Physics 1025: Lecture 7  Properties of light (con't), n, Dispersion, Lenses; Telescopes

Announcements

Properties of light (continued)

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

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: \( \sin \theta_i = n \sin \theta_r \)

   - \( n = 1 \) for incident medium (air)
   - \( n = n \) for refracting medium

There is much evidence for this from ‘bent’ soda straws in a glass of water to stars being elevated near the horizon due to refraction by 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 according 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 refracting surfaces involved as light enters and leaves the raindrop.

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 parallel rays come to a focus.
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.
   (Note: area of a circle \( A = \pi r^2 \))

2) To give angular magnification, i.e. spread out the image so two stars can now be resolved.
   The magnifying power of a telescope \( P \)
   \[ P_M = \frac{-f_{\text{objective}}}{f_{\text{eyepiece}}} \]

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 lens is inverted and the eyepiece only magnifies this and cannot improve on a poor image.

Example: What is 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 ½ inch
   \[ P_M = -40 	imes 12/0.5 = -960 \] (the minus means images are inverted)

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

Another useful formula for lenses from lab: \( \frac{1}{S_o} + \frac{1}{S_i} = \frac{1}{f} \)

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 doesn’t sag, being held only at edge
2) Most importantly: chromatic aberration (lens disperses light and spreads out images by color). This dispersion can be compensated for at two wavelengths by a compound lens but no lens can correct for all wavelengths
3) You need perfect, bubble-free glass and have to grind two surfaces of the objective
4) Spherical aberration: rays at edge of objective focus closer to lens than rays nearer the axis, even for one wavelength