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## Group-Phase Velocity Demonstrator

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Equations (4A) and (4B) can be written as

$$R = t' d\mu/d\lambda, \quad (5)$$

where  $t'$  may be called the effective base of the prism and is the longest path travelled by the light in the prism.

It is evident that the resolving power varies with the angle of incidence, being maximum in the minimum deviation position ( $r_1 = r_2 = A/2$ ) and minimum when  $r_1 = 0$  or  $A$ , i.e., for normal incidence or emergence. Thus  $R_{\min} = R_0 \cos A/2$ .

The variation of  $R/R_0$  with  $r_1$  for a  $60^\circ$  prism is given in Table I and diagrammatically illustrated in Fig. 1.

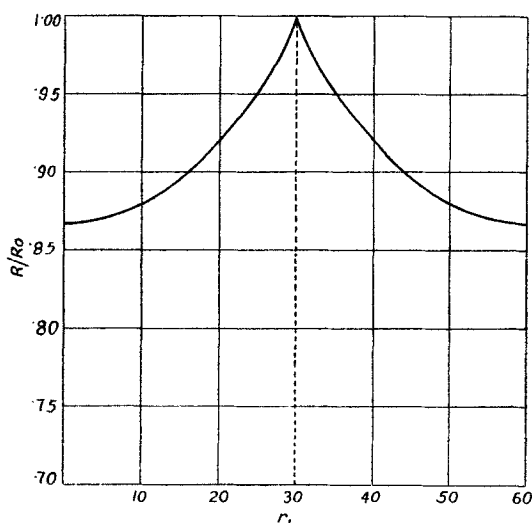


FIG. 1. Variation of the ratio  $R/R_0$  with  $r_1$ , where  $R$  is the resolving power of the prism,  $R_0$  its resolving power in position of minimum deviation, and  $r_1$  the first angle of refraction within the prism. The curve is drawn for a  $60^\circ$  prism.

If, however, the angle of incidence is kept constant the resolving power varies with wavelength in a spectrum. The variation due to the factor  $\cos \frac{1}{2}A / \cos(r_1 \text{ or } r_2)$  is small, as  $r_1$  and  $r_2$  do not change appreciably with wavelength. In such a case the dispersive power  $d\mu/d\lambda$  is mainly responsible for the variation of resolving power. Using Hartmann's dispersion formula we can write, for  $r_1 > A/2$ ,

$$R = \frac{t \cos \frac{1}{2}A \{ -c/(\lambda - \lambda_0)^2 \}}{\cos \left[ A - \sin^{-1} \left\{ \frac{\sin i_1}{\mu_0 + c/(\lambda - \lambda_0)} \right\} \right]}; \quad (6A)$$

and for  $r_1 < A/2$ ,

$$R = \frac{t \cos \frac{1}{2}A \{ -c/(\lambda - \lambda_0)^2 \}}{\left( 1 - \frac{\sin^2 i_1}{\{ \mu_0 + c/(\lambda - \lambda_0) \}^2} \right)^{1/2}}; \quad (6B)$$

## Group-Phase Velocity Demonstrator

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THE speed with which the concepts of group velocity, phase velocity, and beats are grasped, integrated, and retained can be materially aided with the following simple demonstration apparatus.

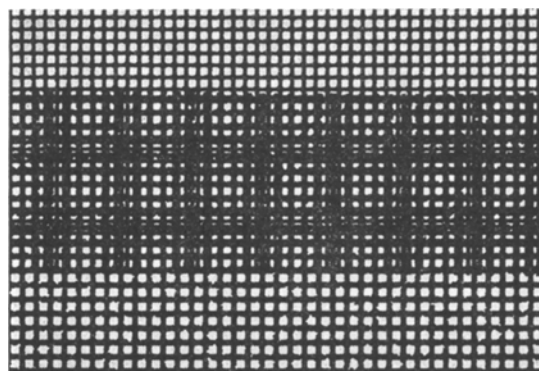


FIG. 1. Fifteen-mesh overlay pattern obtained by overlapping pieces of 65- and 80-mesh screening (magnification approximately 5 times).

Two pieces of Lectromesh screen (an electrolytically deposited screen made by the C. O. Jelliff Manufacturing Corporation, Southport, Connecticut) of dimensions 2 in.  $\times$  10 in. and of 65 and 80 mesh, respectively, are cut along the mesh and are separately mounted between pieces of cleared 2 in.  $\times$  10 in. spectrographic plates. The screening should be mounted parallel to one long edge of the glass plate, and each sandwich should be bound like a lantern slide with care taken so that the binding is parallel to the screen. Finally fiducial marks may be scribed or ruled in corresponding locations on each of the two sandwiches.

When the completed sandwiches are overlapped so that, say, an inch of 65-mesh screening, an inch of overlay, and an inch of 80-mesh screening are visible, the overlay displays a 15 mesh pattern (Fig. 1). Holding the 80-mesh screen stationary, a displacement of the 65-mesh screen to the right causes the 15-mesh pattern to move to the left. Holding the 65-mesh screen stationary, a displacement of the 80-mesh screen to the right causes the 15-mesh pattern to move to the right with greater speed than that of the 80-mesh screen. By superimposing a uniform velocity for the assembly as a whole upon the relative motions of the two screens, the difference between group and phase velocity can be made clear. The overlay 15-mesh pattern may be identified as the group wave while the 65- and 80-mesh screens may be considered as the separate phases. Thus the group velocity is distinctly different from the velocity of either phase, and the concept of group velocity is meaningful only when the two phases move with different velocities, hence in a dispersive medium.

The same apparatus may be used to illustrate beats by moving the two screens at the same speed. Here the

"group velocity" of the beat is the same as the separate phase velocities, corresponding to audible beats in air, an essentially nondispersive medium.

### A Dissipation Factor Anomaly

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IN studying capacitors the question arises as to whether the resistive loss which is present should be considered as a resistance in series or in parallel with the capacitance. It has been found that the dissipation factor is independent of the model used. In working on natural cork with a high moisture content in connection with this problem an anomaly has been found.

The rapid growth of electronics with circuits using inductors and capacitors has led to increased use of these terms:

storage factor (figure of merit)  $Q = X/R = \omega L/R = \tan \theta$   
as applied to an inductor

dissipation factor as applied  $D = R/X = \omega CR = \cot \theta$   
to a capacitor

where  $X$ =reactance;  $R$ =resistance;  $C$ =capacitance;  $L$ =inductance;  $\omega=2\pi$ (frequency);  $\theta$ =angle between the directions of  $X$  and  $R$ . For small values of  $D$ , where  $\cot \theta = \cos \theta$ , the term "power factor" is used.<sup>1</sup>

In each case  $R$  represents what is often an undesirable loss. An ideal inductor would have  $R=0$ , making  $Q$  infinite. An ideal capacitor would have  $D=0$ . For capacitors the question arises as to whether the  $R$  which represents the loss (in this case much smaller than for inductors) is equivalent to an  $R$  in series, in parallel, or to some other combination.

Crosbie<sup>2</sup> assumed three models: an  $R$  in series with a  $C$ ; an  $R$  in parallel with a  $C$ ; and an  $R$  in series with a  $C$  and  $R$  in parallel. He then proved that the working equation is the same regardless of the model. Consequently, using data from a capacitance bridge he obtained the same numerical value for  $D$  for each model. This leads to an interesting conclusion:  $D$  is an important measurable electrical quantity which does not depend on a model. The calculation for dielectric constant  $K$  depends entirely on the model.

In general a low value of  $D$  is desired, but today, with dielectric heating and conductive rubber, studies have been made of large  $D$ 's. Most substances show a steady

increase of  $D$  as  $K$  increases. A careful study of natural cork containing various percentages of water by weight, showed a maximum  $D$  at 7 percent moisture using a frequency of 1 kc/sec. At the same time  $K$  showed a steady increase.

Table I shows the variation of moisture with  $D$ ,  $K$ ,  $G$  (admittance), and  $B$  (susceptance), where  $K$ ,  $G$ , and  $B$  were calculated assuming a parallel model. For the capacitor with no dielectric  $G$  was 0,  $B$ ,  $7.4 \times 10^4$ .

Careful checks were made with the apparatus—a Schering bridge; readings were taken in a few seconds; but the effect still remained. Similar results were obtained using a moisture register<sup>3</sup> with insulating firebrick.

In each case where a reversal of  $D$  occurred,  $K$  increased steadily, regardless of the model. Nothing has been found in the theory to lead one to expect this reversal of  $D$ .

Since these data were taken over a period of a year, it was not possible to study the effect at other frequencies, except for dry natural cork. Indications are that similar results would have been obtained.

<sup>1</sup> ASTM Standards D150-44T.

<sup>2</sup> E. A. Crosbie, "Schering bridge measurements of high loss dielectric materials." Unpublished Master's thesis, Washington and Jefferson College Library, 1948.

<sup>3</sup> Moisture Register Company, Alhambra, California.

### Striations in Electromagnetic Stationary Waves

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IN the Lecher-wire method of measuring the wavelength of stationary electromagnetic waves, using a pair of parallel wires, a short-circuiting bar with a small incandescent lamp in it is usually used to determine the positions of the nodes and loops.<sup>1</sup> A much more striking and effective class demonstration is to use a fluorescent lamp placed between the wires as illustrated in Fig. 1. One of the 8-foot tubes is about the right length for our oscillator, which has a wavelength that is variable (tunable) from about 3 to 4 feet. The lamp lights except at the potential nodes, and

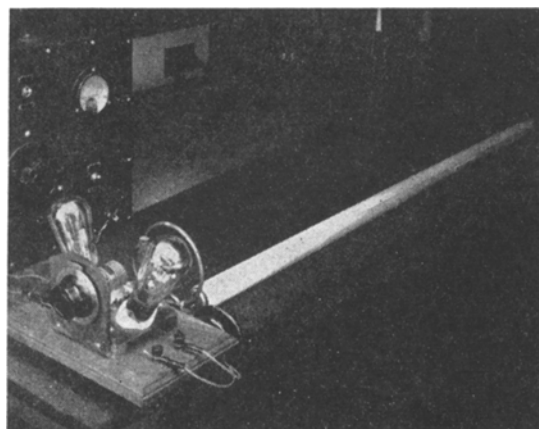


FIG. 1. Luminosity in a fluorescent lamp placed between Lecher wires.

TABLE I. Properties of cork.

| Percent Water | $D$    | $K$  | $G$                 | $B$               |
|---------------|--------|------|---------------------|-------------------|
| 0             | 0.0076 | 1.27 | $0.072 \times 10^4$ | $9.4 \times 10^4$ |
| 2             | 0.013  | 1.40 | 0.135               | 10.4              |
| 4             | 0.125  | 1.60 | 1.46                | 11.7              |
| 6             | 0.890  | 3.27 | 12.0                | 13.5              |
| 7             | 1.200  | 6.05 | 22.1                | 18.4              |
| 8             | 0.870  | 10.2 | 37.3                | 42.9              |
| 9             | 0.605  | 21.5 | 70.7                | 116.9             |
| 10            | 0.445  | 28.3 | 78.9                | 175.2             |
| 12            | 0.305  | 33.6 | 69.0                | 227.0             |