The Science of Optics.

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Emmetropia.

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A much simpler and quicker method, and one that serves quite well enough for general purposes, is to make the refraction normal by the distance test and then to find the nearest point at which the fine print can be read; this is the P.P.; measure its distance from the eyes and divide the distance into 40, the result is the amplitude. For instance, the P.P. is at 8 in., then 8 into 40 gives 5, which is the amplitude in D; or the P.P. is at 4½ in., then that into 40 goes 9 times and the amplitude is 9 diopters. By this test it can be learnt if the accommodation be normal according to age and also, in many cases, if the correcting lenses be about right. It also gives approximately the age of a person; for example, if you find an amplitude of 7D you can reckon the person to be very near to 30 years old. The accommodation in both eyes is always the same; if there be a difference of vision it is due to the refraction. Perhaps a little more accurately it might be found by testing each eye separately, the other being covered.

If parallel rays from a candle 20 ft. distant be focussed on to a screen of white paper by a convex lens of 1 in. focal length or 40D refraction a clear sharp image of the flame will be obtained on the screen if the lens be exactly 1 in. in front of it. If, now, the candle b brought nearer than 20 ft., the rays proceeding from it to the lens are divergent and the image is blurred unless the lens be moved further from the screen and nearer to the candle, or the screen placed further back. But let us suppose that, both the screen and the lens being firmly fixed, the distance between them cannot be increased. In such a case there is but one means of getting a sharp focus, and that is by adding to the 1 inch lens another whose refractive power is just enough to make the divergent rays parallel before they enter the fixed lens. From what has been said before it should be known that if the rays be divergent from, say, 10 in. then a 10 in. lens will make them parallel; and the same with those from any other distance, a convex lens of that focal length will render them parallel. So that if the candle be at 40 in. a 40 in. convex or a + 1D lens must be added to the fixed lens; then the divergent rays from the candle 40 inches off will be rendered parallel; and being parallel when they enter the 1 in. or 40D lens the strength of the latter is sufficient to bring them to a focus on to the screen. If the candle be brought to 20 in. it requires a 20 in. convex or + 2D lens; if it be at 10 inches it requires a 10 in. or + 4D lens, and so with any other position of the candle.

So also the refractive power of the emmetropic eye, 50D, just suffices to bring parallel rays to a focus on the retina, but if the rays come from an object that is nearer than 20 ft., the rays being divergent, the refractive power of the eye is not sufficient, and in order to bring them to a focus at the retina it must be increased in strength; this increase is obtained from the accommodation, and the nearer the object is the more divergent are the rays and the greater is the amount of accommodation required in order that the object be seen. Accommodation can therefore be defined as "The power to form a clear image of divergent rays," or as "The adaptation of the eye to seeing objects at various distances."

The quantity of accommodation exerted for seeing a thing at any certain distance is the same as I illustrated with the lenses thus

	Distance in inches.	Distance in Cm.	Ac. exerted.
At	∞	∞	None
	160	400	0.25D.
	40	100	1.00D.
	20	50	2.00D.
	8	20	5.00D.

To find the quantity employed divide the distance in inches into 40, and the result is the diopters of accommodation; for instance, at 5 in. 8D of accommodation is exerted; at 16 inches 2.5D of accommodation; at 13 inches 3D of accommodation, and so on. If the distance is in centimetres, then divide into 100; if in millimetres, divide into 1,000. For example, the quantity of accommodation employed for seeing an object at six inches, 15 centimetres or 150 millimetres, then these numbers divided respectively into 40, 100, and 1,000 give the same result, viz., 6.50D of accommodation. There is often a small fraction left, as in the last example, which need not be reckoned.

If the calculation of the accommodation be made in inches, it is exactly the same as the distance of the object. If the origin of the rays be at 13 inches, then the accommodation employed is $\frac{1}{13}$, which is the refractive power equal to that found in a $\frac{1}{13}$ or No. 13 lens—namely 3D, but the accommodation can properly only be reckoned by diopters.

When a person is well advanced in age the diminution of the amplitude of accommodation shows itself by the defect known as old sight.

Convergence is that power of the internal recti to turn the two visual axes to any point nearer than 20 feet, so that a single object be seen by the two eyes at the same time.

When the eyes are directed to a distant point the visual axes are said to be parallel. They are not really so, but the amount of inclination is so extremely small as not to be worth considering.

The measurement of convergence is by metre angles (symbol MA). The unit 1 MA, is the quantity of convergence exerted in order to fuse the images of an object 1 metre or 40 inches distant. For points nearer than 40 inches more convergence must be employed and the quantity for any given point is found by dividing 40 by the number of inches the object is distant, or if calculated by centimetres, by dividing 100.

The following gives the convergence for various distances:

	Distance in inches.	In Cm.	Con. exerted.
At	∞	∞	None.
	160	400	0.25 M.A.
	40	100	1.00
	20	.50	2.00
	8	.20	5.00

For more on this subject see chapter on convergence.

Then at ∞ no accommodation is required in order that rays be focussed on the retina, nor is any convergence required in order that a single object be seen by both eyes, but at any point short of 20 feet both functions are brought into play, and the number of MA of convergence for any distance is the same as the number of D of accommodation; in fact, the metre angles measurement of convergence was adopted in order to make this fact more simple of calculation. When the eyes are directed to the reading point of, say, 16 inches, the convergence exerted is 2.50 MA and the accommodation employed for focussing such divergent rays is 2.50D, and at every other distance the same quantity of the two functions is exerted so long as the eyes are normal as to their refraction.

In emmetropia the harmonious working of the two functions takes place quite naturally without jar or cognizance of the fact, and, moreover, if the eyes be converged to a certain point the accommodation necessary for seeing at that distance is also immediately exerted; also, if the eyes be accommodated for a certain distance, they are at once converged to the same point. A person blind of one eye, to whom convergence is therefore useless, will, when reading, turn them both inwards. There is no doubt that the muscles of accommodation and convergence have their innervation at the same source, so that their movements are associated.

So intimate is the connection between the working of the ciliary and that of the internal recti that the slightest disturbance of their joint action in some eyes results in that condition which is called asthenopia—a weak, painful condition of the eyes. This defect can almost invariably be traced to the want of co-ordination between accommodation and convergence, due to one set of muscles being deficient in strength, or to the fact that, owing to an error of refraction, the one function has to be used in excess of the other.

Although the convergence and accommodation are thus intimately connected,