is required in centimetres or millimetres, then divide the number into 100 for the former, into 1,000 for the latter. $2\frac{1}{2}$ centimetres or 25 millimetres equals 1 inch; therefore a 5D lens has a focal length of 8 inches, 20 centimetres or 200 millimetres. By dividing the focal length in inches into 40 you get the *refractive* power of the lens. If the focal length is known in millimetres, divide into 1,000 to get the refractive power. Thus the focal length of a lens is 200 *millimetres*; then $\frac{1000}{200} = 5D$.

The inch in various countries differs, so that the number of a foreign (not English or American) made lens numbered in inches is different from the home-made article. The French inch is longer than the English, and it only takes 37 of them to make a metre, while nearly 40 English are required. A No. 18 lens of French make is about equivalent to a No. 20 English or American. The dioptric scale is, however, the same the whole world over.

The only measurement of refraction is by diopters, that must be remembered. You cannot measure refraction by inches, nor can you measure focal length by diopters. So many diopters represent so much bending power of the lens; so many inches or centimetres focal length represent the distance behind the lens at which the focus is obtained.

The employment of the dioptric scale of measurement and the thorough grasping of the fact that a certaim number of diopters means a certain quantity of refraction facilitates in an extraordinary degree the comprehension of defects of sight and the proper correction by lenses.

A convex or positive lens is known by the following tests:

(1) It is thicker in the centre than at the edges.

(2) It magnifies when the object of within its focal length.

(3) It gives a positive focus, so that a real image of a bright picture, such as a candle flame, a doorway or a window, can be obtained by it and thrown on to a screen.

(4) If an object distant a few feet be looked at through the lens and the latter moved, then the object will appear to move in the contrary direction.

A concave or negative lens is known by the following tests, which are exactly the contrary of those that prove a convex lens:

(1) It is thinner in the centre than at the edges.

(2) It diminishes objects looked at it through it.

(3) It has no real focus, so no image can be got on a screen. It has only a negative focus, and gives only a virtual image by projecting the rays backwards.

(4) When moved in any direction, an object seen through it appears to move in the same direction as the lens.

If a lens made of plain glass be held in front of the eye, the rays from an object looked at are perpendicular to the surface of the lens; there is *no refraction*, the object looks exactly the same as if no piece of glass were held between it and the eye, and if the lens be moved the object remains stationary. This test of lenses by moving them in front of the eye and noting whether the object looked at moves in a contrary or in the same direction as the lens is by far the simplest and most perfect method of distinguishing between convex and concave lenses, and is practically the only one when the glass is very weak. It is sometimes rather hard for beginners to perceive the direction of the movement, but a little practice soon overcomes that difficulty.

The lens must not be moved backwards and forwards—that only confuses; it must be held between the first finger and thumb, about eight inches in front of the eye, and moved directly downwards by one clear movement. The object looked at should be a thin, horizontal line, such as a shelf. When the lens has been moved down, you will be looking at the *horizontal line through the extreme upper* part of the lens, and will be able to see, at the same time, the line on either side of the lens (see Fig. 21). If the part of

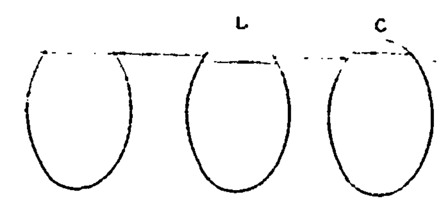

FIG. 21.

the line seen through the lens be continuous with the parts seen outside, the lens is a plano, as in *A*, Fig. 21. If the part of the line seen through the lens is lower than the other parts, the lens is concave, as in *B*, Fig. 21. If the part of the line seen through the lens is higher than the other parts, the lens is convex, as in *C*, Fig. 21. The lens should not be held too close to the eye; as then you cannot see on either side of the glass. If, however, the lens be a strong convex, it must be brought closer, or you will not be able to see through it at all; but in such cases the movement is so very decided that there is no difficulty in deciding as to the positive or negative refraction. It should be noted that the deviation of the object is always in the direction of the apices of the prisms of which the lens is practically formed.

If a strong convex lens be looked through when held a certain distance away greater than its focal length; for instance, if a 5-inch convex lens be held 10 inches in front of the eye, the rays of light passing through it will have come to a focus and crossed in the air, and will, therefore, enter the eye divergent, so that the movement of the object when the lens is moved will be the same as that of a concave lens.

You will not, however, be liable to make a mistake in such a case, as the thickness of the lens in the centre alone *will show its kind of refraction without* any special test, besides which the object is seen inverted, the rays of light having *crossed before entering the eye.*

You will find it of the greatest convenience to get an analyzing card, as in Fig. 22. It consists of a sheet of white

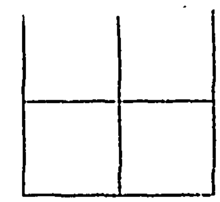

FIG. 22.

cardboard about 2 ft. square, with a clean cross formed of black lines, $\frac{1}{4}$-inch wide, running straight across it vertically and horizontally. This should be employed for all testing and neutralizing of lenses of every description. It is equally good for sphericals, cylinders, or prisms, and for analyzing, neutralizing, centering, etc. It is best used at a distance of about 10 ft.

By the displacement of the horizontal *line on the analyzing card when the lens is* moved vertically downwards, it is easy to neutralize and learn the number of an unknown lens. First, note if it be convex or concave. If it be concave, put over it a convex as near the number as you can judge; then move the two lenses together, and, if the movement be still that of a concave, the neutralizing convex is not strong enough, and you must try a stronger convex lens. *If with the first neutralizing* lens you try you find the movement of the two combined to be that of a convex, the neutralizing convex lens is too strong, and you must try a weaker one. By reducing or increasing the strength of the neutralizer, you will presently find that convex lens which, when placed over the concave, will cause absolutely no displacement of the line when the two together are moved: *they will act as plain* glass (refer to Fig. 13). The number of the neutralized concave is the same as that of the neutralizing convex. To find the number of an unknown convex lens, the neutralizing must, of course, be done with concave lenses.

When the lens is very strong, say, more than 8D, it is difficult to get an absolute neutralization; there will always be some *slight movement in the peripheral (outside)* portion of the lenses, although near the centre there will be practically none when the proper neutralizer is applied; anyhow, the latter will cause decidedly less movement than either the next stronger or the next weaker lens, so that you cannot fail to learn the right number.

This failure to get complete neutralization with strong lenses is due to spherical aberration, or, more likely perhaps, for the following reason.

A substance very like vanillin has been obtained, but only in very minute quantity, from essential oil of cloves.