Electromagnetic Radiation

(How we get most of our information about the cosmos)

Examples of electromagnetic radiation:

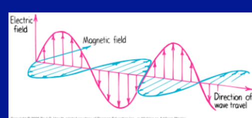
- Light
- Infrared
- Ultraviolet
- Microwaves
- AM radio
- FM radio
- TV signals
- Cell phone signals
- X-rays

Physics Open House

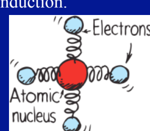
Wednesday, November 5th, 6pm
in Physics and Astronomy (NE corner Lomas & Yale)
Lab Tours!
Free Pizza and Soft Drinks!
Star Party at Campus Observatory!
Learn about the Physics Department and our majors

Faraday's Law and EM Waves

- Change in the magnetic field strength in coils generates a current
  - A magnet at rest in a coil will not induce a current
- More generally
  - A changing magnetic field induces an electric field
  - A changing electric field induces a magnetic field
    - In combination this produces the phenomenon of EM waves!

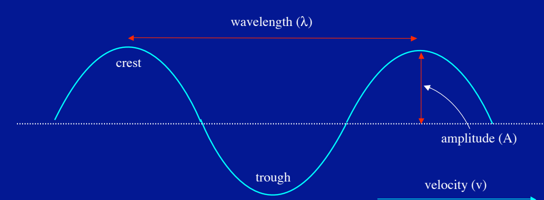


Electromagnetic waves – oscillating electric and magnetic fields that continually regenerate one another via EM induction.



Radiation travels as waves.
Waves carry information and energy.

Properties of a wave



λ is a distance, so its units are m, cm, or mm, etc.

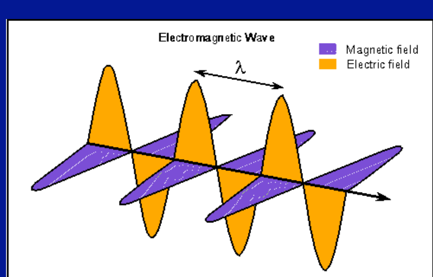
Period (T): time between crest (or trough) passages

Frequency (f): rate of passage of crests (or troughs), $f = \frac{1}{T}$
(units: Hertz or cycles/sec)

Also, $v = \lambda f$

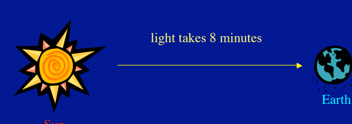
$E = h f$

Scottish physicist James Clerk Maxwell showed in 1865 that waves of electric and magnetic fields travel together => traveling "electromagnetic" waves.



The speed of all electromagnetic waves is the speed of light.

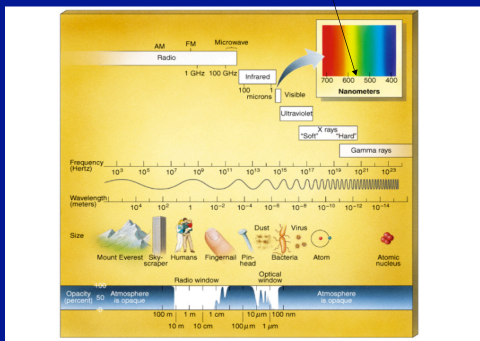
$c = 3 \times 10^{8}$ m / s
or $c = 3 \times 10^{10}$ cm / s
or $c = 3 \times 10^{5}$ km / s



$c = \lambda f$ or, bigger λ means smaller **f**

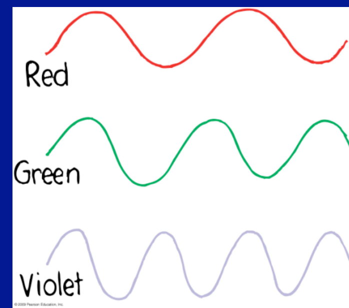
The Electromagnetic Spectrum

1 nm = 10^{-9} m , 1 Angstrom = 10^{-10} m



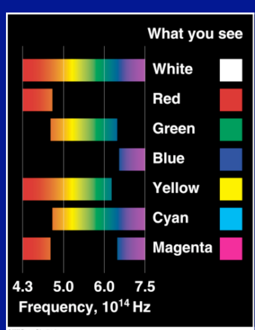
$c = \lambda \nu$

Colors = Spectrum



Demo: white light and a prism

Colors = Spectrum



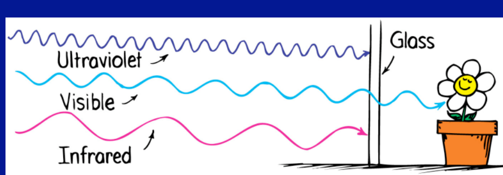
Reflection of light

Some materials are very good reflectors of light

DEMO - Mirrors

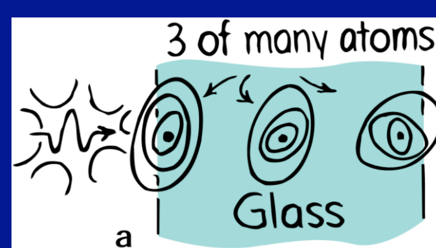
Transmission of light

Some materials only transmit certain wavelengths



Transmission of light

Waves can slow down as they travel through a different material. Here is why:



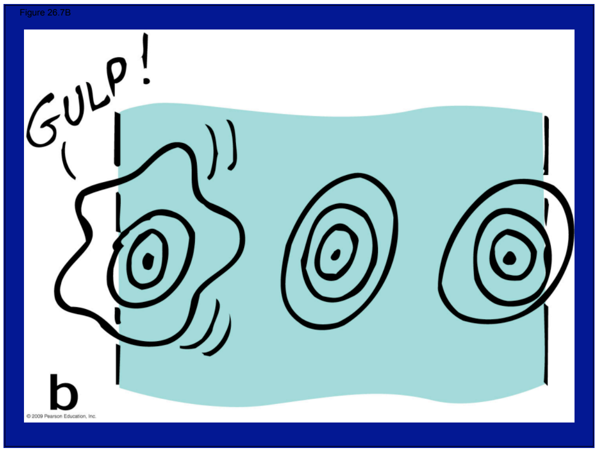


Figure 26.7B
GULP!
b
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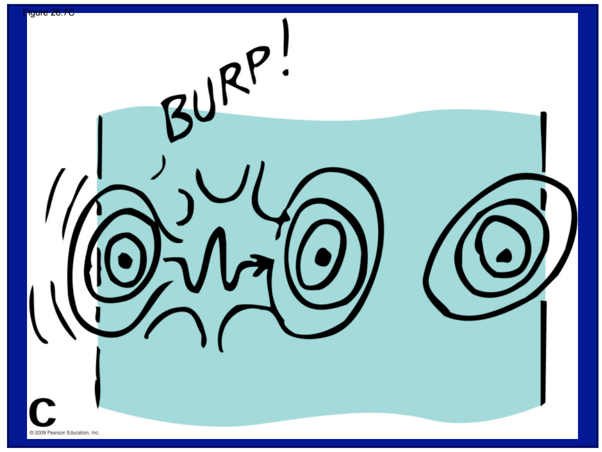
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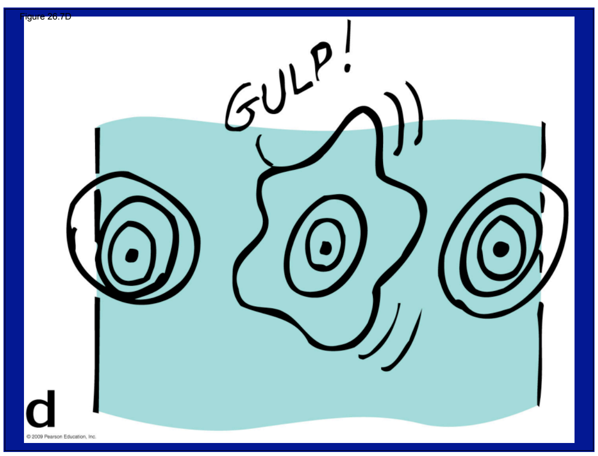
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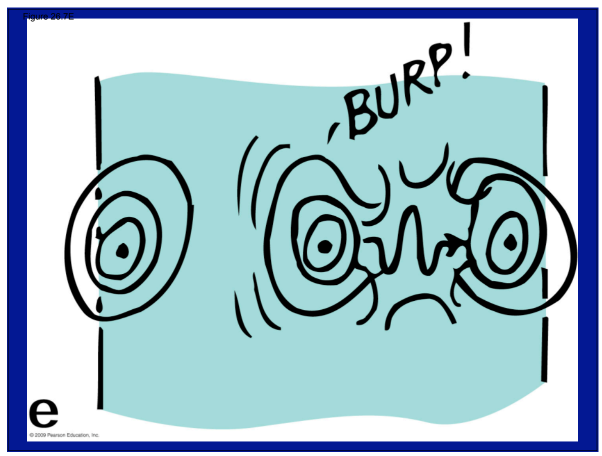
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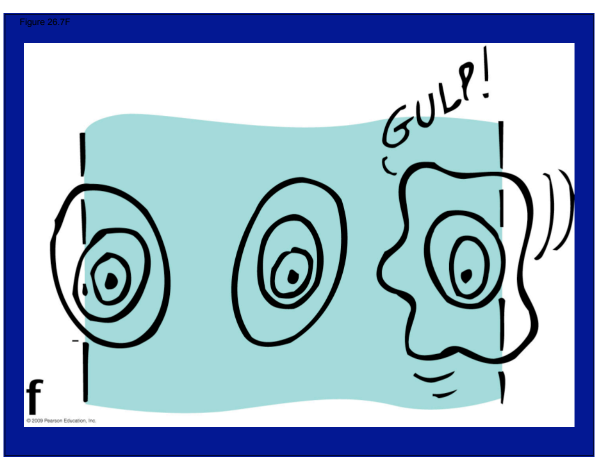
Figure 26.7F
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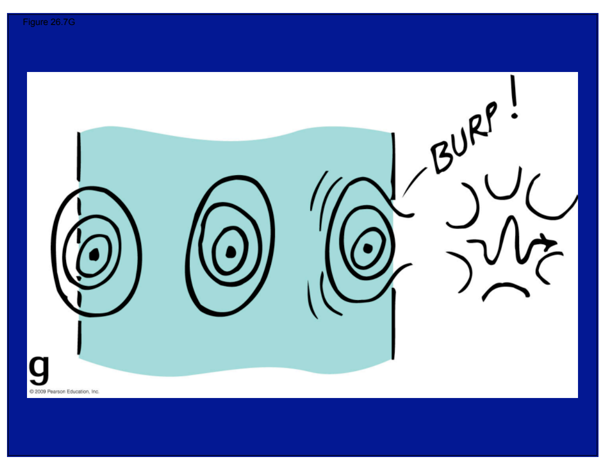
Figure 26.7G
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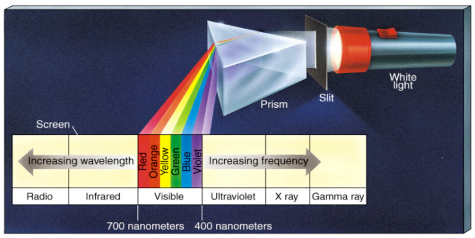
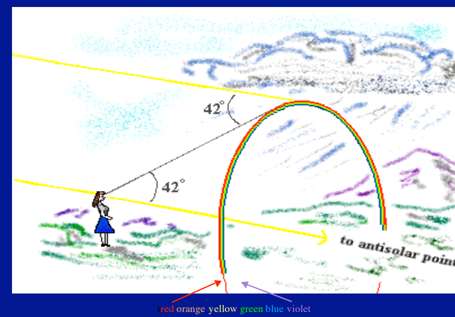
Refraction of light

All waves bend when they pass through materials of different densities. When you bend light, bending angle depends on wavelength, or color.

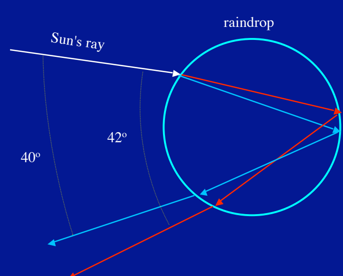


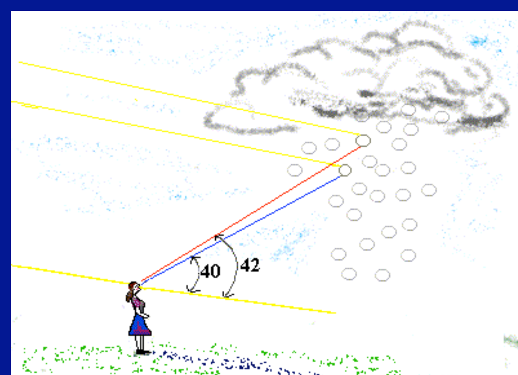
DEMO

Rainbows

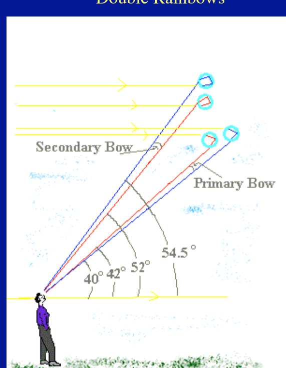


What's happening in the cloud?



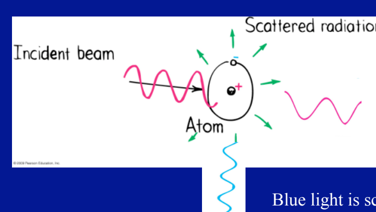


Double Rainbows



Why is the Sky Blue?

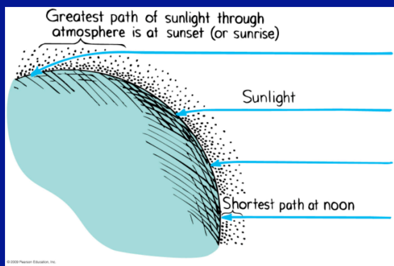
Light from the Sun at short wavelengths scatters to larger angles off dust grains and other particles in the atmosphere than do long wavelengths

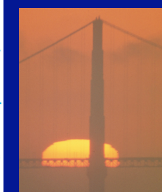


Blue light is scattered more than red light

Why are Sunsets Red?

Scattering by dust grains in the atmosphere is greatest at sunset (sunrise)





DEMO

Why are Deep Lakes Blue?

Clicker Question:

If you look in a mirror, left and right are reversed, but not up and down, why?:

A: our eyes are oriented horizontally: (-) _ (-)

B: gravity defines the up-down axis, but there is no force in the horizontal direction

C: left and right are subjective (not absolute) terms

D: up and down are reversed, but our brain compensates by reversing the image.

Clicker Question:

Compared to ultraviolet radiation, infrared radiation has greater:

A: energy

B: amplitude

C: frequency

D: wavelength

Clicker Question:

Compared to radio waves, X-rays travel:

A: faster

B: slower

C: at the same speed

Clicker Question:

A star much colder than the sun would appear:

A: red

B: yellow

C: blue

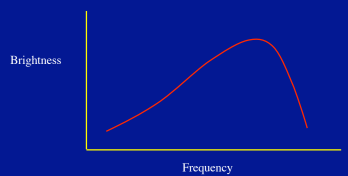
D: smaller

E: larger

We form a "spectrum" by spreading out radiation according to its wavelength (e.g. using a prism for light).

What does the spectrum of an astronomical object's radiation look like?

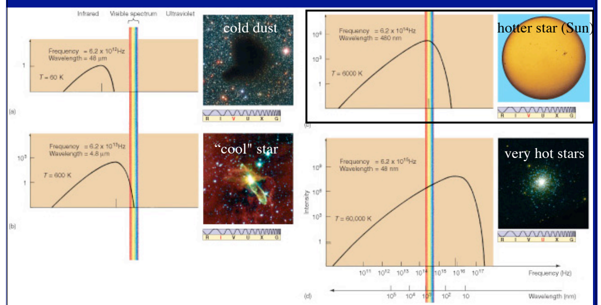
Many objects (e.g. stars) have roughly a "Black-body" spectrum:



- Asymmetric shape
- Broad range of wavelengths or frequencies
- Has a peak

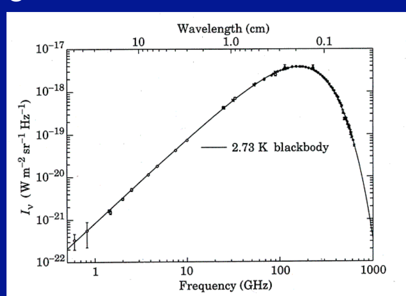
also known as the Planck spectrum or Planck curve.

Approximate black-body spectra of astronomical objects demonstrate Wien's Law and Stefan's Law



frequency increases, wavelength decreases →

Example: Blackbody - the microwave background



Laws Associated with the Black-body Spectrum

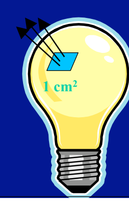
Wien's Law:

$$\lambda_{\text{max energy}} \; \alpha \; \frac{1}{T}$$

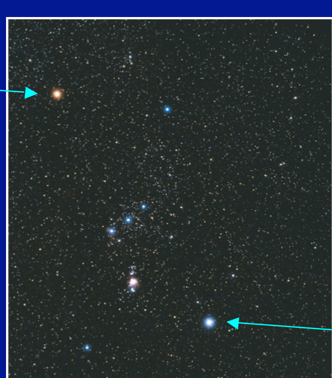
(wavelength at which most energy is radiated is longer for cooler objects)

Stefan's Law:

Energy radiated per cm^2 of area on surface every second α T^4
(T = temperature at surface)

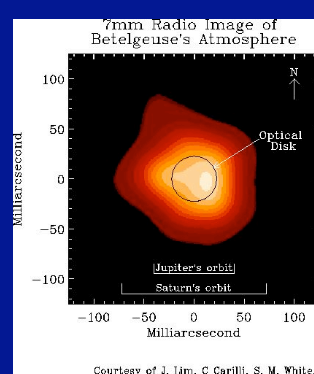


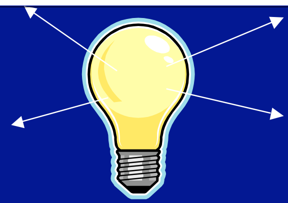
Betelgeuse



Rigel

Betelgeuse



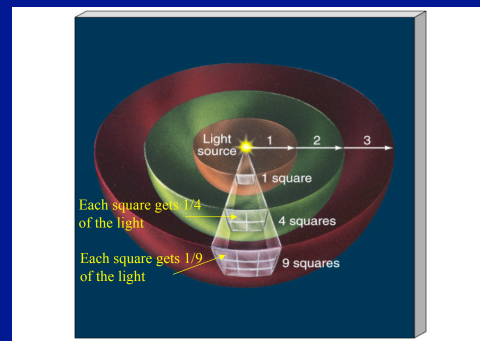


The total energy radiated from entire surface every second is called the <u>luminosity</u>. Thus

Luminosity = (energy radiated per cm^2 per sec) x (area of surface in cm^2)

For a sphere, area of surface is $4\pi R^2$, where R is the sphere's radius.

The "Inverse-Square" Law Applies to Radiation



apparent brightness $\alpha \ \frac{1}{D^2}$

D is the distance between source and observer.

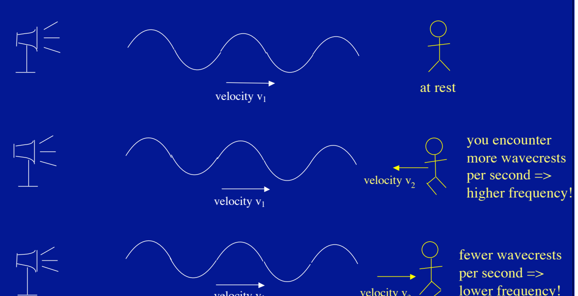
The Doppler Effect

- How does the pitch or tone of a sound wave change when the source of the sound is moving towards or away from you?
- What about when you are moving towards or away from the source?
- Does this effect occur for all types of waves or just for sound waves?

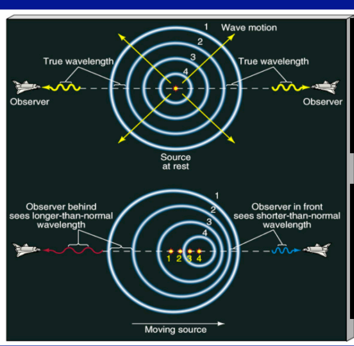
DEMO - Doppler Arm

The Doppler Effect

Applies to all kinds of waves, not just radiation.



The frequency or wavelength of a wave depends on the relative motion of the source and the observer.



Clicker Question:

Which of the following is the hottest:

A: a steel rod glowing red

B: a steel rod glowing blue

C: a steel rod glowing white

D: a stell rod glowing yellow

Clicker Question:

The energy of a photon is proportional to its:

A: period

B: amplitude

C: frequency

D: wavelength

Clicker Question:

If the sun were larger, but at the same temperature, it would appear:

A: redder and brighter

B: yellow and brighter

C: blue and brighter

D: redder and fainter