Problem Set #2 due today!
Problem Set #1 solutions posted
Problem Set #1 graded and available after class
No change in schedule because of the snow day...
Announcements

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Today:
- Light and Electromagnetism
- LIGHT, Chap. 5
Why Study Light?

Astronomy is passive science —
Why Study Light?

Astronomy is passive science — observations!
Why Study Light?

- Astronomy is passive science — observations!
- Can only *VISIT* most nearby celestial objects
- Want knowledge of physical properties!
Why Study Light?

- Astronomy is passive science — observations!
- Can only *VISIT* most nearby celestial objects
- Want knowledge of physical properties!
- Using light we can determine the following properties:
  - Temperature
  - Composition
  - Velocity
Light as particles

Light travels through empty space at a speed of \( c = 300,000 \text{ km/s} \)

Galileo tried to measure speed of light with lanterns on mountains!
Light as particles

Light travels through empty space at a speed of
\[ c = 300,000 \text{ km/s} \]

Galileo tried to measure speed of light with lanterns on mountains!

Olaus Romer (1676) discovered that eclipse timing depended on distance of Earth to Jupiter

Implies a speed of light propagating in a vacuum \[ \Rightarrow 214,000 \text{ km/s} \]
Fizeau and Foucalt (1850) measured speed of light by bouncing a beam off of a rotating mirror.

Mirror moves as light travels.

The light returns to its source at a different position.

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A114: Lecture 8—16 Feb 2007
Read: Ch. 5
Astronomy 114—5/16
Fizeau and Foucalt (1850) measured speed of light by bouncing a beam off of a rotating mirror.
Mirror moves as light travels.
The light returns to its source at a different position.

To summarize:
Light has a well-defined speed, as if it were made of bullets!
Light as waves (1/3)

- Light is composed of all colors (rainbow).
- How and Why?
Isaac Newton suggested that light was made of tiny particles called **PHOTONS**

Attempted to explain spectrum using properties of the particles
“Nothing is more requisite for producing all the variety of Colours, and degrees of Refrangibility than that the Rays of Light be Bodies of different Sizes, the least of which may take violet the weakest and darkest of the Colours, and be more easily diverted by refracting Surfaces from the right Course; and the rest as they are bigger and bigger, may make the stronger and more lucid colours, blue, green, yellow, and red, and be more and more difficultly diverted.”

Sir Issac Newton, Opticks
Young (1801): light has wave-like properties.

Light passing through two narrow slits which resulted in a pattern of bright and dark bands.
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Propagation of waves (1/2)

Material does not move in the direction of wave propagation!!

Example:
- Bobber in water
- Swimming in ocean

Waves move past the object . . . [Demo]
Propagation of waves (1/2)

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What is the medium for light propagation?
Propagation of waves (1/2)

- Material does not move in the direction of wave propagation!!
- Example:
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- What is the medium for light propagation?
- *Luminiferous Aether*: a massless vapor that filled the Universe (19th century) to propagate heat and light
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What is the medium for light propagation?

Luminiferous Aether: a massless vapor that filled the Universe (19th century) to propagate heat and light

All attempts to measure the aether failed. By Occam’s razor: no need for the aether

Light propagates in a vacuum!
wavelength: distance between crests
Propagation of waves (2/2)

- **wavelength**: distance between crests
- **frequency**: rate at which crests move past a fixed point
Propagation of waves (2/2)

- **wavelength**: distance between crests
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- \( \text{wavelength} \times \text{frequency} = \text{speed} \)
Propagation of waves (2/2)

- **wavelength**: distance between crests
- **frequency**: rate at which crests move past a fixed point
- **wavelength** × **frequency** = **speed**
- FM radio waves transmit information by changing the frequency of the waves. Your radio can then create sound by recognizing these changes in frequency.
Electromagnetic waves are waves of energy that travel through space at the speed of light.

Consist of combined electric and magnetic waves that result when a charged particle accelerates.

The acceleration creates a wave with both electric and magnetic components.
Astronomically important frequencies range from:  
- $10^2$ Hz (low) to $10^{24}$ Hz (high)

Astronomically important wavelengths range from:  
- $10^8$ cm (long) to $10^{-14}$ cm (short)
William Herschel and Infrared

- Circa 1800: used mercury thermometers to measure the energy in different colors of light
- Highest temperature was just beyond the red part of the spectrum
- Discovered energy beyond the visible spectrum: infrared!
Energy and Intensity of Light

- Energy carried by a photon is proportional to its frequency
  \[ E = h \nu = \frac{hc}{\lambda} \]

  Planck’s constant:
  \[ h = 6.63 \times 10^{-34} \text{ Joule-sec} \]

- Therefore, the total energy carried by a beam of light (its intensity) depends both on the number of photons per second and their frequency
Properties of Light: Summary

- Particle properties
  - Travels in straight lines (bullets)
  - “Rays” are parallel far from source
  - \( E = h \nu \)

- Wave properties
  - “Rainbow” spectrum
  - Interference

- Light is electromagnetic radiation

- Wave-Particle Duality: light has both wave-like and particle-like properties!