1 Converging and Diverging Lenses

a. **Lens** is a piece of glass that had just the right shape, as it bends parallel rays of light so that they cross and form an image. When arranged in certain positions, prisms bend incoming parallel rays so they converge to or diverge from a single point.

b. Real lenses are not made up of prisms but of solid pieces of glass with surfaces that are usually ground to a spherical shape. **Converging lenses** occur where it’s the thickest in the middle, causing parallel rays of light to converge to a focus. On the other hand, **diverging lenses** are the thinnest in the middle and causes parallel rays of light to diverge.

c. **Principal axis** occurs when a line joins the centers of curvature of the surfaces of a lens. For converging lens, **focal point** is the point at which a beam of parallel light, parallel to the principal axis converges. Incident parallel beams that are not parallel to the principal axis focus at points above or below the focal point. All such possible points make up a **focal plane**. A lens affects light coming from right in the same way as light coming from left. Thus, a lens has two focal points planes. For a diverging lens, incident beam of light the principal axis is not to a point, but is diverged light appears to come from a point. **Focal length** of a lens is the distance between center of the lens and its focal point, whether it’s converging or diverging. When lens is thin, focal lengths on either side are equal, even when curvatures on tow sides are not.

2 Image Formation by Lens

a. An object can be seen through a small angle of view, even if it’s far away. That same object can be seen through a larger angle, when it’s closer. Magnification occurs when an image is observed through a wider angle with the usage of lens than without lens which allows more detail to be seen.

b. With a magnifying glass, it’s held closer to an object. Converging lens will magnify only when the object is between the focal point and lens. A **virtual image** is formed through reflection or refraction that can be seen by an observer but cannot be projected on a screen since light from the object doesn’t actually come to a focus.

c. When the object is far away from the focal point of a converging lens, light from the object does converge and can be focused on a screen. Thus, a **real image** is formed by converging light rays and that can be displayed on a screen. Converging lenses are used for projecting slides, motion pictures on a screen.

d. When a diverging lens is used alone, image is always virtual and smaller than the actual object. It does not matter how far or how close the object is.

3 Construction of Images Through Ray Diagrams

a. **Ray diagrams** show principal rays that can be used to determine the size and location of an image. In order to construct a ray diagram, size and location of the object, distance from the center of lens must be known.

b. In order to locate the position of the image, paths of two rays from a point on the object must be known. Path of one refracted ray is known from the definition of the focal point. A ray parallel to principal axis will be refracted by the lens to the focal point. A ray of light will pass through the center with no appreciable change in direction. A ray of light that passes through the focal point in front of the lens emerges from the lens and proceeds parallel to the principal axis. Any two of the rays is enough to locate the relative size and location of the image.

c. When the distance from the lens to the object is less than the focal length, the rays diverge as they leave the lens. The rays of light appear to come from a point in front of the lens. The location of the image is found by extending the rays backward to the point where they converge. Thus, the virtual image that is formed is magnified and right-side up.
d. In order to construct a ray diagram, follow:
   i. A ray parallel to the principal axis that passes through the focal point after refraction by the lens.
   ii. A ray through the center of the lens that does not change its’ direction.
   iii. A ray through the focal point in front of the lens that emerges parallel to the principal axis after refraction by the lens.

e. This method is useful for diverging lenses. A ray parallel to the principal axis from the tip of the arrow will be bent by the lens in the same direction as if it had come from the focal point. A ray through the center goes straight through. A ray that is heading for the focal point on the far side of the lens that is bent so that it emerges parallel to the axis of the lens.

f. When emerging from lens, rays appear to come from a point on the same side of the lens as the object. This point explains the position of the virtual image. Image is nearer the lens than the object. Thus, it appears smaller than the object and right-side up. The image formed by a diverging lens is always virtual, reduced and right-side up, regardless of the object’s position.

4 Summary of Image Formation

a. A converging lens is a simple form of magnifying glass when the object is within one focal length of the lens. Thus, the object becomes virtual, magnified, and right-side up.

b. When that object is beyond one focal length, a converging lens produces a real, inverted image. The location of the image depends on how close the object is to the focal point. If it is close to the focal point, the image is far away. If the object is far away from the focal point, the image seems nearer. When a real image is formed, the object and the image are on opposite sides of the lens.

c. When that object is viewed with a diverging lens, the image becomes virtual, reduced, and right-side up. This is so for all positions of the object. When a virtual image is formed, the object and the image are on the same side of the lens.

5 Common Optical Instruments

a. Today’s world uses lenses more than any other time in history. Some of the common devices used in optical instruments are described below:

i. **Camera**: Camera is consisted of a lens and sensitive film mounted in a light-tight box. For many cameras, the lens is mounted in such a way that it can be moved back-and-forth to adjust the distance between the lens and film. Lens forms a real, inverted image on the film. Most cameras make use of compound lenses to minimize distortions, known as aberrations. A diaphragm and a shutter control the amount of light that gets to the film.

ii. **Telescope**: Simple telescopes use a lens to form a real image of a distant object. Real image is not caught on film, but is observed in space to be examined by another lens used as a magnifying glass. Eyepiece is positioned so that an image produced by first lens is within one focal length of the eyepiece. Eyepiece creates an enlarged virtual image of the real image. There are astronomical telescope, terrestrial telescope and refracting telescopes, which all functions in various forms. Binocular is such a form of telescope that has a pair of telescopes side-by-side with each having a pair of prisms to provide four reflecting surfaces to turn images right-side up. Since no lens transmits 100% of the incident light upon it, astronomers prefer to get brighter, inverted images of a two-lens telescope to the less bright, right-side up images that a third lens or prisms would normally provide.

iii. **Compound Microscope**: This type of microscope uses two converging lenses of short focal length. An objective lens produces a real image of a close object. Since the image is farther from the lens than the object, it is enlarged. Eyepiece forms a virtual image of the first image, enlarging it further. Thus, this instrument is called compound as it enlarges an already enlarged image.

iv. **Projector**: In this device, a concave mirror reflects light from an intense source back onto a pair of condenser lenses, which direct the light through the slide or movie frame to a projection lens, which is mounted in a sliding tube so that it can be moved back-and-forth to focus on a sharp image on the screen.

6 **Eye**

a. Human eyes are similar to cameras. Iris controls the amount of light that enters through this colored part of the eye, surrounding an opening, pupil. Light enters through cornea, a transparent covering, which allows
passing through pupil and lens, and is focused on a layer of tissue at the back of the eye, retina, which is sensitive to light. Different parts of this retina get light from different direction.

b. For both camera and eye, the image is upside down and this is compensated for both cases. Just like camera film is turned around, our brains learned to turn the image around from retina.

c. For both of them, focusing is achieved by changing the distance between the lens and the film. In human eye, most of the focusing is done by cornea. Adjustments in focusing of the image on retina are made by changing the thickness and shape of the lens to control its focal length. This is a form of accommodation that is brought about by the action of ciliary muscle, surrounding the lens.

7 Defects in Vision

a. Eyes of a farsighted person form images behind the retina. Farsighted people have to hold things more than 25 cm away to be able to focus them. This remedy is to increase the converging effect of the eye. Converging lenses will converge the rays that enter the eye enough to focus them on the retina instead of behind the retina. Here, the eyeball becomes too short.

b. A nearsighted person can see nearby objects clearly, but cannot see distant objects clearly because they are focused too near the lens, in front of retina. Here the eyeball becomes too long.

c. Eye astigmatism is a defect that results when the cornea is curved more in one direction than the other. For this, the remedy is cylindrical corrective lenses that have more curvature in one direction than in another.

8 Defects of Lenses

a. When a distortion occurs in an image, it is called aberrations. This can be minimized by adding lenses in certain ways. That is why most optical instruments use compound lenses instead of single lenses.

b. Spherical aberrations occurs when light passes through the edges of a lens and focuses at a slightly different place from light passing through the center of the lens. Chromatic aberration is another result of the different speeds of light of various colors and hence the different refractions they undergo. In simple red light and blue light bend by different amounts so they don’t come to focus in the same place.

c. Vision is sharpest when the pupil is smallest because light then passes through only the center of the eye’s lens where spherical and chromatic aberrations are at the minimal level for some eyes.

d. Contact lenses or spectacles are used by people with poor sight. But nowadays, eye surgeons can reshape the cornea of the eye for normal vision.