Module #12: Geometric Optics

* Introduction
  + The study of the propagation and behavior of light is called optics.
  + Think about light as a beam of particles (photons) in this module.
* The Law of Reflection
  + Law of Reflection = the angle of reflection equals the angle of incidence.
    - The angle of reflection refers to the angle of the reflected light beam relative to a line perpendicular to the mirror.
    - The angle of incidence refers to the angle of the incoming light (relative to the line perpendicular to the mirror)
  + Experiment 12.1 p.385-386
* Flat Mirrors
  + You see when light reflects off the thing you are observing and enters your eyes – cannot see without light.
  + How a reflection is made when a woman looks at a mirror
    - Light that bounces off her and hits the mirror will reflect off the mirror.
    - A certain angle of incidence will result in the reflected light hitting the woman’s eyes.
    - If you extrapolate the reflected ray backwards (Fig 12.1), it appears to be coming from behind the mirror, and so that is where the image appears to be.
    - The brain forms an image where the light appears to have originated
    - This is a fake image (object is not really there)
  + Virtual image = an image formed as the result of extrapolating light beams
  + When the mirror is flat, the image your brain constructs is the same size as the object, and is the same distance behind the mirror as the object is in front of the mirror.
    - The image is precisely opposite the object in front of the mirror
* Spherical Mirrors
  + A mirror that is curved so that it bends away from the person looking at it is called concave.
  + A light beam reflecting from a concave mirror: Figure 12.2
  + Two light beams reflecting from a concave spherical mirror: Figure 12.3
    - Any light beam traveling towards the mirror and parallel to the optical axis (black line) will be reflected so that it will pass through the focal point.
    - Figure 12.4
  + The focal point will depend on how curved the mirror is
    - f = R/2
      * f = distance from the mirror
      * R = radius of curvature
  + For a curved mirror to focus all horizontal light beams to a single focal point, the mirror must be shaped as a parabola.
    - Hard to manufacture
    - Spherical mirrors are easier to make
  + Spherical mirrors do not focus horizontal light beams precisely at the focus, which leads to distortions in the image – spherical aberration.
* Ray Tracing in Concave Spherical Mirrors
  + Figure 12.6, 12.7
  + When a beam of light travels horizontally and hits a spherical, concave mirror, it is reflected so that it passes through the mirror’s focal point
  + When a beam of light travels through the focal point of a spherical, concave mirror, it is reflected so that it travels horizontally
  + When a beam of light travels through a spherical, concave mirror’s radius of curvature, it will be reflected backwards along precisely the same path
  + Example 12.1 p.392-394
    - Ray tracing
  + A real image is an image formed as the result of intersecting light beams
  + If the light beams that you draw intersect to form the image it is real, but if you have to extrapolate backwards the image is virtual.
  + Example 12.2 p.395-397
  + A magnifying mirror is concave, but in order for it to be magnifying and have an upright image, the object must be closer to the mirror than the focal point
  + OYO p.398 #12.1-12.2
* Ray Tracing in Convex Spherical Mirrors
  + A mirror that bends towards the object is a convex mirror.
  + Basic rules of ray tracing still apply
  + Example 12.3 p.398-399
    - A ray that travels horizontally before it hits the mirror will reflect as if it came from the focal point
    - A ray that is supposed to come from the focal point and be reflected is drawn as if it is headed to the focal point and then reflected horizontally
  + OYO p.400 #12.3
* Snell’s Law of Reflection
  + Light cannot travel through an opaque object
  + Transparent objects allow light to pass through them
    - A portion of the light passes through, and a portion is reflected back
  + When light travels though a transparent object, it bends a little
  + Refraction = the process by which a light ray bends when in encounters a new medium
  + Figure 12.8
    - Despite changing mediums the frequency of light waves must be the same
      * If the wave travels more slowly then the wavelength is shortened
  + Snell’s Law: n1 sin(θ1) = n2 Sin(θ2)
    - N represents the index of refraction for the mediums
    - Index of refraction = the ratio of the speed of light in a vacuum to its speed in another medium
      * n = c/v
      * c is the speed of light
      * v is the speed of light in the medium of interest
  + The index of refraction of air is 1.00
  + Example 12.4 p.402-403
  + Experiment 12.3 p.403-404
  + OYO p.405 #12.4-12.6
  + Dispersion is the spreading out of light because the angle of refraction is slightly different for each wavelength of light
* Converging Lenses
  + A converging lens makes all horizontal light rays converge to its focal point
  + Figure 12.9
  + All light rays that enter the lens traveling horizontally will exit the lens traveling through the focal point
  + All light rays that enter the lens traveling through the focal point will exit the lens horizontally
  + All light rays that enter the lens traveling directly towards the center will experience no deflection as they exit the lens
  + Example 12.5 p.406-407
  + OYO p.408 #12.7-12.8
* Diverging Lenses
  + A diverging lens bends horizontal light rays away from each other
  + Figure 12.10
  + Horizontal light rays are bent as if they were coming from the focal point on the same side of the lens as that from which they entered
  + Example 12.6 p.408-410
  + OYO p.410 #12.9-12.10
* The Human Eye
  + Our eye detects light and sends signals to the brain which form an image in our mind
  + The cornea is a thin, transparent substance that covers the eye and provides protection
  + The iris is a cover that opens and closes to regulate how much light gets into the eye
    - The opening left by the iris is called the pupil
  + Light enters the pupil and is focused with a converging lens
    - The eye can change the shape of the lens using the ciliary muscle to keep the image focused on the retina regardless of where the object is
  + The light is focused on the retina, which sends electrical signals down the optical nerve to the brain
  + If a person has myopia, the combination of lens and cornea focuses light too strongly
    - Focal length is too small and the image forms in front of the retina
    - Corrected with a diverging lens
  + If a person has hyperopia, the cornea and lens cannot bend light strongly enough
    - The image is formed behind the retina
    - Corrected with a converging lens