the mathematical theory of the motion developed in this way was given by Rayleigh¹ in 1917, in explanation of the model cyclones devised by Aitken²; the mathematical theory was extended by Brunt³ in 1921 to apply to motion on a rotating earth.

The inner regions generally are found not to be examples of 'solid spin', at least in the lowest 2 km. of the atmosphere, but rather, in certain parts, regions of specially marked convergence. In brief, it is found that—below the 2 km. level—convergence towards the centre goes on, roughly with complete conservation of moment of momentum up to a certain distance (which in different cases varies from 300 km. to 500 km.) from the centre, and then—in place of conservation—there is, instead, as the air enters the inner region, a gradual fall of speed with closer approach to the centre.

The total inward flux of kinetic energy across the periphery of the inner region is so considerable—speeds at this periphery being commonly of the order of 40 m.p.h.—that a question naturally arises as to what work is being done to account for the loss of kinetic energy by the air in the course of its closer approach to the centre. The obvious explanation is that here is the work required in the later stages of the depression's life to raise bodily the large central core of troposphere which, by reason of continued ascent, has become colder, level for level, than its environment. Calculation in a typical case indicates that about half the probable inward flux of kinetic energy below the 2 km. level would suffice to keep the core above this level moving upward until it had become on the average about 7° C. colder, level for level, than surrounding regions. This result, therefore, explains the manner in which depressions can continue in being until they acquire temperature characteristics which have hitherto seemed paradoxical, more especially in regard to any theory of origin in which convection may have played a part.

In one exceptional case—a vigorous and still developing system with a long course still to run—the feature characteristic of the inner regions of the other depressions was not developed, at least at the time when the depression crossed the British Isles. In this depression by contrast, a high wind speed was found up to relatively near the centre.

A. H. R. GOLDIE.

Meteorological Office,
Edinburgh.

¹ *Proc. Roy. Soc., Lond.*, A, **93**, 148 (1917).

² *Trans. Roy. Soc., Edin.*, **40** (1900–01); *Proc. Roy. Soc., Edin.*, **36** (1915); and *Proc. Roy. Soc., Lond.*, **94** (1917–18).

³ *Proc. Roy. Soc., Lond.*, A, **99**, 397 (1921).

Transmission of High-Voltage Impulses at Controllable Speed

SIR J. J. THOMSON¹ first observed that if a difference of potential was applied to the ends of a long discharge tube (by an induction coil) the luminosity traversed the tube with a finite velocity. When either a positive or negative impulsive potential is suddenly applied to one end of a discharge tube while the other end is maintained at ground potential, one of us² found that the luminosity traversed the tube from the high-voltage electrode to ground. Immediately following this, a luminosity frequently

traversed the tube from the ground back to the high-voltage electrode. A similar type of propagation of luminosity has been observed in a million volt spark between point and plane by Allibone and Schonland³ and by Schonland and others⁴ for certain types of lightning flashes. In order to obtain more information about the initial breakdown in gases, we have undertaken an investigation of the propagation of potential in long discharge tubes when impulsive voltages are applied to one end of the tube while the other end is earthed.

By means of a high-speed cathode ray oscillograph, it was found that in the case of both positive and negative applied impulses, a definite potential wave traversed the tube from the high-voltage electrode to the earthed electrode, immediately followed by a much faster return wave from ground back to the high-voltage electrode. In the case of the initial impulse, the wave velocity, wave form, voltage attenuation and energy carried in the wave front were measured and found to vary with both pressure and applied potential. A few values for the speed of the initial impulse in a 5 mm. glass tube containing air are shown in the accompanying table.

Applied Voltage (kv.)	Pressure (mm. Hg.)	Speed of Impulse (cm./sec.)
+127	0.08	9 × 10 ⁸
+127	0.24	43 × 10 ⁸
−125	0.03	15 × 10 ⁸
+171	0.17	27 × 10 ⁸
+74	0.017	5.4 × 10 ⁸
+74	0.24	14 × 10 ⁸

For the greater applied potentials the voltage wave showed no observable distortion or attenuation, at least for lengths of tube less than 10 metres. However, at 74 kv. and the higher pressure (0.24 mm.), the voltage wave was very much flattened. For the 170 kv. and 74 kv. applied impulses with 0.025 mm. pressure in the tube, the maximum current during the initial wave was 429 amp. and 146 amp. respectively. In addition to the information the above results give as to the nature of the initial breakdown in gases, they show that a discharge tube may be used as a transmission line in which the velocity of propagation of the voltage wave is easily controllable over quite wide ranges. This type of transmission line should be of use in many problems⁵ where it is necessary to transmit high-voltage impulses from point to point at predetermined velocities less than that of light.

The detailed results of this experiment will be submitted for publication elsewhere. We wish gratefully to acknowledge a grant from the American Philosophical Society, which has made this work possible.

L. B. SNODDY.

J. W. BEAMS.

W. T. HAM, JUN.

H. TROTTER, JUN.

Rouss Physical Laboratory,
University of Virginia.
June 20.

¹ "Recent Researches", 115 (1893).

² Beams, *Phys. Rev.*, **36**, 997 (1930).

³ Allibone and Schonland, *NATURE*, **134**, 736 (1934).

⁴ Schonland, Malan and Collins, *Proc. Roy. Soc., A*, **152**, 595 (1935).

⁵ Beams and Snoddy, *Phys. Rev.*, **44**, 784 (1933).