8. Selected Applications

8.1 Ophthalmic Glasses

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8.1.1 History of Ophthalmic Lenses

Since ancient times, lenses fashioned from sections of clear glass or crystalline spheres have been used for the converging or concentrating of the sun’s rays to ignite fires. These so-called burning glasses as well as other hand-held magnifying lenses were known to the ancient Greeks as well as to the Chinese. Records describing the wearing of lenses before the eyes, in some sort of crude frame fastened to the head, to modify the vision of the wearer, did not appear until the latter decades of the thirteenth century in northern Italy [8.1, 2]. By the fifteenth century spectacles had become more widely accepted; however, only the wealthy could afford them. The frames became more elaborate and fashionable, but not much in the way of advancement in the correction of vision was realized. In the mid seventeenth century, the German astronomer Johannes Kepler described the refraction of incoming light by the cornea and the crystalline lens of the eye and the formation of an inverted image of the retina. He also demonstrated that the eye could be farsighted or nearsighted and that these conditions could be improved with the aid of convex or concave ophthalmic lenses. As the understanding of the physiology of vision improved, advances in spectacle design appeared. Notable inventions of the eighteenth century included achromatic lenses in 1758 by Dollan and bifocals in 1784 by the famous American scientist and statesman, Benjamin Franklin.

8.1.2 The Optics of Vision and Ophthalmic Lenses

One must understand a bit of the biology of human vision and elementary optics in order to fully appreciate the need for ophthalmic lenses. Many excellent texts provide detailed descriptions of the mechanics of human vision, far beyond the scope of this text [8.3, 4]. A basic overview of the formation of images by the visual system will be given. The details of the perception of colour will be omitted here for the sake of brevity.
One can describe the human eye as a positive lens system, containing several refractive elements, which gathers light and forms a real image on a light-sensitive surface. Figure 8.1 illustrates a simplified version of its basic components. The eye is a nearly spherical body surrounded by a tough membrane called the sclera. With the exception of the transparent front portion of the cornea, the sclera is white and opaque. The air–cornea interface provides the greatest refraction of light within the human eye as a result of the large difference in refractive index between the air and the cornea. The chamber behind the cornea is filled with a clear watery liquid called the aqueous humor. Little refraction of incoming light will occur at this interface because of the similarities in refractive index between the cornea and aqueous humor. This chamber also contains a diaphragm known as the iris which controls the amount of light entering the eye through the circular pupil at its centre. The pupil contracts or dilates in response to changes in the intensity of ambient light. The pupil will also contract to increase image sharpness when doing close work, thereby enhancing the depth of focus to the eye. The crystalline lens, a complex, layered fibrous structure surrounded by an elastic membrane, is located just beyond the iris. Its laminar structure varies in refractive index from 1.406 at the centre to approximately 1.386 at the surface. It is attached to the ciliary muscles by a series of radially arranged ligaments around the periphery of the lens. The crystalline lens provides the visual system with the necessary means of adjusting fine focusing through changes in its shape which vary the focal length and, therefore, the power of the lens. Behind the lens is another chamber filled with a transparent, gelatinous material known as the vitreous humor. The inner surface of the sclera is covered by an inner shell called the choroid, whose main function is to absorb stray light entering the eye. The final component of the eye’s optical system is the retina which is composed of a thin layer of light-sensitive cells that covers a large part of the choroid. These receptor cells absorb the light impinging upon the retina and convert the image via photochemical reactions to an electrical signal which is transmitted via the optic nerve to the brain. It is interesting to note that while the image focused on the retina is both inverted and reversed with respect to the true orientation of the object, the brain has learned to interpret this signal as normal [8.3].