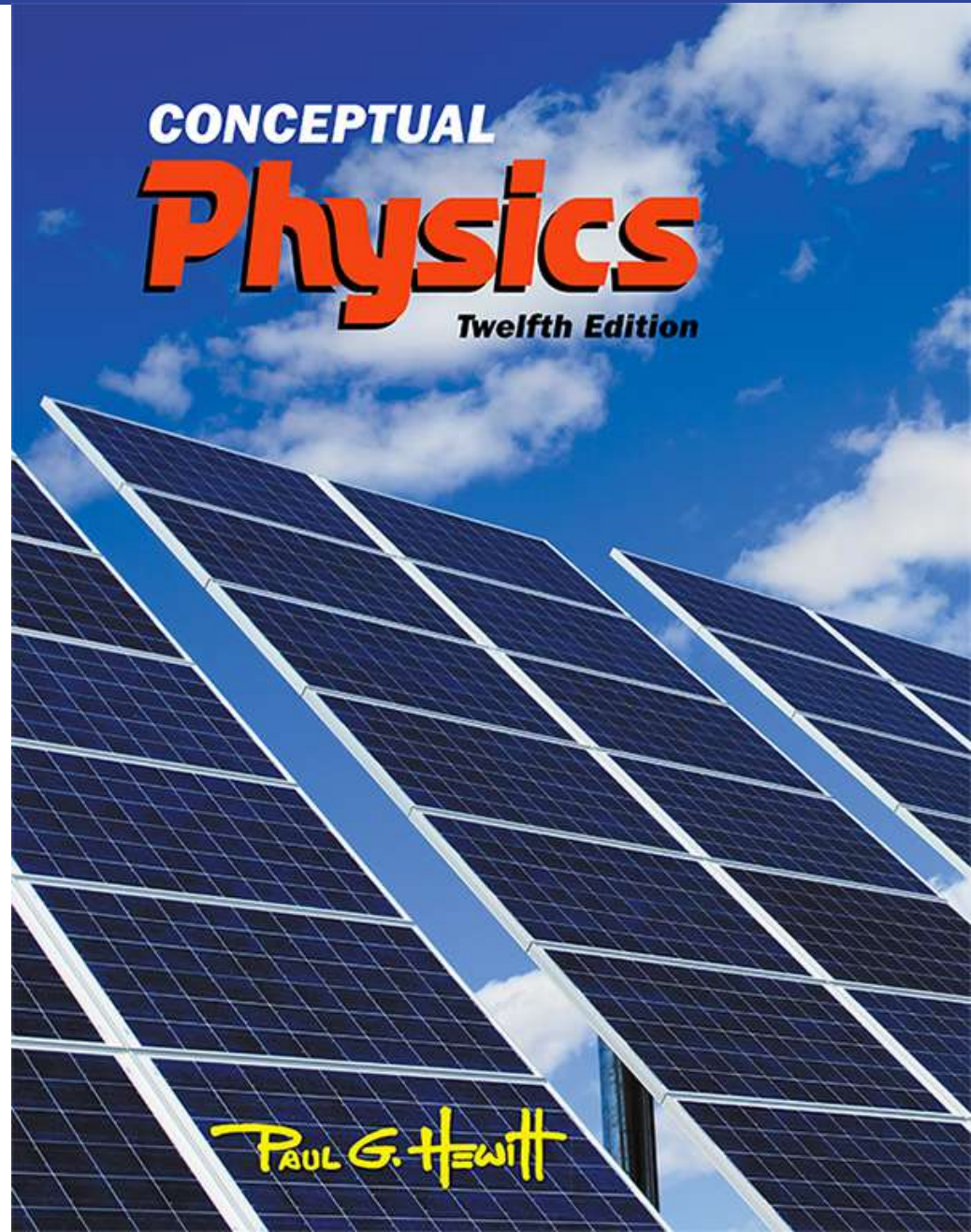


Lecture Outline

Chapter 26: Properties of Light

Part 1



Electromagnetic (E&M) Waves

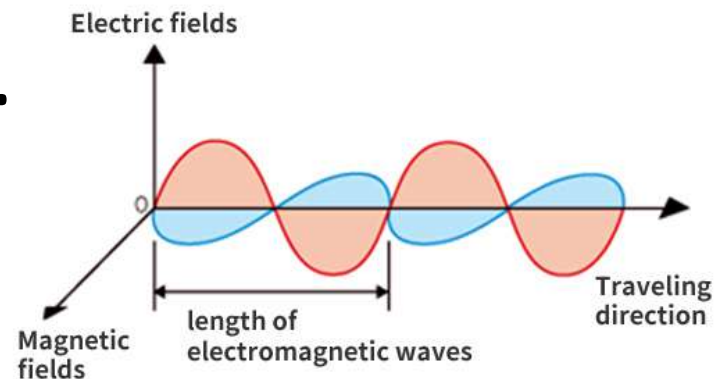
- Light is the only thing we can see.
 - It originates from the accelerated or vibrating motion of electrons
 - The frequency of vibration equals the frequency of the E&M wave:

Vibrating charges



produce.....

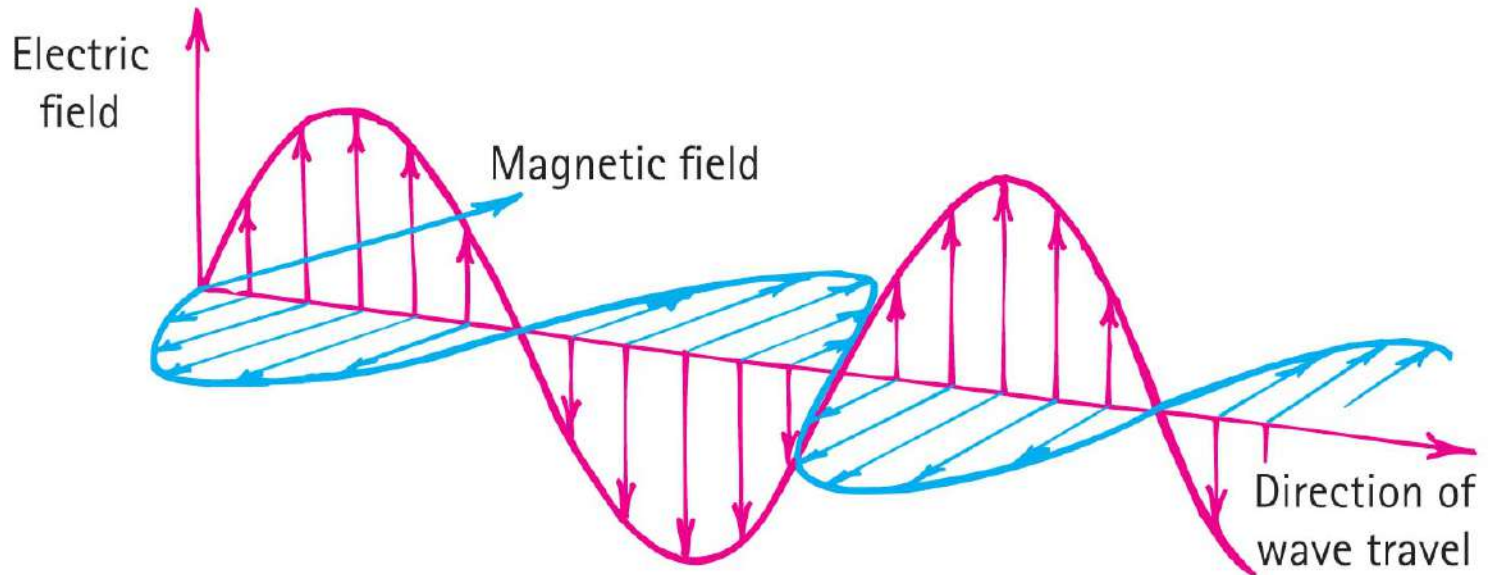
...E&M waves with same frequency



Classwork:

10. How does the frequency of a radio wave compare to the frequency of the vibrating electrons that produce it?

- Electromagnetic (E&M) wave
 - Made up of vibrating electric and magnetic fields



- Changing magnetic field induces an electric field.
- Changing electric field induces an magnetic field.
- E&M waves contain and transport **energy**.

Classwork: Turn in at end of period.

1. What does a changing magnetic field induce?

2. What does a changing electric field induce?

3. What produces an electromagnetic wave?

6. What do electric and magnetic fields contain and transport?

Electromagnetic Waves

CHECK YOUR NEIGHBOR

If an electron vibrates up and down 1000 times each second, it generates an electromagnetic wave with a

- A. period of 1000 s.
- B. speed of 1000 m/s.
- C. wavelength of 1000 m.
- D. None of the above.

Electromagnetic Waves

CHECK YOUR ANSWER

If an electron vibrates up and down 1000 times each second, it generates an electromagnetic wave with a

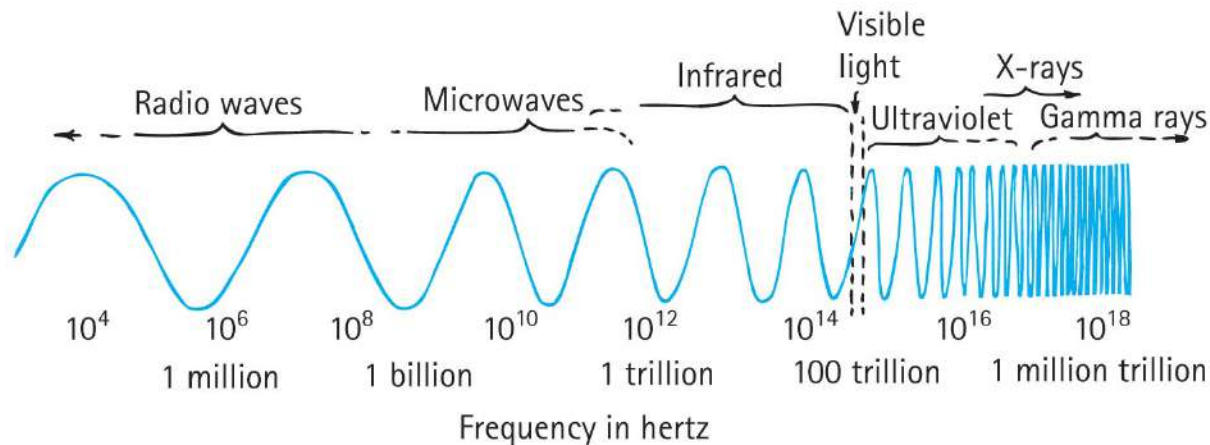
D. None of the above.

Explanation:

The vibrating electron would emit a wave with a *frequency* of 1000 Hz, which is not in the list above.

Electromagnetic (light) spectrum

- Waves ranked by frequency f (or wavelength λ):
- No sharp boundaries between each type

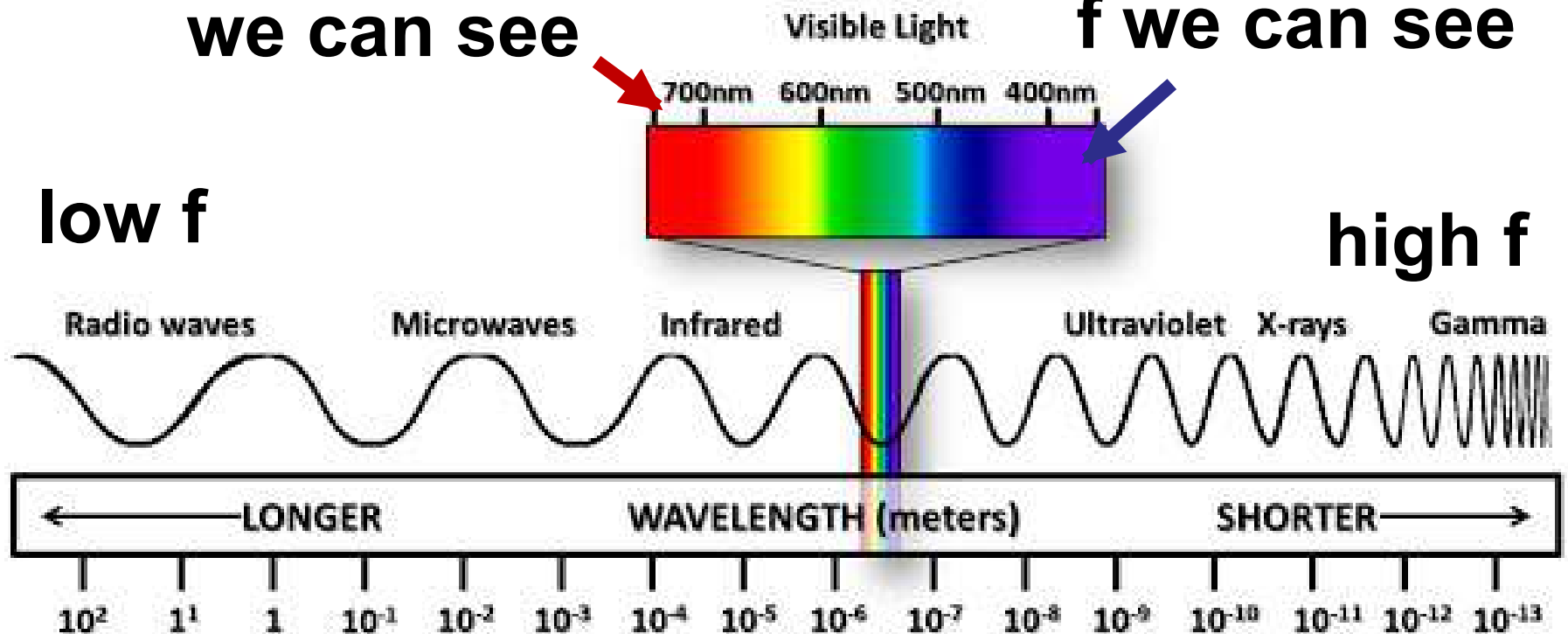


- Lowest frequency = radio, then microwaves
- Highest frequency = x-rays and gamma rays
- Visible light = in the “middle”
- infrared (IR): lower f than visible
- ultraviolet (UV): higher f than visible

visible light is only 1% of a
millionth of the spectrum

red = lowest f
we can see

violet = highest
 f we can see



long λ

short λ

Classwork:

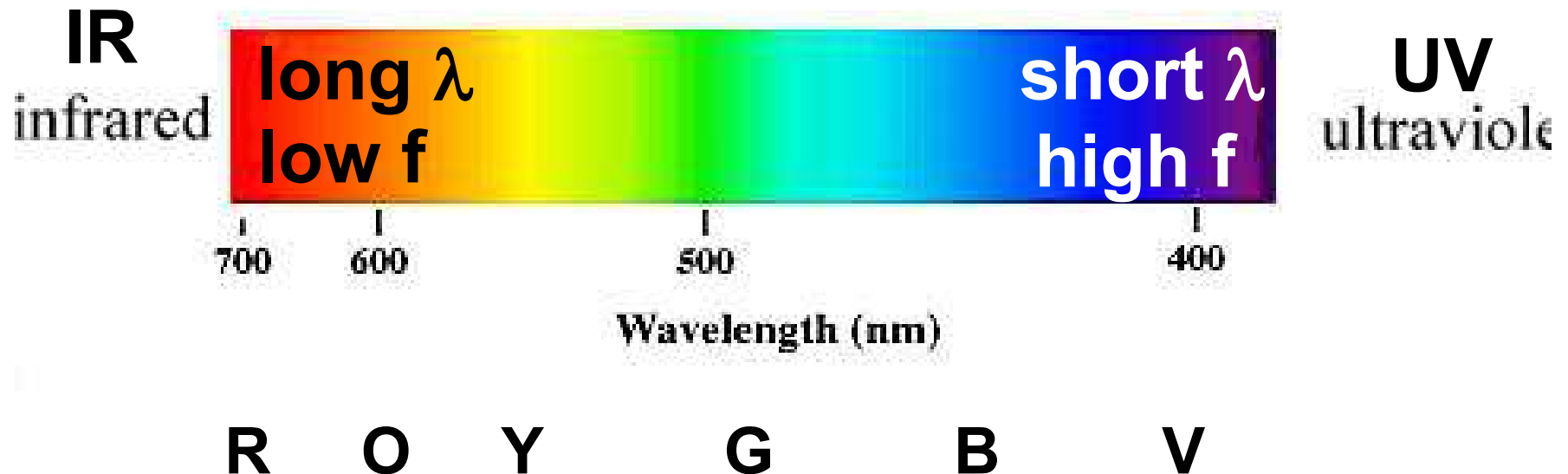
7. What is the principal difference between a radio wave and light? Between light and an X-ray?

8. About how much of the measured electromagnetic spectrum does light occupy?

The visible light spectrum: ROY G. B(I)V

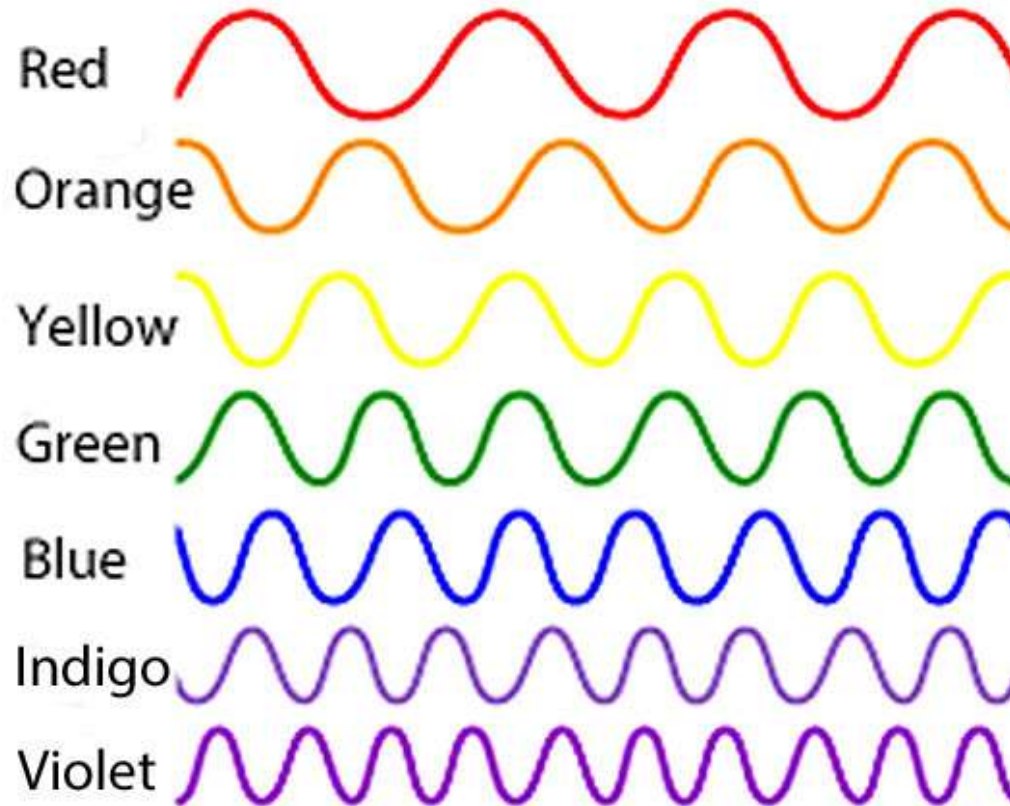
From long to short wavelength λ , or
From low to high frequency f .

The visible spectrum



Arranged vertically:

IR (invisible)



**low f
long λ**

**high f
short λ**

UV (invisible)

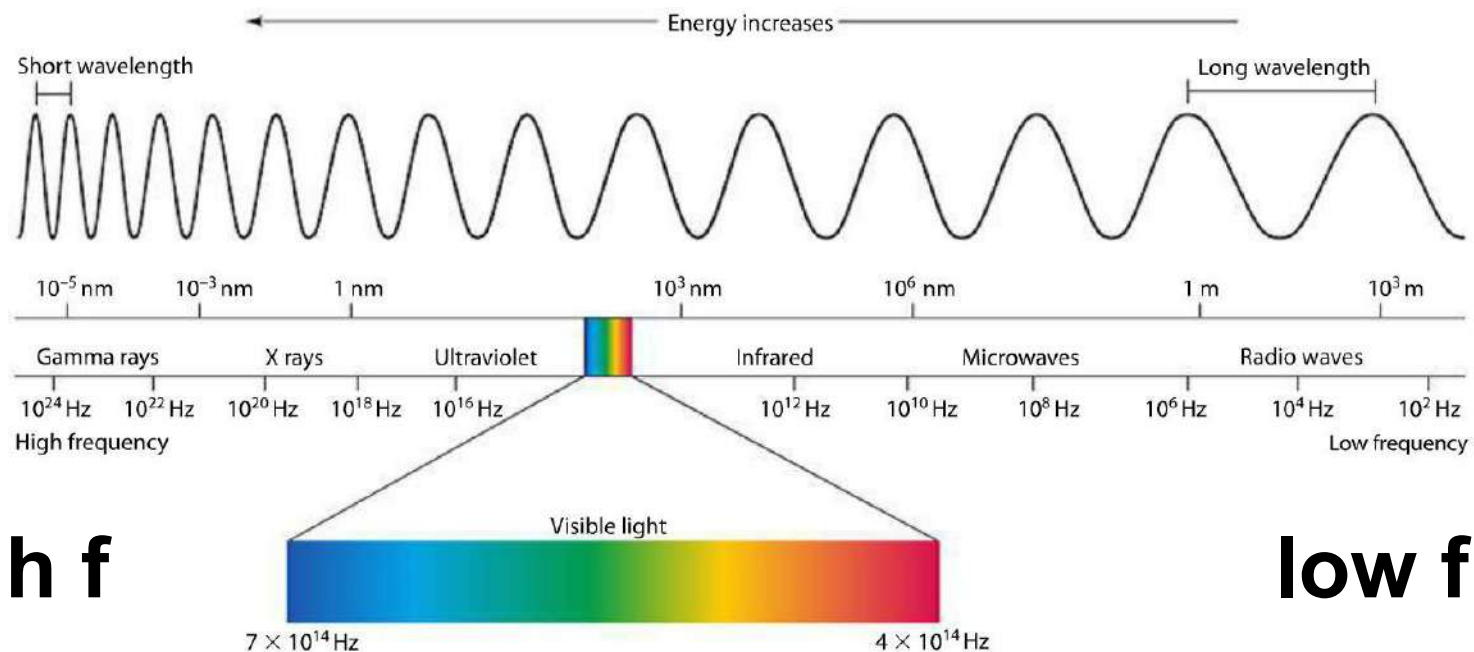
Classwork

9. What is the color of visible light of the lowest frequencies? Of the highest frequencies?

The spectrum is often shown “reversed”

short λ

long λ

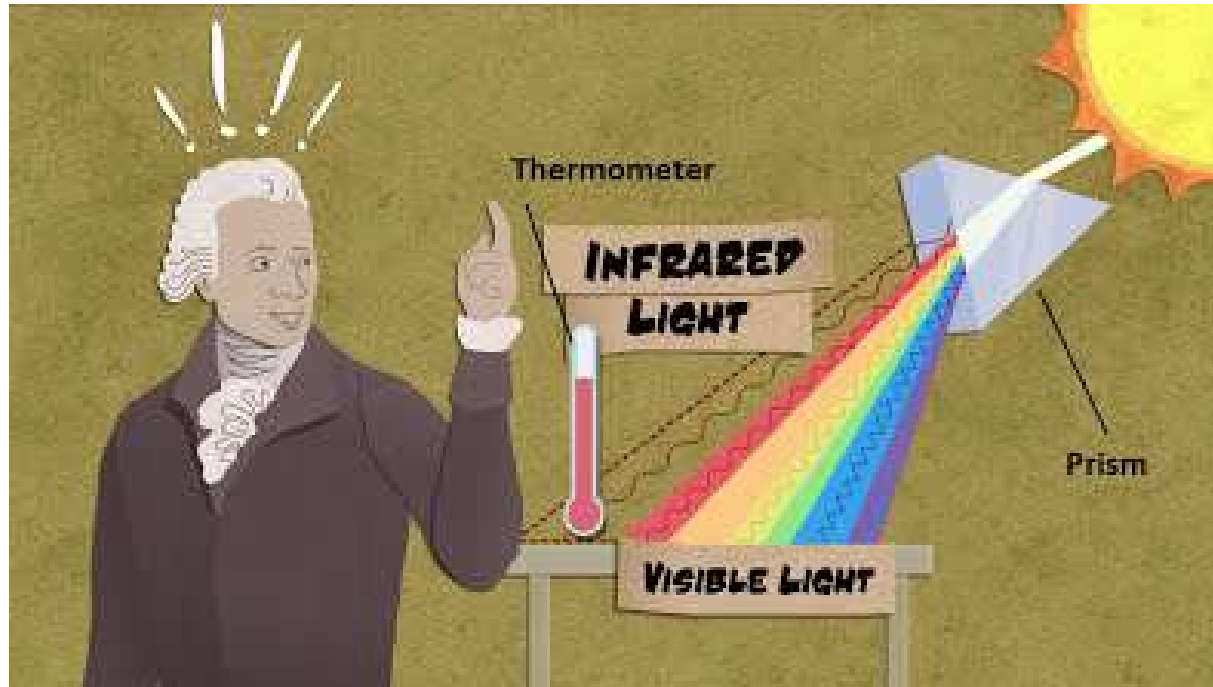


high f

low f

All of these types, including visible light, are also called *electromagnetic radiation*.

Discovery of infrared (IR) light:



William Herschel discovered IR light when he placed a thermometer to the side of red light produced by a prism.

More than half of energy from Sun is IR.

Night vision

Heat imaging

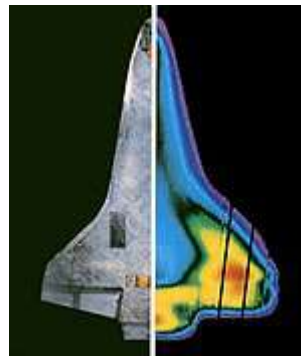
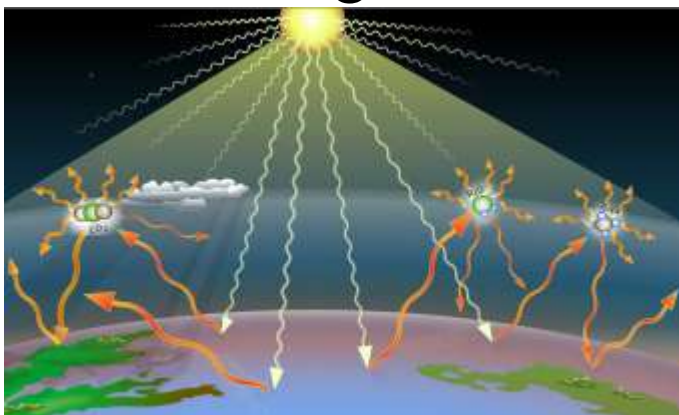
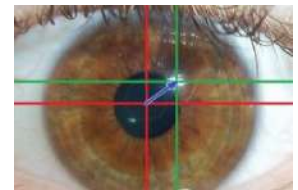
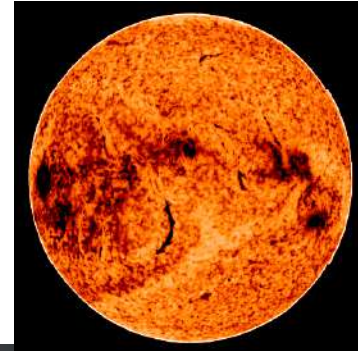
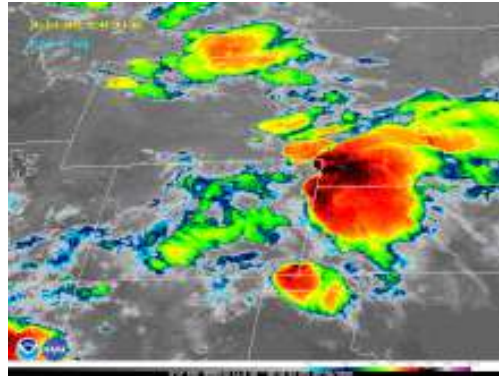
Tracking

Astronomy

Meteorology

Trapped by greenhouse gases

Leads to global warming.

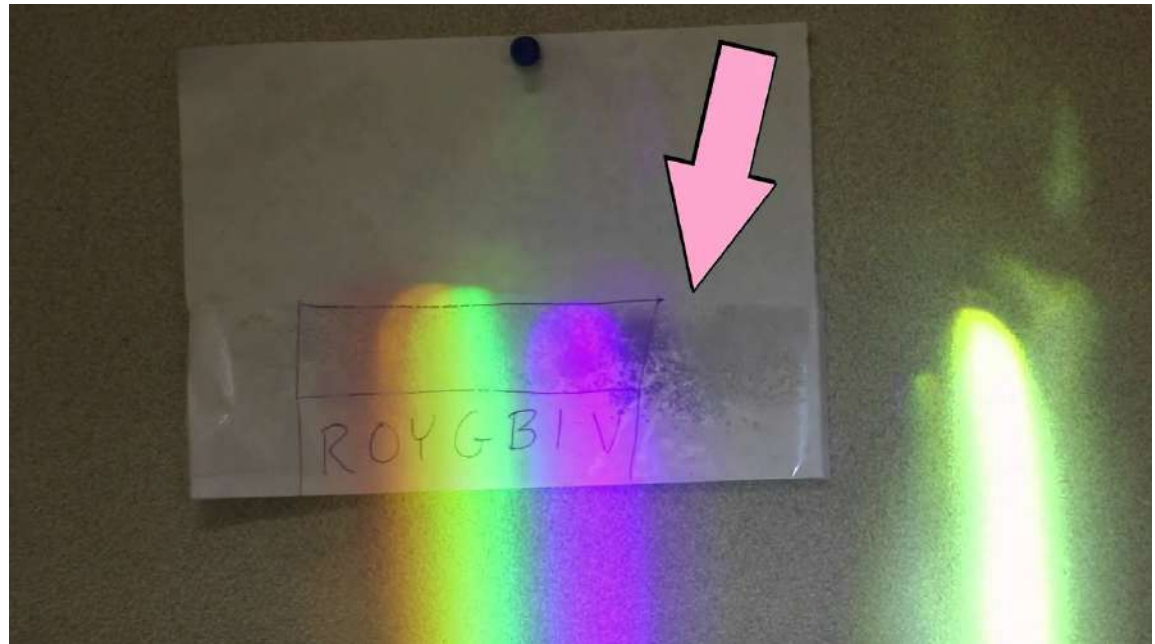


UV light

UV radiation was discovered in 1801 when the German physicist Johann Wilhelm Ritter observed that invisible rays just beyond the violet end of the visible spectrum darkened silver chloride-soaked paper more quickly than violet light itself.



Johann Wilhelm Ritter
(1776-1810)



UV light

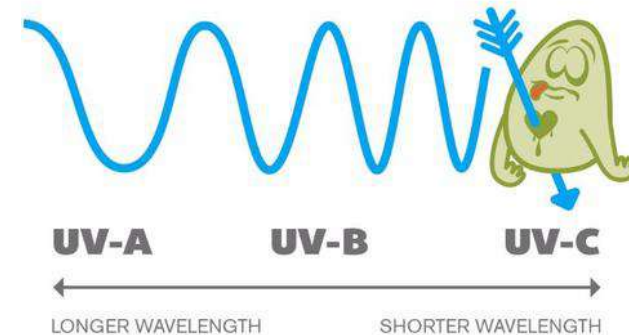
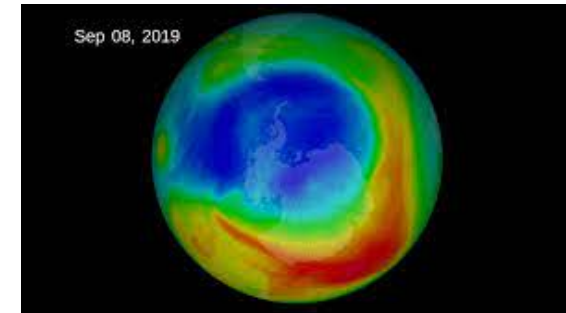
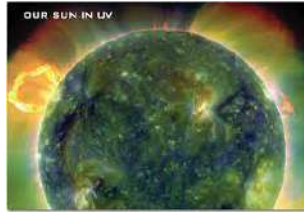
10% of Sun's energy

Most filtered out by atmosphere and the ozone layer

UVA: produced by black lights

UVB: responsible for vitamin D

UVC: Highest $f \rightarrow$ most dangerous



In general, UV:

Damages your DNA, your skin (burns) and your retina

Is blocked by sunscreen, glass, and some sunglasses

Is used in forensics, disinfection, etc.

Electromagnetic Spectrum

CHECK YOUR NEIGHBOR

The electromagnetic spectrum spans waves ranging from lowest to highest frequencies. The smallest portion of the electromagnetic spectrum is that of

- A. radio waves.
- B. microwaves.
- C. visible light.
- D. gamma rays.

Electromagnetic Spectrum

CHECK YOUR ANSWER

The electromagnetic spectrum spans waves ranging from lowest to highest frequencies. The smallest portion of the electromagnetic spectrum is that of

C. visible light.

Electromagnetic Spectrum

CHECK YOUR NEIGHBOR, Continued

Which of these is fundamentally different from the others?

- A. Sound waves
- B. Light waves
- C. Radio waves
- D. X-rays

Electromagnetic Spectrum

CHECK YOUR ANSWER, Continued

Which of these is fundamentally different from the others?

A. Sound waves

Explanation:

All are electromagnetic waves except sound, which is a mechanical wave.

The speed of light (E&M) radiation

In a vacuum:

All types of E&M radiation travel at the same speed

$$v = 300,000,000 \text{ meters per second}$$

$$= 3.0 \times 10^8 \text{ m/s}$$

$$= 300,000 \text{ kilometers per second}$$

This speed has a special symbol: c

c = the speed of light in a vacuum

→ It is the speed limit. (Do you “c” the light?)

→ Nothing except light can travel this fast

→ Can travel 7x around Earth in 1 second!

Light is a transverse E&M wave

The equation for wave speed:

$$\text{wave speed} = \text{wavelength} \times \text{frequency}$$

For light, this becomes:

$$c = \lambda \times f$$

Because c is constant:

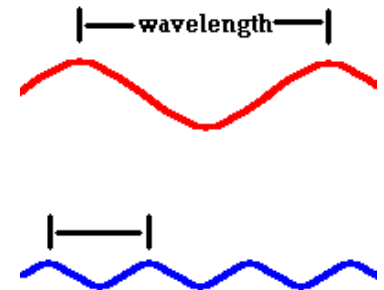
Increasing frequency f means decreasing λ

Decreasing frequency f means increasing λ

Blue light has a higher f and a lower λ :

Red light has a lower f and a longer λ :

→ λ and f are *inversely* related.



Classwork

11. How is the wavelength of light related to its frequency?

Thought Question

Q: Rank the E&M waves from slowest to fastest:

- A) radio
- B) microwaves
- C) visible light
- D) gamma rays

Answer: No ranking. All travel at the speed c .

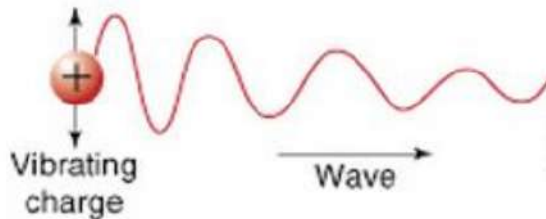
Transparent Materials

- Light is transmitted similarly to sound.
 - Both are vibrations due to a vibrating source.

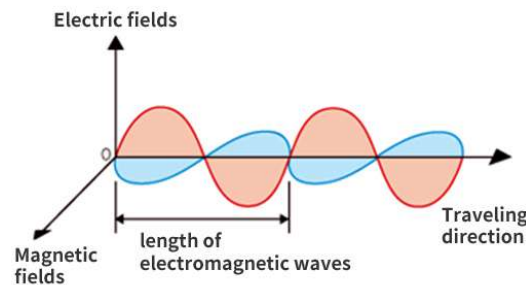
sound:



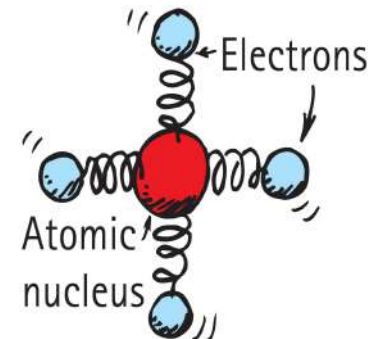
light:



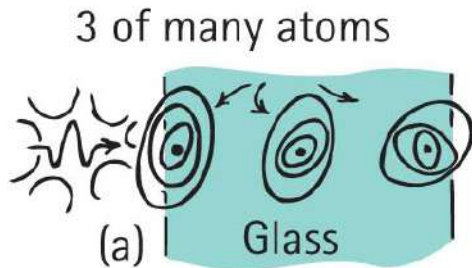
E&M wave



glass atom

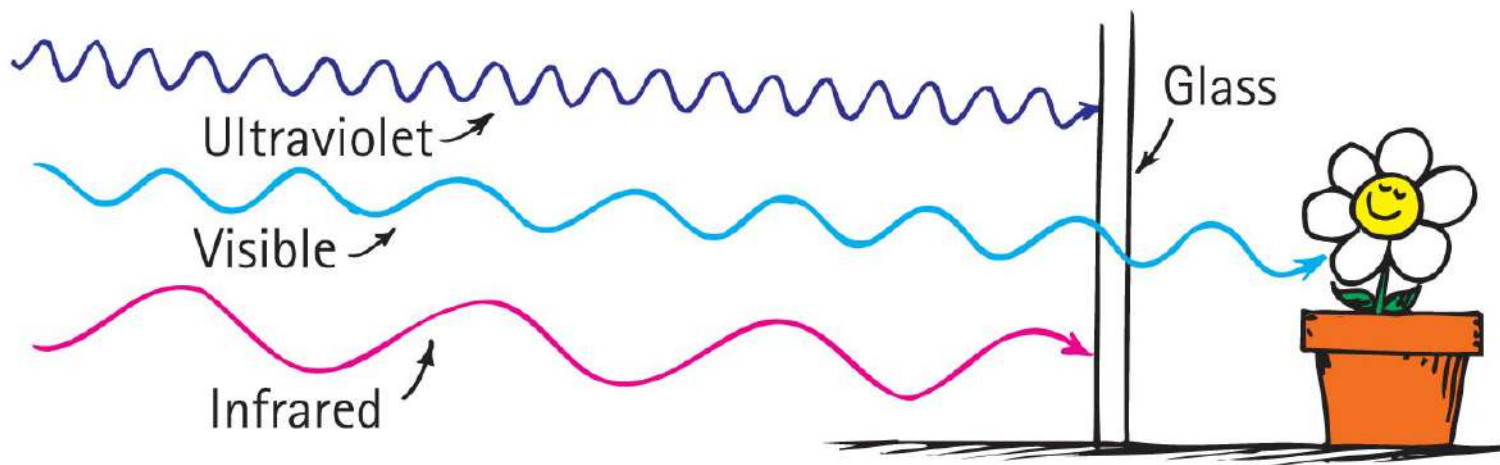


- When visible light enters transparent material such as glass, it passes from one glass atom to the next.



- Light wave energy is momentarily absorbed and vibrates the electrons in the glass. The **wave** is emitted to next atom
- Time delay between absorption and re-emission of energy of vibrating electrons lowers speed of light through glass.
- Once it leaves the glass, light again travels at speed c !

- But....
- If UV light: **electrons** resonate and absorb energy
- so UV light is not passed along
- If IR light: not only the electrons but entire atoms or molecules vibrate, increasing the temperature of the structure and producing heat
- → IR light is sometimes called “heat waves.”
- So we see that glass is transparent to visible light, but not to UV and IR light.



Transparent Materials, Continued-3

- Average speed of light through different materials
 - vacuum— c (300,000,000 m/s)
 - atmosphere—slightly less than c (rounded to c)
 - water— $0.75 c$
 - glass— $0.67 c$, depending on material
 - diamond— $0.41 c$
- *As you go down list, density increases.*
- *There are more atoms to absorb and emit light.*
- *Time delay increases, so speed decreases.*
- *Diamond is the most optically (for light) dense.*

Transparent Materials

CHECK YOUR NEIGHBOR

Strictly speaking, the photons of light incident on glass are

- A. also the ones that travel through and exit the other side.
- B. not the ones that travel through and exit the other side.
- C. absorbed and transformed to thermal energy.
- D. diffracted.

Transparent Materials

CHECK YOUR ANSWER

Strictly speaking, the photons of light incident on glass are

B. not the ones that travel through and exit the other side.

Explanation:

Figure 26.8 illustrates this nicely. The light that exits the glass is not the same light that begins the process of absorption and re-emission.

Transparent Materials

CHECK YOUR NEIGHBOR, Continued

Compared with the frequency of illuminating light on a sheet of transparent plastic, the frequency of light that is transmitted

- A. is slightly less.
- B. is the same.
- C. is slightly higher.
- D. depends on the type of plastic.

Transparent Materials

CHECK YOUR ANSWER, Continued

Compared with the frequency of illuminating light on a sheet of transparent plastic, the frequency of light that is transmitted

B. is the same.

Explanation:

Speed of light in plastic may vary, but the frequency transmitted doesn't.

Transparent Materials

CHECK YOUR NEIGHBOR, Continued-1

The average speed of light is less in

- A. air before entering glass.
- B. glass.
- C. air after emerging from glass.
- D. None of the above.

Transparent Materials

CHECK YOUR ANSWER, Continued-1

The average speed of light is less in

B. glass.

Classwork:

20. How does the average speed of light in glass compare with its speed in a vacuum?

21. How does the speed of light that emerges from a pane of glass compare with the speed of light incident on the glass?