Physics 155: Lecture 7 Properties of Light (con't), Telescopes

Announcements

4. Light travels more slowly in a medium than in vacuum.
   Definition: \( n = \) index of refraction
   \( n = \) velocity of light in vacuum/velocity in the medium
   \( n = \frac{c}{v} \)

Example: \( n = 1.5 \) for glass. Thus light travels \( \frac{1}{1.5} = \frac{2}{3} \)
   as fast in glass as in vacuum (since \( v = \frac{c}{n} \))

5. Refraction. Light is bent as it enters a medium according to
   Snell's law: \( \sin \theta_i = n \sin \theta_r \)

   ![Diagram of Snell's Law](image)

There is much evidence for this from 'bent' soda straws in a
   glass of water to stars being elevated near the horizon due to
   the earth's atmosphere. The egg-shaped setting sun is
   an example of differential refraction where the top of the
   sun is elevated but the bottom is elevated more due to the
   denser path through the atmosphere at the horizon.

6. Dispersion
   In fact \( n \) depends on wavelength so light is spread out ac-
   cording to color or wavelength. In a prism red light is bent
   less than blue; Isaac Newton showed this first. The rainbow
   is another example of dispersion where there are two surfaces
   involved in the raindrop.

   ![Diagram of Dispersion](image)

Telescopes

A lens is just a pile of prisms which can be used to focus
   light, with the prism edges smoothed out. The aperture of a
   lens is its diameter. The focal length is the place where para-
   llel rays come come to a focus.

   ![Diagram of Telescope](image)

The first telescope dates from 1608 in Holland, but Galileo made
   the first astronomical telescope in 1609 and made discoveries
   for which he is so famous: craters on the moon, sunspots,
   Jupiter's moons and phases of Venus.

The two main purposes of a telescope:
1) light-gathering power, which is proportional to telescope area
Example: a 10 cm aperture telescope gathers 4 times as much light as a 5 cm aperture one. (area of a circle A=πr²)

2) to give angular magnification, spread out the image so two stars can now be resolved.

The magnifying power of a telescope P

\[ P = \frac{\text{focal length of objective}}{\text{focal length of eyepiece}} \]

where in a typical Galilean refracting telescope, the objective forms the primary image, which is then magnified by the ocular or eyepiece. Note that the image by the objective lense is inverted and the eyepiece only magnifies this and cannot improve on a poor image.

Example: the magnifying power of the biggest refractor in the world at Yerkes Observatory, aperture 40 inches, objective focal length 40 feet, used with an eyepiece of focal length 1/2 inch

\[ P = -40 \times 12/0.5 = -960 \] (the minus means images are inverted)

The size of the telescope image is directly proportional to the focal length of the objective.

Another useful formula for lenses from lab: \[ \frac{1}{f} = \frac{1}{s_0} + \frac{1}{s_1} \]

where \( s_0 \) is object distance, \( s_1 \) is image distance, \( f \) =focal length

There are four main types of telescopes: refractors, reflectors, Schmidt camera, and radio telescopes (plus many exotic new gamma-ray, x-ray, infra-red, types). Refractors were discussed above, typified by a simple Galilean telescope.

Disadvantages of refractors:
1) weight hard to handle so glass not sag, held only at edge
2) most importantly: chromatic aberration (lense disperses light and spreads out images by color). This dispersion can be compensated for at two wavelengths by a compound lense but no lense can correct for all wavelengths.
3) you need perfect, bubble-free glass and have to grind two surfaces of the objective
4) spherical abberation: rays at end of objective focus closer to lense than rays nearer the axis, even for one wavelength