NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

EVIDENCE THAT PERSISTENCE OF VISION IS A PHYSICAL CONDUCTION PHENOMENON.

By Herbert E. Ives.

In developing a physical theory to explain persistence of vision and the behavior of the flicker photometer, Ives and Kingsbury[1] have made use of the Fourier conduction equation, thereby assuming that the necessary sluggishness of the visual apparatus is introduced by the transmitting medium, *e.g.*, the optic nerve, which would accordingly have the characteristics of a cable or telephone line of considerable length.

An alternative and perhaps simpler assumption would be that the inertia is a property of the surface at which the reaction due to light takes place, the effective length of the transmitting system being negligibly small, so that the reaction may be considered as being measured at the point of occurrence.

This condition may be expressed by the equation

$$I_0 = c\frac{d\Theta}{dt} + b\Theta \qquad (1)$$

where I_0 = intensity of stimulus, *i.e.*, rate of reception of radiant energy.
- t = time.
- c = capacity of surface.
- θ = quality (*e.g.*, temperature, potential, concentration, etc.).
- b = coefficient of loss of energy, as by radiation or conduction.

If this surface receives radiant energy whose intensity varies in a periodic manner, as represented by the equation

$$I_0 = \frac{I_1}{2} + \frac{I_1}{2}\sin \omega t \quad \begin{pmatrix}\omega = \text{angular speed} = 2\pi \times \text{frequency} \\ t = \text{time.}\end{pmatrix} \qquad (2)$$

the resultant reaction is given by the equation

$$\Theta = \frac{I_1}{2(b^2 + c^2\omega^2)}(b \sin \omega t - c\omega \cos \omega t) + \frac{I_1}{2b} + \left(\frac{I_1 \omega c}{2(b^2 + c_2\omega^2)} - \frac{I}{2b}\right)e^{-\frac{bt}{c}} \qquad (3)$$

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* Communicated by the Chief Physicist.

[1] *Philosophical Magazine*, November, 1914, p. 708, and April, 1916, p. 290.

It is evident that if ω is made large enough a uniform effect is produced after the steady state is reached, proportional to $\frac{I_1}{2}$. This treatment is therefore satisfactory in so far as Talbot's law is concerned.

In order to choose between this treatment and the one involving the idea of conduction, it is necessary to study the speed of disappearance of flicker. An apparently crucial test is furnished by studying the critical speed for two dove-tailed sine-curve stimuli, I_1 and I_2. Introducing these in equation (3), it is found by differentiation that the range of amplitude of the reaction is

$$R = \frac{I_1 - I_2}{\sqrt{b^2 + c^2\omega^2}} \tag{4}$$

and the fraction this is of the mean amplitude is

$$\delta = \left(\frac{I_1 - I_2}{I_1 + I_2}\right)\frac{2b}{\sqrt{b^2 + c^2\omega^2}} \tag{5}$$

If we assume that the condition for disappearance of flicker is the constancy of δ we may solve for the critical speed, obtaining

$$\omega_c = \frac{2b}{c\delta}\sqrt{\left(\frac{I_1 - I_2}{I_1 + I_2}\right)^2 - \left(\frac{\delta}{2}\right)^2} \tag{6}$$

If ω is plotted against $I_1 - I_2$ for small values of δ, it is evident that the result is practically a straight line. Actually, as shown by experiment, the relationship is represented by a pronounced curve, to which fact is largely due the sensibility of the flicker photometer.

The equation similar to (6) which is derived from the conduction theory is

$$\omega_c = 2K\frac{\left(\log\frac{2}{\delta} + \log\frac{I_1 - I_2}{I_1 + I_2}\right)^2}{(x \log e)^2} \tag{7}$$

which represents the experimental facts excellently.

Other equations similar to (1) which have been suggested for visual processes and which do not take into account the effect of a transmitting medium appear to fail in the same way.

It thus appears that the damping effect to which persistence of vision is due is located in a conducting medium, which fact must be recognized in any theory of visual response.