A simple focometer for the determination of short focal lengths, both negative and positive

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A SIMPLE FOCOMETER FOR THE DETERMINATION OF SHORT FOCAL LENGTHS, BOTH NEGATIVE AND POSITIVE.

By Mr. T. F. Connolly, M.Sc.

Read 9th March, 1916.

The object set out to achieve is the measurement to a fair and sufficient degree of accuracy of focal lengths of positive lenses (chiefly single lenses), from ½ to 3 inches focus, and also similar measurements for simple or compound negative lenses from ¼ to 2½ inches in focal length. These measurements are not those required in careful design of optical systems but correspond rather to workshop requirements or students' laboratory work. In the case of the instrument for negative lenses, I find that an accuracy of one or two per cent. or better can be obtained with moderate care on simple lenses. This accuracy, I think it will be recognised, is adequate for most purposes.

In both cases the measurement of focal length depends on a measurement of the distance from the lens to the focal plane. It is, therefore, necessary to have some knowledge of the position of the "nodal points" or "equivalent points" of the lens under examination. For positive lenses the following cases must be recognised.

(1) Plano-Convex Lens.

In this case the lens should be so placed in the instrument that the convex side is turned towards the ground glass. This is theoretically very disadvantageous on account of "spherical aberration," but as the aperture of the beam is limited to one third of an inch in the instrument, the aberration can be practically neglected. When focus is obtained in the position stated the focal length is measured from the screen to the apex of the curved surface and is at once read off in millimeters or inches on the scales provided.

(2) Double Convex Lens.

In the case of double convex lenses the measurement is no longer from the lens surface to the screen but from a point (" nodal point ") within the lens. If the thickness of the lens does not exceed a few millimeters, this point may be taken as being one third of the thickness from the back surface. As the instrument records the thickness of the lens under examination, this extra $\frac{1}{3}$ has only to be added to the reading given by the back index.

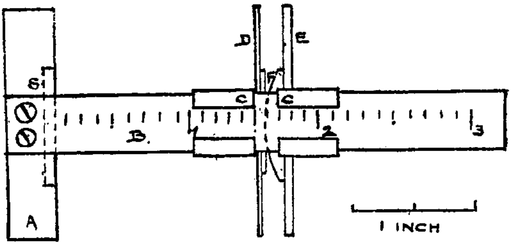

FIG. 1.

(3) Meniscus Lenses.

Here the nodal points are often outside the lens altogether and the " image-size " method, to be described later, is recommended.

From the above the limitations of the instrument will be clearly recognised but it is thought that its simplicity and convenience will be some compensation.

The positive instrument consists essentially of a 2-inch square wooden base to which are attached two bars. These bars guide and support the lens holder. This latter consists of two thin plates of glass (E D) attached to metal slides. As will be seen from the drawing, the

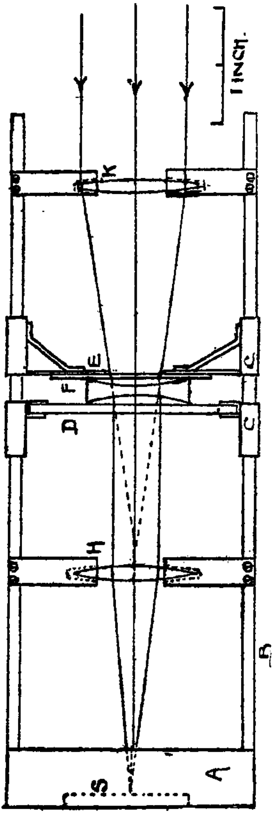

Fig. 2.

position of the two inner surfaces of the glass plates, and consequently the size of the lens enclosed, correspond to the readings of the two indices on the graduated bar.

The instrument is easily calibrated (or scaled) by using a lens of known focal length, and can similarly be checked at any time.

Thus scaled focal lengths, within the accuracy stated, are immediately available.

Without an optical bench or some rather elaborate or expensive apparatus it has not been possible hitherto to make measurements with any pretentions to accuracy of short negative focal lengths. The simple and handy optical system to be described allows this to be done with great ease.

A positive lens (K, fig. 2) gives a converging cone of rays. The next positive lens (H) is so adjusted that, if it receives parallel rays, or rays from a distant object, they are sharply focused on the screen. On placing the negative lens to be measured between the glass plates (D E) and adjusting the position along the bar, the converging beam is converted into a parallel beam as shown. This is easily recognised, as focus is once more obtained on the screen (S).

The distance from the point of convergence, or focus, of the first positive lens and the centre of the negative lens gives practically a a very close approximation to the focal length. It is thus seen that the mean position between the two reading indices (C C) on the scales is the focal length. The above, of course, applies to symmetrical concave lenses, the nodal points of which are always inside the thinnest central part and, therefore, practically central. The positive lens (H) now used is a corrected achromatic lens so that the convergng cone of rays is without aberration. This is of importance when the negative focal lengths are relatively small.

In use the instrument is conveniently mounted on a base as shown in the photograph (fig 3) and the light from a workshop window, gas lamp, etc., situated at least 16 or 20 feet away, is directed vertically through the instrument by means of the small movable mirror below.

In cases where the positions of the "nodal points" are not evident both instruments lend themselves easily to a focal length measurement which is independent of a knowledge of these positions.

In both cases the addition required is a small photographed scale of conveniently half mm. (approximately $\frac{1}{50}$ inch) which can be fixed on the ground glass screen. If a standard positive lens is available any focal length, within the limits of the instrument, can be found as the image sizes of any object are *directly proportional to the focal lengths.* With a standard negative lens a similar statement holds. In this case, however, the image sizes are *inversely* proportional to the focal lengths. The reason for this, as will be obvious from fig. 2, is that the negative lens under examination, in conjunction with the achromatic positive, forms a Galilean binocular and what we are really doing

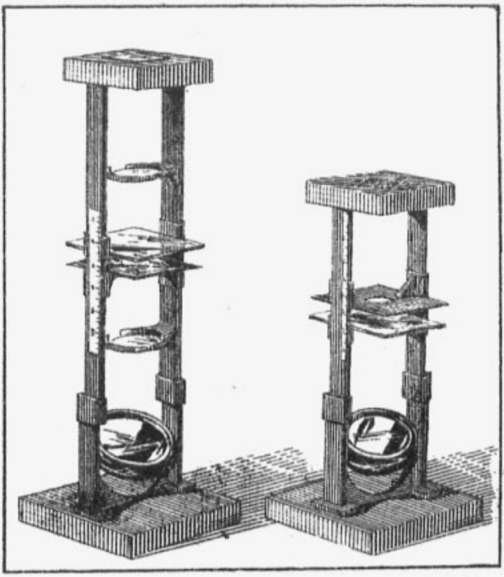

FIG. 3. FIG. 4.

is comparing the magnifying power of two different binoculars. The higher power is, of course, given by the system with the shorter focus negative lens.

The whole instrument has been designed so that its cost may be a minimum and thus it may be easily available to all.

I wish in conclusion to express my thanks to Messrs. Henry Hughes & Sons, opticians, Fenchurch Street, who have carried out my suggestions in a most skilful and sympathetic manner. I understand that they are willing, and they have my fullest permission, if that be necessary, to make a similar instrument for any one to whom it may be useful. My thanks are also due to Mr. W. Shackleton, F.R.A.S., for making me an experimental stand, and to Mr. Chalmers, M.A., for his general helpfulness and for the loan of carefully measured lenses which I used as standards. I am also grateful to Mr. Cheshire for his aid.

Discussion.

The PRESIDENT said that before proceeding with the discussion he wished to show two instruments which he would explain in a few words. The first was a workshop focometer made up from a simple rigid microscope stand. This was an instrument with which the true focal length of any lens not greater than four inches could be determined very quickly to a high order of accuracy. The essential part of the focometer was a collimator fitted to the substage, after the suggestion of Mr. Blakesley. This collimator consists of a short tube with an achromatic lens of about one inch focal length at the middle. At the lower end of the tube in the anterior focal plane a glass diaphragm is inserted with two lines a millimeter apart, crossed by a fine line at right angles, thus making the ruled diaphragm to the shape of a letter H. In the upper end of the tube in the posterior focal plane of the lens a metal diaphragm is fixed, made with a long narrow slit arranged parallel to the millimeter lines in the glass diaphragm below. The draw tube of the microscope is fitted with a low power objective at its lower end and a centimeter divided into one hundred parts in the eyepiece. In practice it is very desirable that the magnifying power of the draw tube microscope should be made equal to the focal length of the collimating lens in centimeters. When this is done each division of the eyepiece scale represents one millimeter of focal length. To determine the focal length of a lens it is only necessary to place it upon the microscope stage on the upper end of the collimator, and then rack back the microscope body until the two lines of the collimator scale —that is the two lines a millimeter apart—are focused on the eyepiece scale. The distance between the two projected line images in divisions of the eyepiece scale, is the focal length of the lens being tested, in millimeters. The apparatus may be employed either for negative or positive lenses. The image of the horizontal line on the collimator scale is projected with the aperture of the lens determined by the length of the slit already referred to for adjusting the position of a focal plane, therefore, the image of this line is observed.

The second instrument is an instrument for measuring back focal lengths in diopters and has been patented by Carl Zeiss on specification No. 12,100 of 1914. [This was reproduced in No. 1,304 of The Optician.—Ed.] The instrument itself had been invented more particularly for dealing with spectacle lenses.

Mr. Chalmers suggested that some of the members might prefer to send in written communciations rather than attempt to criticise Mr. Connolly's paper orally.

Mr. Everitt considered the application of an auxiliary positive lens to focus a parallel beam was particularly useful, and he was not aware that it had ever been done before.