

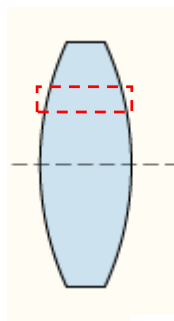
PHYS:1200 LECTURE 31 — LIGHT AND OPTICS (3)

In lecture 30, we applied the law of reflection to understand how images are formed using plane and curved mirrors. In this lecture we will use the law of refraction to describe how images are formed by lenses – curved pieces of glass or transparent plastic. The law of refraction allows us to determine how a light ray is bent when it travels from air into glass or clear plastic. We will not explicitly write down the law of refraction, because it involves the use of trigonometric functions, but rather, we will use ray diagrams to explain image formation by lenses. Finally, we will discuss the optical properties of the human eye and how lenses are used to correct for the two most common vision problems – nearsightedness and farsightedness.

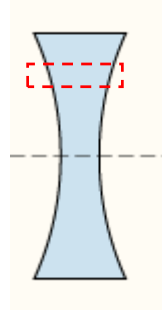
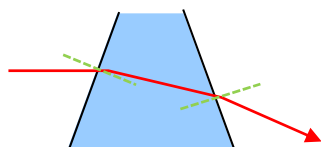
The phenomenon of refraction is illustrated on **slide 5**. A light ray originating from a source in air hits the planar surface of another medium, e.g., glass, and is bent toward the normal line as it travels into the medium. The amount of bending depends on the index of refraction, n of the medium. A lens is a piece of transparent material (glass or plastic) through which light rays enter then exit with an overall change in direction relative to the direction of the incident ray. To produce this change in direction, at least one surface of the lens must be curved. The diagram on **slide 6** illustrates the fact that a piece of flat glass does not produce a change in direction of the incident ray, rather the outgoing ray is just displaced parallel to the incident ray. If the plate is very thin, as in a typical window pane, this displacement is negligible and certainly not noticeable.

31-1. Converging and Diverging Lenses

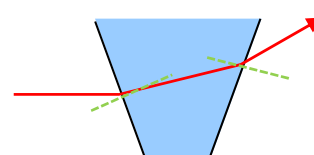
a. General properties.—These lenses have at least one curved surfaces; the converging lens (concave or positive lens) is thicker in the center and the diverging lens (convex or negative lens) is thinner in the center as shown below. To understand the refracting properties of these lenses,



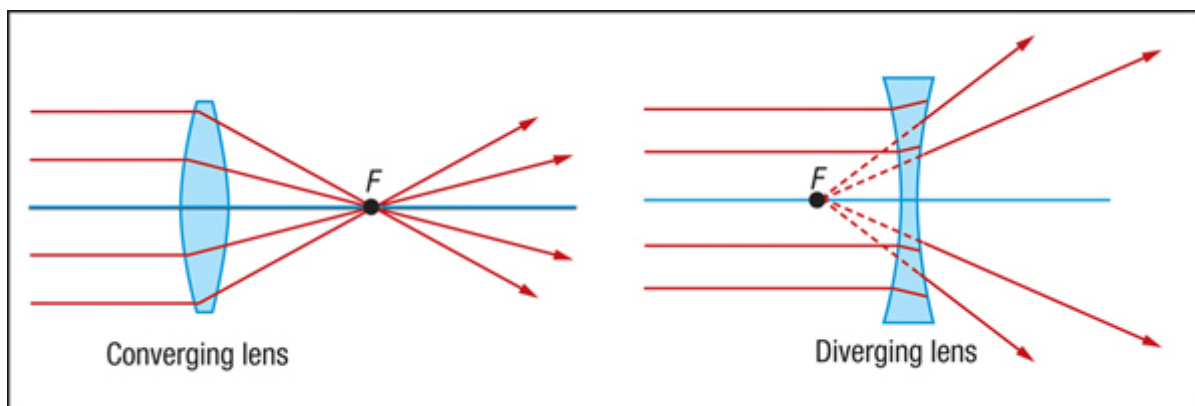
Converging lens



Diverging lens

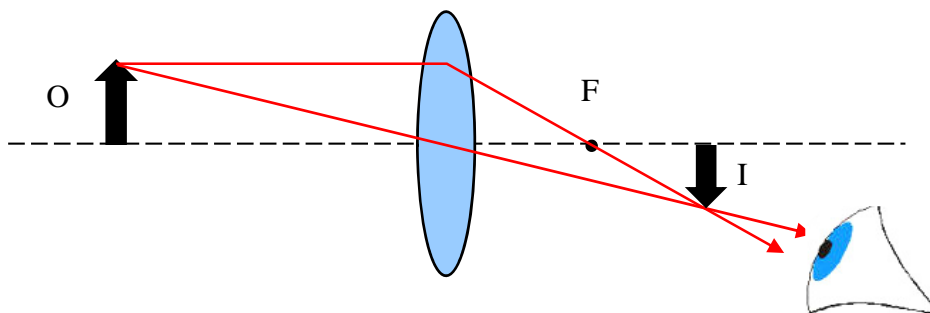


consider light rays that fall on the lenses from the left in the area of the red dashed boxes. These small portions of the lenses, the surfaces look approximately flat. The green dashed lines are the normal lines. Because of the outward curvature, the converging lens causes the light ray to bend down, while for the diverging lens, the ray is bent outward. The overall effect on parallel light

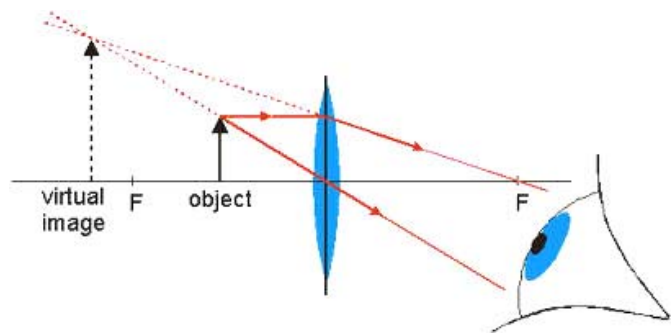


rays is shown below. A converging lens causes parallel light rays to converge to a focal point F on the right side. A diverging lens causes parallel rays to diverge or spread out as if they originated at the focal point F on the left side

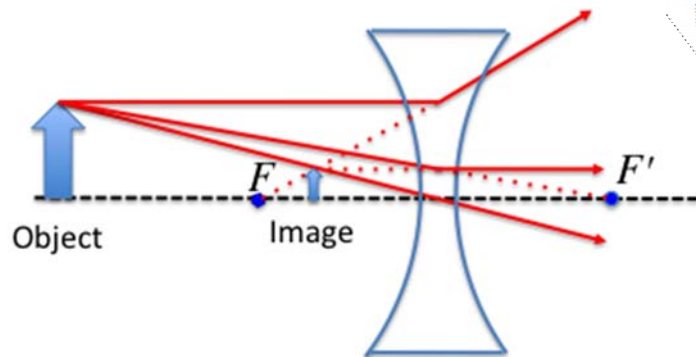
b. Image formation by a converging lens.—The diagram below illustrates how an image is formed by a converging lens for an object that is located far from the lens. Two rays leaving the top of the object are shown as they are refracted by the lens. These rays converge on the right side of the lens, so the image is REAL. It is also inverted and larger than the object.



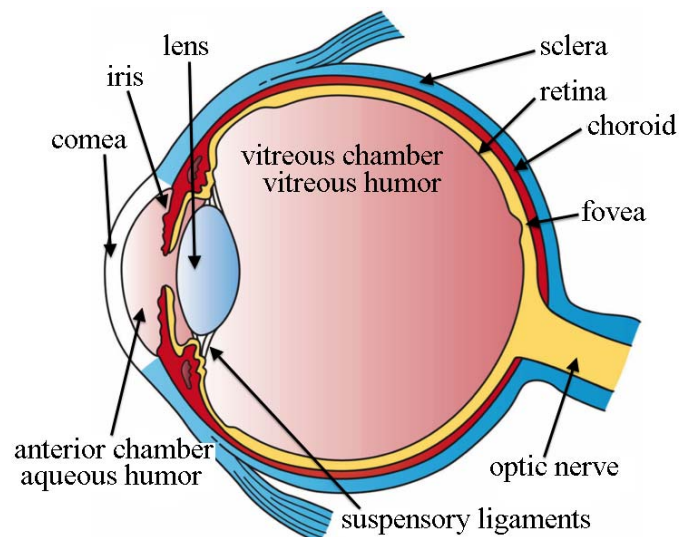
The diagram on the right illustrates the formation of an image by a converging lens when the object is close to the lens. In this case the refracted rays do not converge, but appear to originate at a point on the left side of the lens. In this case, the Image is VIRTUAL, UPRIGHT, and ENLARGED. This is the configuration of a magnifying lens.



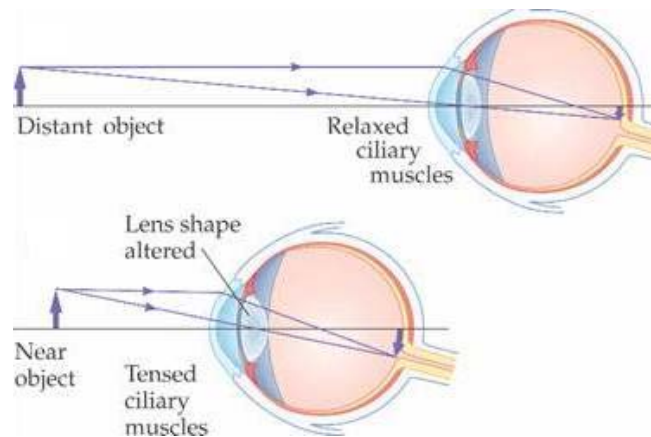
c. Image formation by a diverging lens.—The diagram below illustrates the formation of an image by a diverging lens. Because the rays are diverging after passing through the lens, a virtual image is formed that is upright.



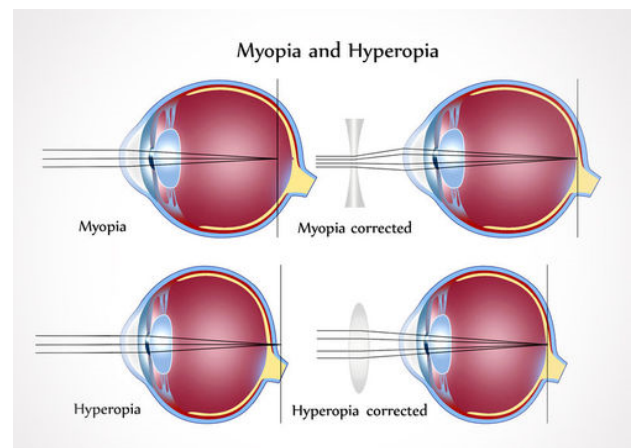
31-2. The Human Eye.—The human eye uses two lenses, one that has a fixed focal length called the cornea, and an inner lens whose focal length is variable. A diagram showing a cross sectional view of the eye is shown below. Both the cornea and lens are converging, and together form a focused image on the retina. The lens is a membrane-like material that is held in place by ligaments



that are attached to the ciliary muscles that can change its shape – making it more converging when we are looking at objects that are close-up and less converging when we are looking at distant objects. The lens is located behind the iris, which is like a camera shutter which open and closes automatically to control the amount of light entering the eye. The iris is the part of the eye that gives it its characteristic color. The ability to focus on near and far objects is called accommodation, and is illustrated on the right. The closest distance from our eyes where a clear image can be formed is called the near point. The near point recedes as we get older because the ability of the lens to change shape deteriorates.



31-3. Corrective Lenses.—The most common vision problems are nearsightedness (myopia), farsightedness (hyperopia), and astigmatism. These vision problems are related to the inability of the lens to attain the proper focal length, or to the shape of the lens. Myopia and hyperopia are illustrated in the diagrams on the right along with the lenses that correct these problems.

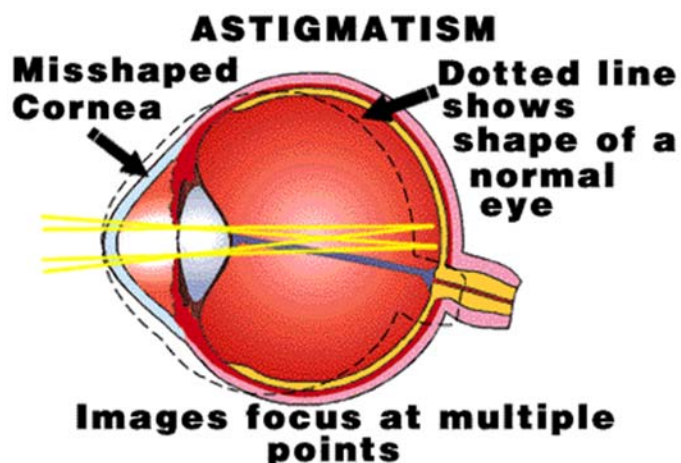


a. Nearsightedness.—In the **nearsighted (myopia) person**, the lens is not capable of relaxing sufficiently to focus the rays from a distant object on the retina. As a result the rays focus at a point in front of the retina. This problem is corrected by placing a **diverging** (or negative) lens in front of the eye to cause the rays to diverge before entering the eye (top right). The combination of the corrective lens and the lenses in the eye then produce a focused image on the retina.

b. Farsightedness.—In a **farsighted (hyperopia) person**, the eye lens is not capable of being squeezed sufficiently when the person is viewing a near object (reading for example). The focus

point would be behind the retina. The corrective lens in this case is a **converging lens** (bottom right) which begins to focus the rays before they enter the eye, so that in combination with the eye lenses, a focused image is formed on the retina.

c. *Astigmatism*.— **Astigmatism** is a vision problem that causes blurred vision due either to the irregular shape of the cornea, the clear front cover of the eye, or sometimes the curvature of the lens inside the eye. An irregular shaped cornea or lens prevents light from focusing properly on the retina, the light sensitive surface at the back of the eye. As a result, vision becomes



blurred at any distance. Astigmatism is a very common vision condition. Most people have some degree of astigmatism. Slight amounts of astigmatism usually don't affect vision and don't require treatment. However, larger amounts cause distorted or blurred vision, eye discomfort and headaches. Eyeglasses are the primary choice of correction for persons with astigmatism. They will contain a special **cylindrical lens** prescription to compensate for the astigmatism. This provides for additional lens power in only specific parts of the lens.