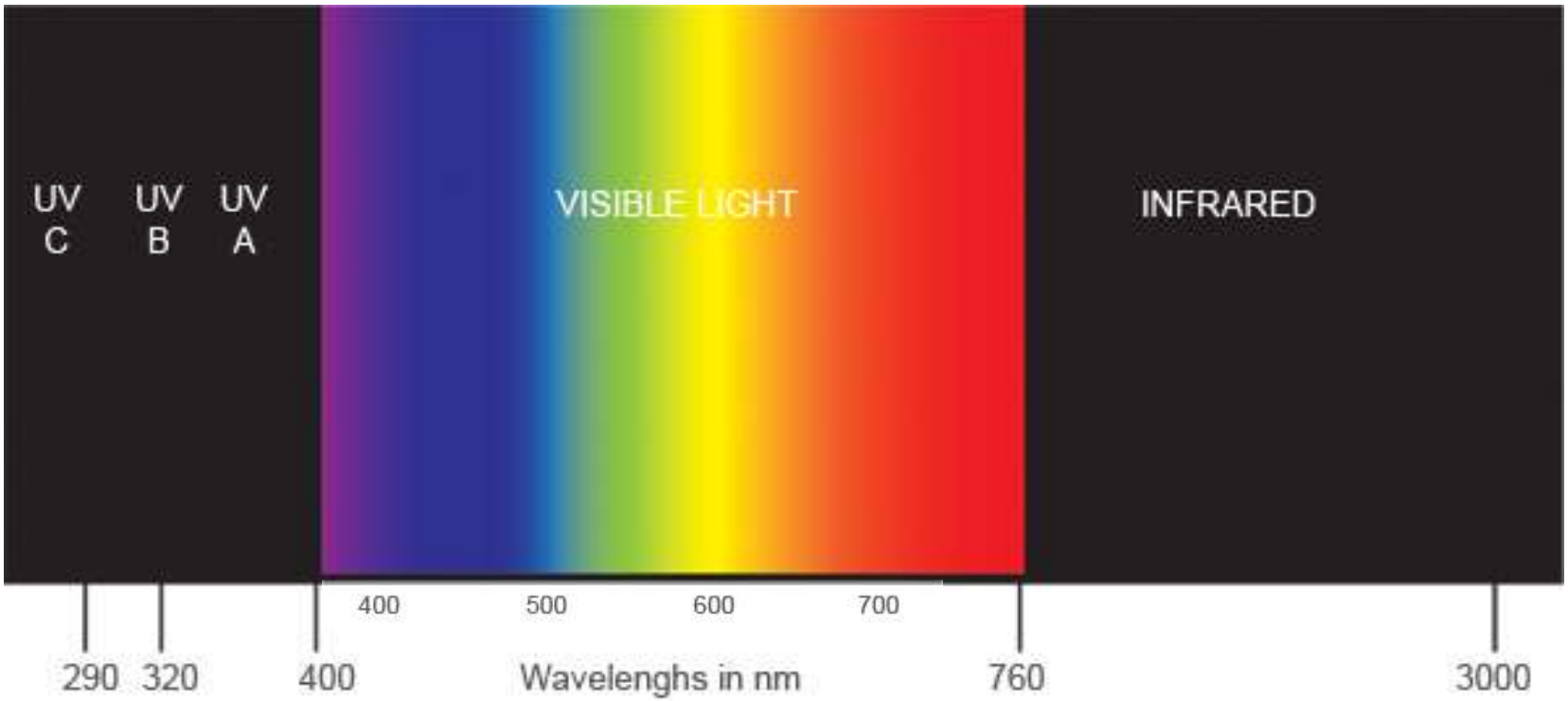


Infrared

Ultraviolet

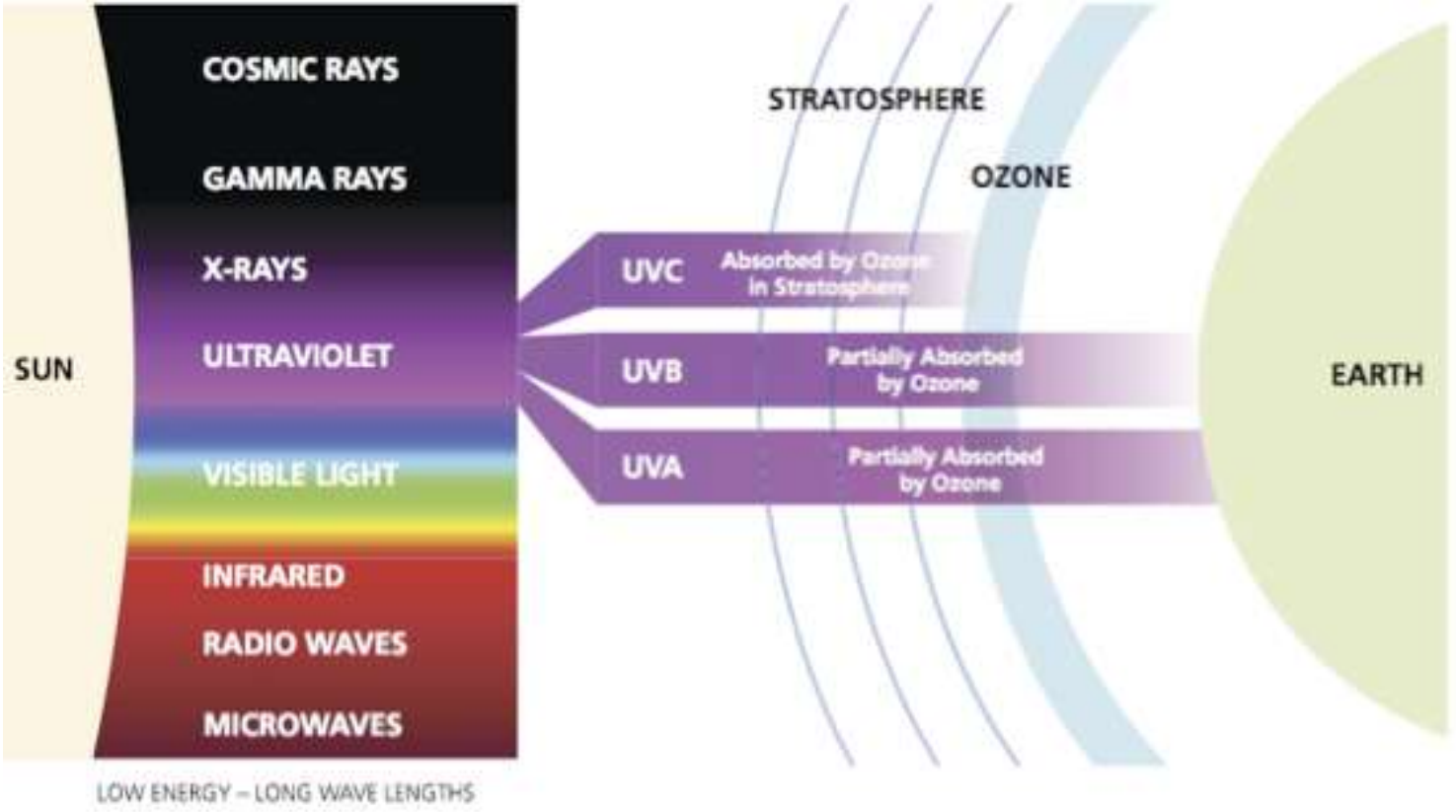
Near-visible light

Increasing frequency



Increasing wavelength

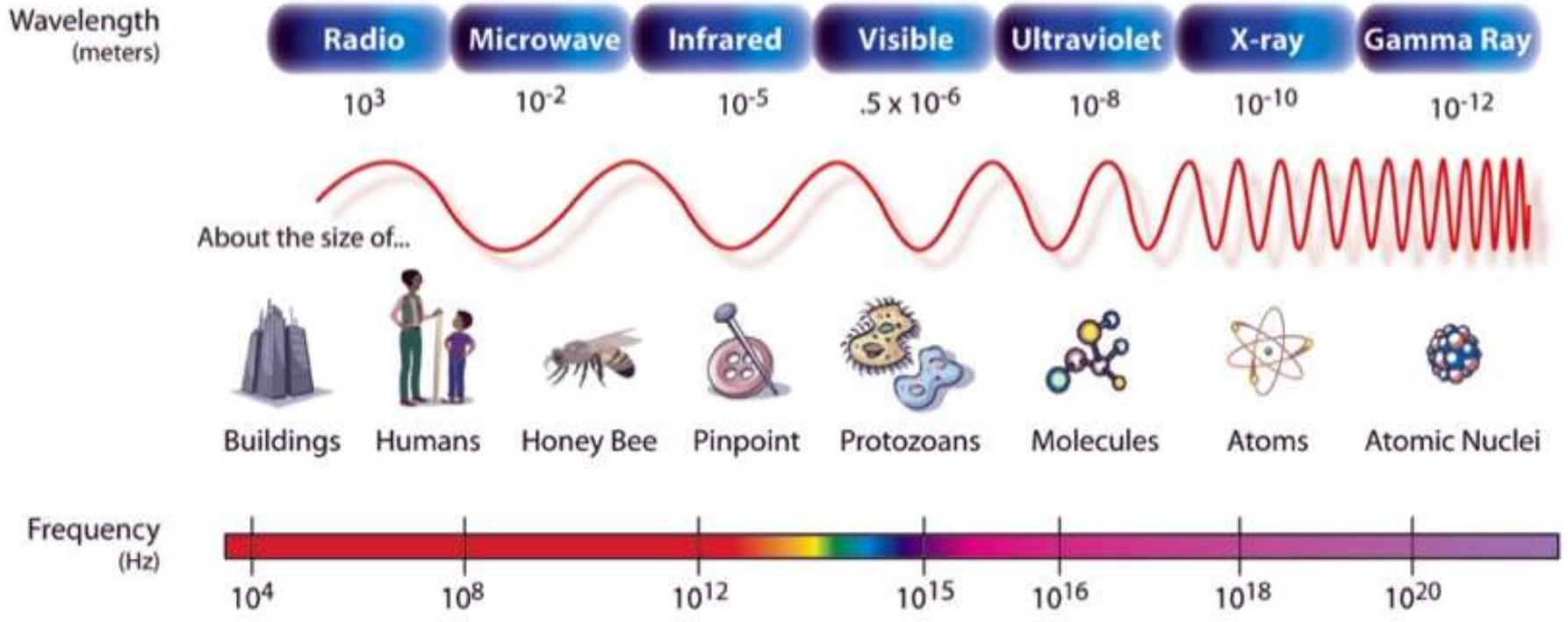
Ultraviolet

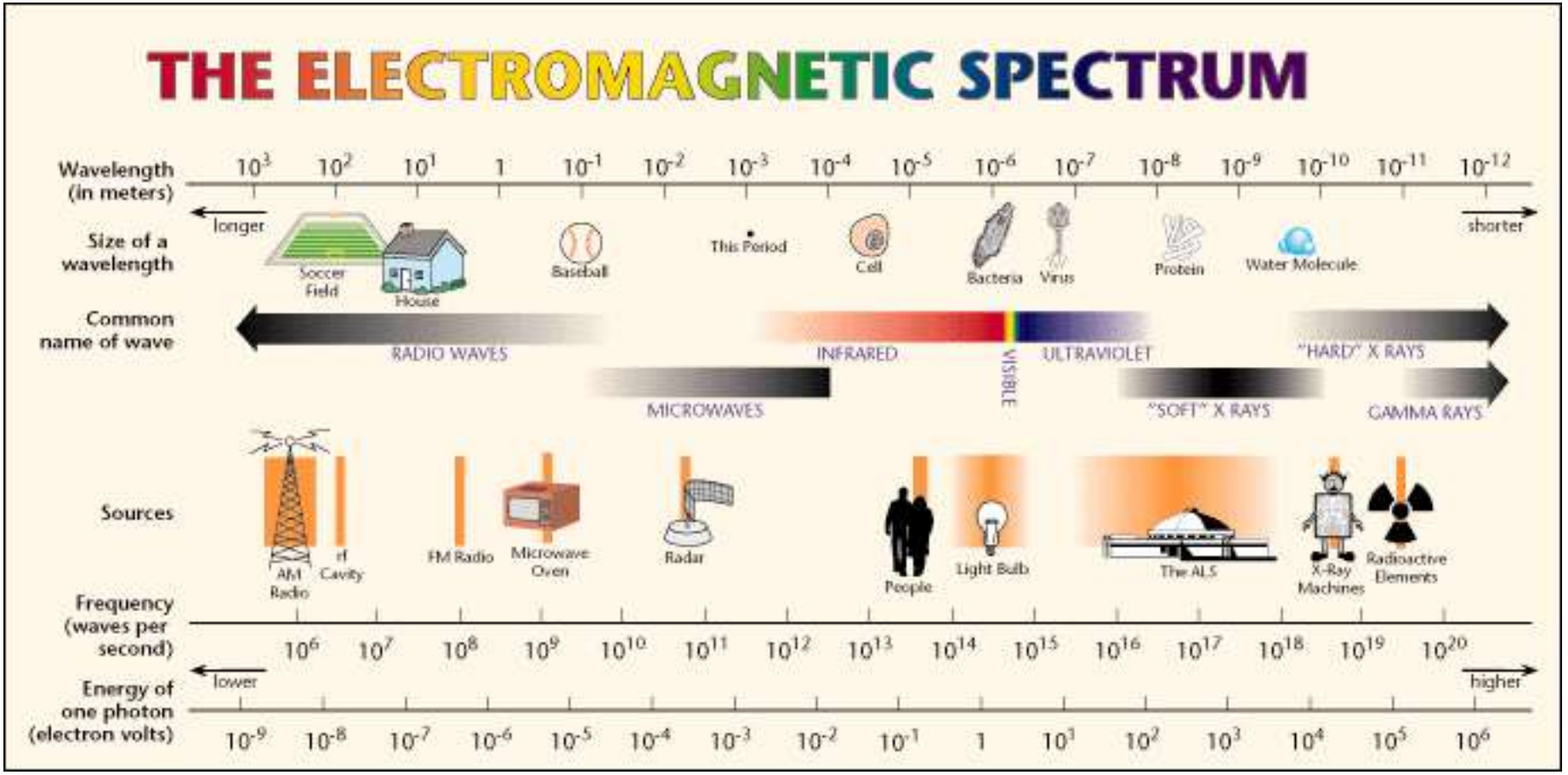


Invisible ultraviolet light is described as three wavelengths. UVC is absorbed by the ozone layer of Earth's atmosphere. UVB is partially absorbed by the ozone layer. UVA penetrates the atmosphere and reaches the earth.

Ultraviolet

Electromagnetic waves





Low energy
Small frequencies
Large Wavelengths

High energy
High frequencies
Small Wavelengths

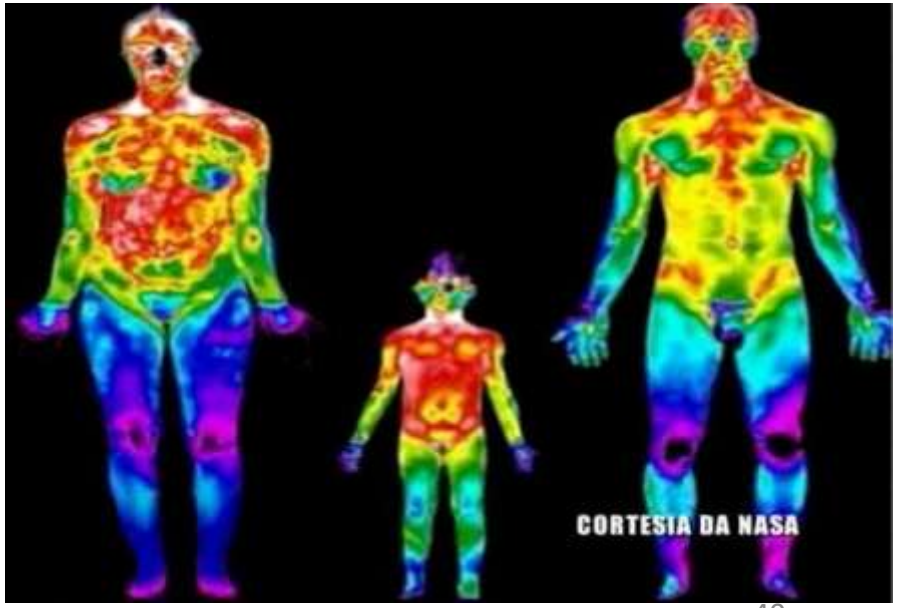
X-rays

Gamma rays

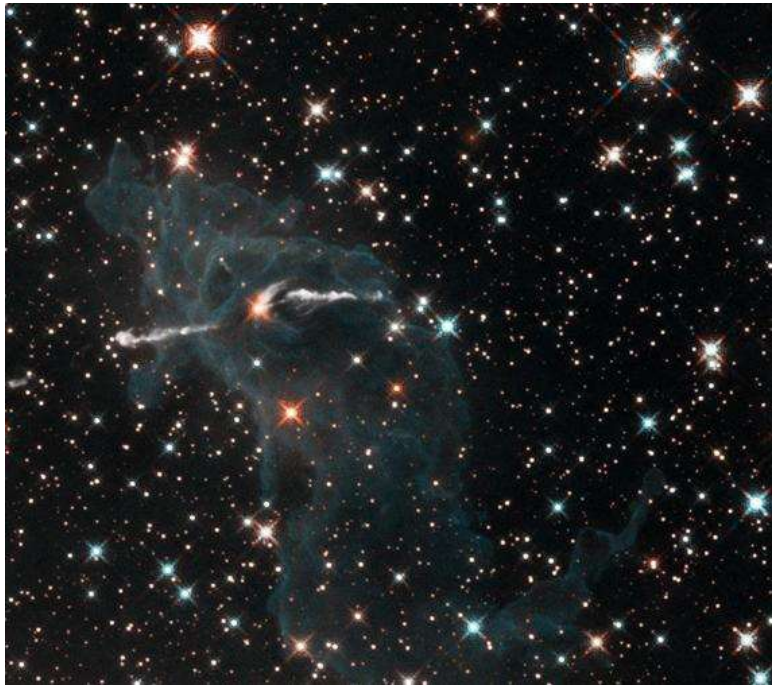
One of three kinds of nuclear radiation…

Infrared cameras

Night vision goggles



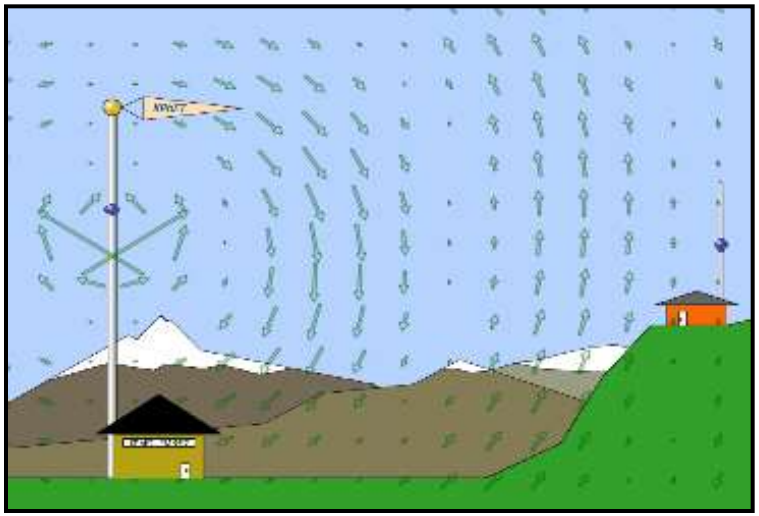
Infrared light

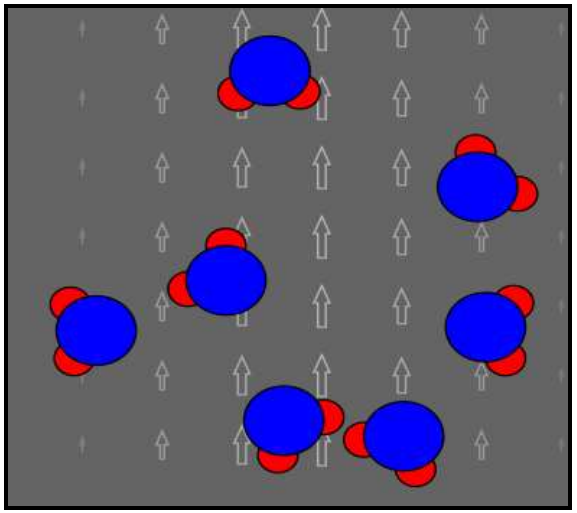


Alternating Hubble Space Telescope images:

- Visible
- Infrared

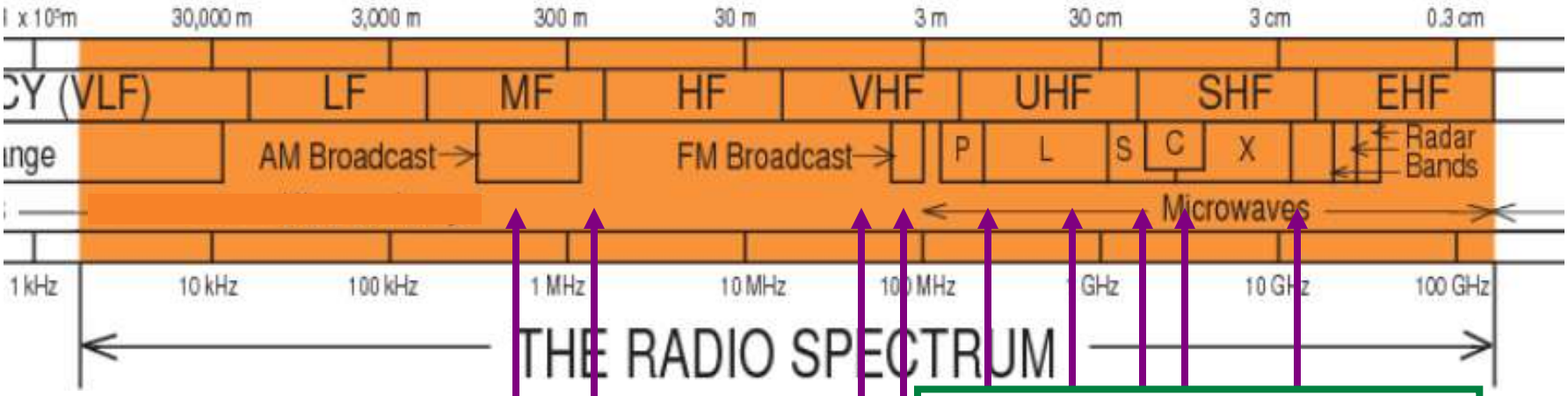
Radio waves and microwaves





https://phet.colorado.edu/en/simulation/legacy/radio-waves
https://phet.colorado.edu/en/simulation/legacy/microwaves

Radio waves



MICROWAVES

AM Radio

Cordless phones

Broadcast TV, Ch 2-6

FM Radio

Broadcast TV, Ch 7-13

Satellite TV

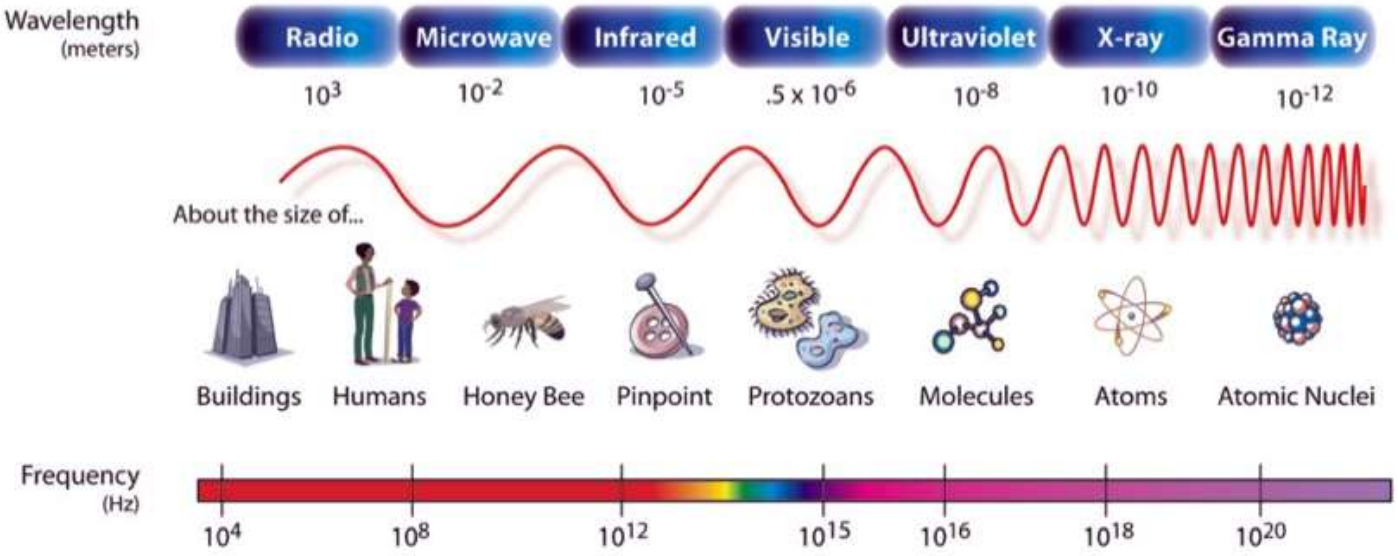
5G Cell Phones

Laptop WiFi

GPS

4G Cell Phones

All are electromagnetic waves!



Characteristics:

- Speed of waves = 3.00×10^{8} m/s
- Can travel through vacuum

Clicker

Which list is correctly ordered from lowest frequency to highest?

A) Ultraviolet, infrared, visible, X-ray, gamma ray

B) Gamma ray, X-ray, ultraviolet, visible, infrared

C) Visible, X-ray, gamma ray, ultraviolet, infrared

D) Infrared, visible, ultraviolet, X-ray, gamma ray

E) Visible, invisible, incomprehensible

Clicker

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Clicker

Which list is correctly ordered from shortest wavelength to longest?

A) Ultraviolet, infrared, visible, X-ray, gamma ray

B) Gamma ray, X-ray, ultraviolet, visible, infrared

C) Visible, X-ray, gamma ray, ultraviolet, infrared

D) Infrared, visible, ultraviolet, X-ray, gamma ray

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Clicker

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