M_r being the factor of multiplication in the electron avalanche, r_i and r_e the radii of the central wire and the cylinder respectively. This equation can be shown to be valid with the observed values of α and β in hydrogen and nitrogen.

A similar expression for the photo-electric mechanism is not valid with the observed values of α and $\theta\eta g$. In this case the starting potentials would be expected to be at voltages equal to half the actual observed values.

Since the ionization by positive ions is confined to a narrow zone around the wire, the calculated time for development of the secondary avalanches will be of the order of 10^{-7} sec., even with the comparatively small mobilities of the positive ions. It can further be shown that many of the properties of the Geiger discharge hitherto unexplained can be easily accounted for by this interpretation of the discharge mechanism. The details of the investigation will shortly be published elsewhere.

The new explanation of the Geiger discharge will involve reconsideration in other gaseous discharges of the role of the positive ions for avalanche multiplication.

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The Scintillation of Stars

THE observational evidence provided in the letters which have appeared under this heading in *Nature* of April 29 and earlier suggests to a meteorologist that scintillation may be associated with waves at an interface between two currents of air. It is rather unlikely to be associated with turbulence because in a turbulent (that is, well-mixed) atmosphere the light from the star from one moment to another, passing, as it does, through thousands of random eddies, would be most unlikely to vary appreciably or in any systematic manner.

Waves at a discontinuity in the atmosphere, if traversed by the light, should, however, be capable of producing substantial and systematic optical differences. From the evidence of microbarograms, anemograms and cloud photographs, I estimated[1], a number of years ago, that such waves should not uncommonly have an amplitude of the order of up to 500–1,000 ft. at the interface, wave-length up to 10 miles or more, speed anything up to 40 ft. per sec., but probably usually lower. Such waves are most easily seen in the anemograms from a well-exposed station (for example, Bell Rock), where they are not obscured by surface turbulence effects. Though the waves can be seen from time to time in the records of individual stations, especially in the evening, it is seldom that the same fluctuations can be sufficiently related at a number of stations to enable the speed of propagation to be determined. The periods range from a minute or two up to an hour or more.

Quite recently a number of horizontal flights have been made by the Meteorological Research Flight, measuring temperature and frost point at intervals of about a mile (20 sec. flying time). In at least one case where a suitable discontinuity of wind and temperature existed, the measured temperatures and frost points appeared as wave-like oscillations consistent with waves of the dimensions mentioned earlier. It has to be kept in mind that usually, whenever there is a well-marked discontinuity in the atmosphere, the air below the discontinuity is characterized by saturation or near saturation, and very often a haze layer, while the air above is notably dry. The discontinuity of temperature may be of the order of 5°–7° F., so that waves of the dimensions mentioned might produce a sufficient optical effect; alternatively the periodic intervention of cloud or haze might be responsible. I have also examined and illustrated[2] the formation of cloud when the wave motion takes place under adiabatic conditions. The direction of travel of the waves is not usually, of course, the direction of the lower air current; it depends on the relative movement of the two currents.

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May 16.

[1] Goldie, A. H. R., *Quart. J. Roy. Met. Soc.*, **51**, No. 215 (1925).

[2] Goldie, A. H. R., *Proc. Roy. Soc. Edin.*, **45**, Pt. II, No. 17 (1925).

Magneto-Hydrodynamic Waves in a Plasma

AT low frequencies transverse waves can be propagated through a conducting liquid, situated in a magnetic field, as was first shown by H. Alfvén[1] and verified by S. Lundquist[2] in a laboratory experiment. The waves, as obtained by the reciprocal action between electric currents and motion of the liquid, were called magneto-hydrodynamic waves.

The theory was derived from Maxwell's equations:

$$\text{curl } \mathbf{H} = \frac{1}{c}\left(4\pi\mathbf{i} + \frac{\partial \mathbf{D}}{\partial t}\right) \qquad (1)$$

$$\text{curl } \mathbf{E} = -\frac{1}{c}\cdot\frac{\partial \mathbf{B}}{\partial t}\,; \qquad (2)$$

combined with

$$\mathbf{i} = \sigma\left(\mathbf{E} + \left[\frac{v}{c}\mathbf{B}\right]\right) \qquad (3)$$

$$\text{and } \rho\frac{d\mathbf{v}}{dt} = \left[\frac{\mathbf{i}}{c}\mathbf{B}\right] - \text{grad } p. \qquad (4)$$

Since the liquid is incompressible, the equation of continuity can be written

$$\text{div } \mathbf{v} = 0. \qquad (5)$$

A treatment of these equations shows that waves can be propagated along the lines of force of the applied magnetic field H_0 and that the phase velocity, for infinite conductivity, is

$$V = H_0/(4\pi\rho)^{1/2}, \qquad (6)$$

where ρ is the mass density of the liquid.

The displacement current is negligible compared with the conduction current. The latter is capacitive, storing energy as kinetic energy, which consequently takes the same role as the electric energy in the vacuum wave.

It is interesting to study whether waves of this type can exist in an ionized gas, where (3) and (5) do not hold. In order to investigate this problem, we use Maxwell's equations (1) and (2). Ignoring collisions, the current is

$$\mathbf{i} = \sum_{\nu} n_\nu e_\nu \mathbf{v}_\nu, \qquad (7)$$

where n_ν is the number of particles, e_ν the charge and $\mathbf{v}_\nu$ the directed velocity of the νth type of particle. The sum is to be extended over all types of particles.