Today's Class: Space Telescopes - Optics

- Homework #3 due on Oct. 5 .
- Read Section 6.2 in Cosmic Perspective.

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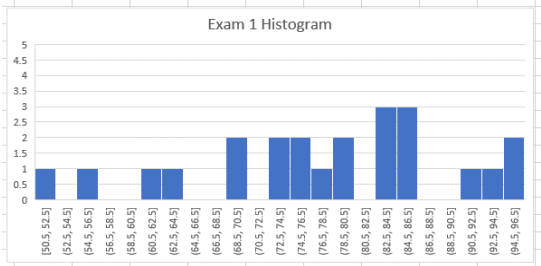
Exam 1 Results



Mean	76.79598
Std Dev.	11.91895
Median	79

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Exam 1- troublesome questions

1. Which of the following is the **LEAST** persuasive reason for America's space program?
   a. To defend the United States against threats from other nations.
   b. To expand scientific frontiers and human knowledge.
   c. To improve our abilities to solve tough problems.
   d. To learn how to terra-form (i.e., transform) other planets to be like Earth.
   e. To create technological spin-offs and benefit the nation's economy.

10. Suppose the Sun were suddenly to shrink in size but that its mass remained the same. According to the law of conservation of angular momentum, what would happen?
    a. The Sun would rotate faster than it does now.
    b. The Sun's rate of rotation would slow.
    c. The Sun's angular size in our sky would stay the same.
    d. This could never happen, because it is impossible for an object to shrink in size without an outside torque.

Conservation of Angular Momentum states: $L = m \times v \times r$, where L= angular momentum, m = mass, v = velocity, and r = radius. To keep L constant when the radius r is reduced, then v must increase. That means the Sun would rotate faster.

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Space In The News

Presented by Grant Repine

Tiny cubesat launching next year to blaze trail for NASA moon-orbiting space station

Article By Leonard David

Question: Do you think a return to the moon is the best way for NASA to be using their budget or should they focus on exploring further into space, such as going to Mars? Why?

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Last Class

- **NASA's Commercial Orbital Transportation Services Program**
  - Orbital Sciences' *Antares + Cygnus*
  - Space X's *Falcon + Dragon*
  - Sierra Nevada *Dream Chaser*
- **NASA's Commercial Crew Program**
  - Boeing CST-100 *Starliner*
  - Space X *Dragon*
- **NASA's CLPS and Human Lunar Landing System.**

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Today's Class

- **Refraction**
  - Focusing light
  - Image formation
- **Fundamental Properties of Telescopes**
  - Light Collection Area
  - Angular Resolution
- **Designs of Telescopes**
  - Refracting telescope
  - Reflecting telescope

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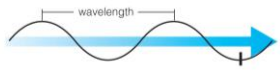
Properties of Light Waves



b The vibrations of the electric field determine the wavelength and frequency of a light wave. Light also has a magnetic field (not shown) that vibrates perpendicular to the direction of the electric field vibrations.

- **Wavelength** is the distance between two wave peaks.
- **Frequency** is the number of times per second that a wave vibrates up and down.

  Speed of Light (c) = wavelength (λ) × frequency (υ)
- **Energy** of light (photon) (E) = constant (h) × υ.

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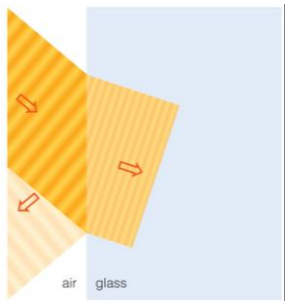
Refraction



- Refraction is the bending of light when it passes from one substance into another.
- Your eye uses refraction to focus light.

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Example: Refraction at Sunset

Sun appears distorted at sunset because of how light bends in Earth's atmosphere

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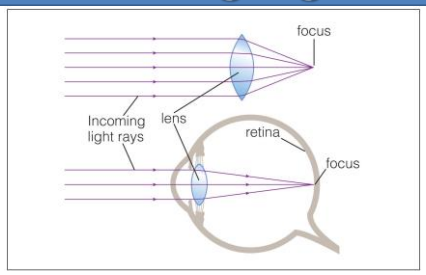
Focusing Light



Refraction can cause parallel light rays to converge to a focus

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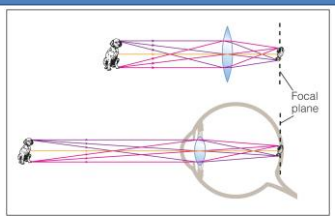
Image Formation



- The focal plane is where light from different directions comes into focus.
- The image behind a single (convex) lens is actually upside-down!

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The two most important properties of a telescope

1. **Light-collecting area:** Telescopes with a larger collecting area can gather a greater amount of light in a shorter time.
2. **Angular resolution:** Telescopes that are larger are capable of taking images with greater detail.

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Light-Collecting Area

- A telescope's diameter (d) tells us its light-collecting area: $A = p(d/2)^2$
- The largest telescopes currently in use have a diameter of about 10 meters.

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Class Exercise

How does the collecting area of a 10-meter telescope compare with that of a 2-meter telescope?

a) It's 5 times greater.
b) It's 10 times greater.
c) It's 25 times greater.

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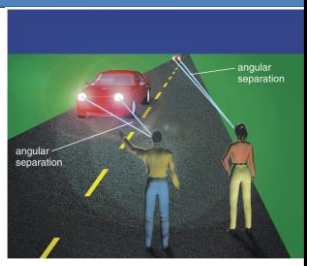
Angular Resolution

- The *minimum* angular separation that the telescope can distinguish
  = 2.5×10^5 arcsec × **λ/D**,
  where λ = wavelength and
  D = telescope diameter



- Better resolution corresponds to small values of the ratio **λ / D**. For example, the Hubble Space Telescope:
  D=2.4 meters, λ=5x10^{-7} meters, this limit is **0.05 arcseconds**.

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Refracting Telescope

- Refracting telescopes need to be very long, with large, heavy lenses.

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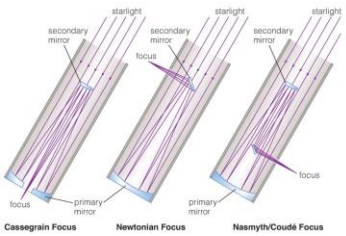
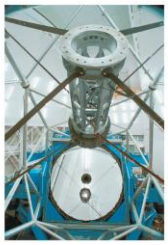
Reflecting Telescope





- Reflecting telescopes can have much greater diameters.
- Most modern telescopes are reflectors.

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What did we learn today?

- **Refraction**
  - Focusing light
  - Image formation
- **Fundamental Properties of Telescopes**
  - Light Collection Area
  - Angular Resolution
- **Designs of Telescopes**
  - Refracting telescope
  - Reflecting telescope