Slide 2:. Wave motion can be visualized in terms of water waves. High points (crests) and low points (troughs) move radially outward; direction of energy flow in the wave. Connect the points, make a ray, each of the rays describes the motion of a wave front along a particular direction. Light waves behave in a similar fashion. **Ray optics** considers only the direction and power of the EM wave. O**nly the direction of propagation is relevant**. Waves as rays, and **simplifies the problem. We can manipulate these waves, but first let's talk about EM waves**

Slide 3: The Electromagnetic Spectrum is the range of all the types of electromagnetic waves arranged according to frequency and wavelength. Light waves are separated into 7 regions: Radio (longest), microwave, Infrared, visible, ultraviolet, x-ray, and gamma rays (shortest). Wavelength and frequency are inversely proportional. As wavelength decreases and frequency increases energy increases. Tiny section in the middle is visible light.

Slide 4: Reflection, refraction, and diffraction and dispersion are all behaviors associated with the bending of the path of a light wave. **Diffraction** spread out as a result of passing through a narrow aperture or across an edge, typically accompanied by interference. **Dispersion** is the property by which light is spread out according to its color, related to refraction, as each wavelength of light bends a different amount.

Slide 5: Today we are focusing on reflection and refraction **Use sheet F with the rectangular block to demonstrate this on single beam mode. Reflection** is the abrupt change in the direction. **Law of reflection:** $\theta_i = \theta_r$ **Refraction** is the change in direction of propagation of a wave when the wave passes from one medium into another, and changes its speed. speed of light is different in different media. Glass.. They are slowed down! The waves become more compact. $v = c/n$ ***light in glass is approximately two-thirds the speed of light in air. The distance between wave fronts will therefore be shorter in the glass than in air, since the waves travel a smaller distance per period T. Think of trying to swim through honey instead of water!***

Slide 6: Types of lenses and how they work ***show with the ray box in 3 ray mode and diagram F using **lens 1 (convex)** and **lens 5 (concave)** A lens is made up of a transparent refracting medium, some type of glass or plastic, with spherically shaped surfaces on the front and back. Lens can be used to manipulate light rays. A **convex lens (lens 1) thicker in the middle**. This shape causes the light to refract **or bend towards the normal perpendicular**. All rays entering perpendicular to the axis of the lens will refract and **meet at a single point, or focal point**. The distance between that point and the center of the lens is the **focal length (*fl*).** Thinner lenses will have a longer *fl*, this is because a thicker lens will bend the light more. A **concave lens (lens 5)** is **thinner in the middle**. They cause parallel rays passing through them to spread as they leave the lens.

Slide 7: Lens use: The eye *** Use Sheet A
Consider your eye. Our eye contains a lens that focuses light onto the sensors in the back of our eye. There is a sensor in the back of your eye that translates optical information. The **eye flips the image inside your head, then the brain reprocesses it right side up.** Vision **problems** can stem from **abnormalities in the shape** of that **lens**. Lets explore:
1= normal 2=near sighted, focus point too far in front of sensor 3=far sighted, focus point behind sensor. The shape of the lens alters the focal point. The **addition of a corrective lens** can fix this! Show:**3 + 4 2 + 5 scientists use combinations of lenses to focus lasers too**

Slide 8: The average camera lens functions mechanically much like the human eye. A camera lens operates in much the same fashion, focusing the light on a sensor in the back of the camera : **** Use **Sheet B with lens 1** The aperture: how much light the lens gathers. The aperture of a camera opens and closes to let more or less light in, exactly like your iris lets more or less light into the eye. These diagrams and lenses will be up here for you to experiment with at the end of the period.

Slide 9: Greek, Celtic, and Norse mythology all reference the power of invisibility. H.G. Well's story "**The Invisible Man**" tells the tale of a scientist obsessed with the idea. The character later manages to **change the refractive index** of his body to match that of air, rendering himself invisible. The fantasy of invisibility also emerges, albeit in a less scientific fashion, in tales such **as Harry Potter and Lord of the Rings**. Although these situations are beyond reality, **scientists around the world are working on cloaking technology.** The use of **ray optics** seeks to **prevent the light from interacting with the object at all.** Bending light around the object. The weaknesses of this method are the uniaxial (single direction) nature of the device as well as background distortion. If you move out of the exact line of sight the object becomes visible or the background becomes so distorted that the presence of the cloak becomes apparent.

Slide 10: Rochester Cloak was invented by **Professor John Howell and his doctoral student Joseph Choi at the University of Rochester**. It uses a series of **convex lenses to redirect light** in such a way that it **never comes in contact with an object in the cloaked region**. No light, no image in your brain! Therefore, the viewer only sees the background! Uses two pairs of lenses with two different focal lengths. **Convex, or converging, lenses are key to the operation of this device.** The lenses are set up in tandem with the **thicker two in the middle**. The thin lens will be referred to as f_1 and the thicker f_2. It is important for the spacing between the lenses to be very precise, as the device depends entirely on the focal lengths to bend light around the cloaked region. **Use the provided formulas** to calculate the distance between the lenses and follow the instructions to build your own invisibility cloak!