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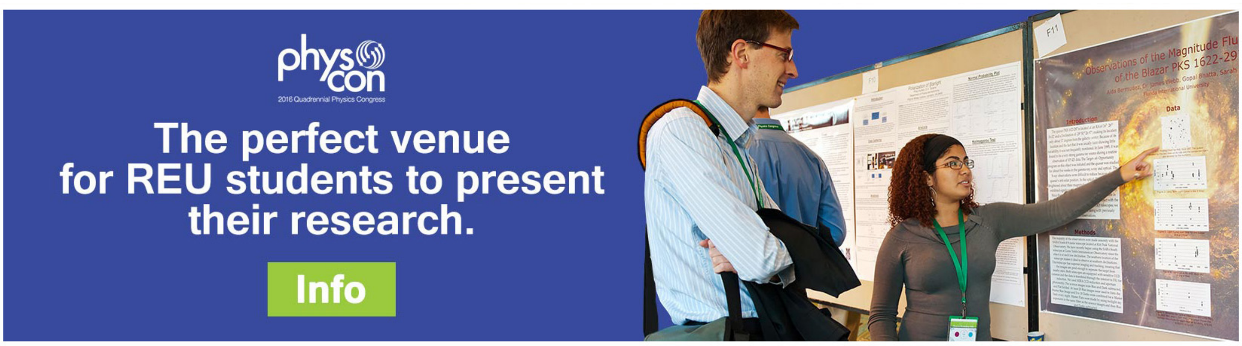

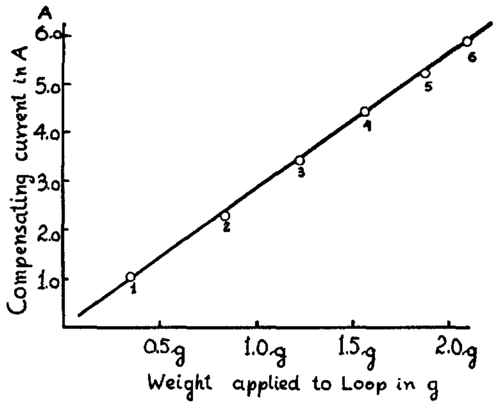

FIG. 2. Relationship between current and compensating weights.

with 0.1 amp reading is used. A simplified construction of somewhat different design of the instrument described above was used in a general physics laboratory course at the University of Prague, Department of Physics, Prague, Czechoslovakia before World War II.

* This instrument was exhibited at the Colloquium of College Physicists, State University of Iowa, Iowa City, Iowa, June, 1947.
† Research Paper No. 934, Journal Series, University of Arkansas.
[1] A. A. Cotton, J. Phys. 9, 384 (1900).

A Basic Principle for the Telescope and Microscope

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WHEN introducing telescopes and microscopes in our physics and optics courses, the characteristic features of each instrument are usually described. Thereafter, they are too often thought of as unrelated pieces of equipment except that light passes through each of them. Although the individuality of each instrument must be emphasized, the close relationship between them will be imparted to the student if he is first introduced to a basic principle from which both instruments can be derived. The usual prerequisites, including the formation of real and virtual images, magnification, and an understanding of accommodation in the eye should forego this presentation.

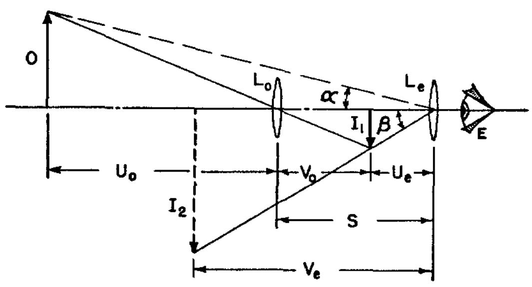

FIG. 1. The basic optical principle. L_o, objective lens; L_e, eyepiece lens; O, object; I_1, length of initial (real) image; I_2, length of final (virtual) image; U_o, distance from O to L_o; V_o, distance from I_1 to L_o; U_e, distance from I_1 to L_e; V_e, distance from I_2 to L_e; α, β, angles subtended at eye by O and by I_2; S, distance between L_e and L_o; E, the eye, deemed coincident with L_e.

The basic optical principle concerned can be demonstrated from Fig. 1. Lens L_o forms an image I_1 of an object O. In either a telescope or a microscope this image is viewed with the eye through an eyepiece L_e. Angular magnification is used in describing the performance of visual instruments. A general expression for magnification is derived as follows.

When considering the linear image I_2 and the linear object O, in Fig. 1,

$$M = \tan\beta/\tan\alpha, \qquad (1)$$

where M is the angular magnification. Now

$$\tan\beta = I_2/V_e, \quad \text{and} \quad \tan\alpha = O/(S+U_o). \qquad (2)$$

By similar triangles

$$I_2 = (V_e/U_e)I_1, \quad \text{and} \quad I_1 = (V_o/U_o)O. \qquad (3)$$

From Eqs. (1)–(3)

$$M = \frac{I_2/V_e}{O/(S+U_o)} = \frac{S+U_o}{U_e}\frac{V_o}{U_o}. \qquad (4)$$

This equation defines the magnification in terms of linear axial distances that apply to the general two-lens system shown.

In a telescope the angular subtense of the final image is compared with that of the object viewed at a distance. The object O is at ∞; S is negligible compared with U_o, and Eq. (4) becomes

$$M = V_o/U_e. \qquad (5)$$

Since $U_o = \infty$, $V_o = f_o$, and $U_e = f_e$, where f_o is the focal length of the objective and f_e is the focal length of the eyepiece. Then Eq. (5) becomes

$$M = f_o/f_e. \qquad (6)$$

This is the familiar expression for the magnification of a telescope.

In a microscope the angular subtense of the final image is compared with that of the object viewed by the naked eye at the distance of distinct vision, D. (This distance is generally taken as 10 in. or 25 cm.) In this case

$$D = S + U_o. \qquad (7)$$

Substituting Eq. (7) into Eq. (4) we find that

$$M = DV_o/U_eU_o. \qquad (8)$$

For the usual condition in a microscope, image I_2 is located at distance D from the eye, so $D = V_e$. Then $D/U_e = V_e/U_e = m_e$, where m_e is the magnification due to the eyepiece. Similarly, $V_o/U_o = I_1/O = m_o$, where m_o is the magnification due to the objective. Then Eq. (8) becomes $M = m_e m_o$. This is the familiar expression for the magnification of a microscope. The relationship between the telescope and microscope has thus been established by deriving the expression for the magnification of each from a common general equation.