Solution of the Experimental Problem

While looking at objects through lenses it is easy to establish that there were given two converging lenses and a diverging one.

The peculiarity of the given problem is the absence of a white screen on the list of the equipment that is used to observe real images. The competitors were supposed to determine the position of the images by the parallance method observing the images with their eyes.

The focal distance of the converging lens may be determined by the following method.

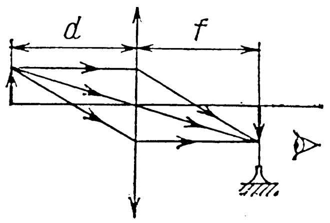

Fig. 7

Using a lens one can obtain a real image of a geometrical figure shown on the screen. The position of the real image is registered by the parallax method: if one places a vertical wire (Fig.7) to the point, in which the image is located, then at small displacements of the eye from the main optical axis of the lens the image of this object and the wire will not diverge.

We obtain the value of focal distance F from the formula of thin lens by the measured distances d and f:

$$\frac{1}{F_{1,2}} = \frac{1}{d} + \frac{1}{f}; \qquad F_{1,2} = \frac{df}{d+f} .$$

In this method the best accuracy is achieved in the case of

$$f = d.$$

The competitors were not asked to make a conclusion.

The error of measuring the focal distance for each of the two converging lenses can be determined by multiple repeated measurements. The total number of points was given to those competitors who carried out not less fewer than n=5 measurements of the focal distance and estimated the mean value of the focal distance Fav:

$$F_{\text{av}} = \frac{1}{n}\sum_{1}^{n} F_i$$

and the absolute error ΔF

$$\Delta F = \frac{1}{n}\sum_{1}^{n} \Delta F_i , \qquad \Delta F_i = \left| F_i - F_{\text{av}} \right|$$

or root mean square error ΔF_{rms}

$$\Delta F_{\text{rms}} = \frac{1}{n}\sqrt{\sum\left(\Delta F_i\right)^2} .$$

One could calculate the error by graphic method.

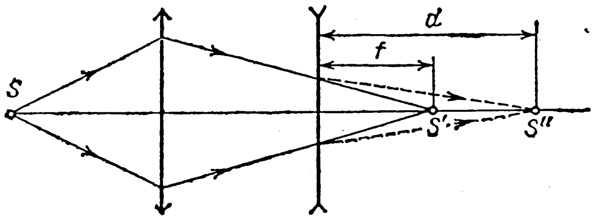

Fig. 8

Determination of the focal distance of the diverging lens can be carried out by the method of compensation. With this goal one has to obtain a real image *S*' of the object *S* using a converging lens. The position of the image can be registered using the parallax method.

If one places a diverging lens between the image and the converging lens the image will be displaced. Let us find a new position of the image *S*". Using the reversibility property of the light rays, one can admit that the light rays leave the point *S*". Then point *S*' is a virtual image of the point *S*", whereas the distances from the optical centre of the concave lens to the points *S*' and *S*" are, respectively, the distances *f* to the image and *d* to the object (Fig.8). Using the formula of a thin lens we obtain

$$\frac{1}{F_3} = -\frac{1}{f} + \frac{1}{d}; \qquad F_3 = -\frac{fd}{d-f} < 0 .$$

Here F < 0 is the focal distance of the diverging lens. In this case the error of measuring the focal distance can also be estimated by the method of repeated measurements similar to the case of the converging lens.

Typical results are:

$F_1 = (22{,}0 \pm 0{,}4)cm$, $F_2 = (12{,}3 \pm 0{,}3)cm$, $F_3 = (-8{,}4 \pm 0{,}4)cm$.

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