number of possible answers, will perhaps see that the first alternative (so long as it is a possibility) demands the most thorough exploration, whereas the second alternative, even if it should be right, is for the present not a very productive field of research.

A. S. EDDINGTON.

Observatory, Cambridge.
Aug. 10.

The Hardest Cosmic Rays and the Electric Charge of the Earth

SOME years ago¹ I detected the coincidences of cosmic radiation by placing two Geiger-Müller tube counters above one another and side by side. Repeating this experiment² in the salt-mine of Stassfurt (Berlepschschacht der Preussischen Bergwerks- und Hütten A.-G.) in different levels, systematic coincidences were still found in the first level, whereas in the fourth level no coincidences occurred within 3 hours. The coinciding corpuscular radiation in the first level, that is, at a depth equivalent to 500 m. of water, is predominantly directed in the vertical, the mass absorption coefficient $(\mu/\rho)_{H_2O}$ being less than $5 \times 10^{-5} \text{ cm.}^2 \text{ gm.}^{-1}$, and the minimum energy greater than 10^{11} e-volt .

Earlier experiments with ionisation chambers³ suggested that the radiation penetrates to 700–800 m. of water, which is now confirmed by further coincidence experiments. These rays are doubtless cosmic rays, at least four times harder than the hardest component found by Regener⁴ at a depth of 230 m. in Lake Constance. On account of their energy, penetrating power and for other reasons, such as smallness of latitude effect, and so on, they may perhaps represent the primary cosmic radiation. Leaving the small number of incident rays out of the question for the present, a radiation has been found, which has the properties needed for a corpuscular penetrating cosmic radiation capable of maintaining the electric charge of the earth.*

W. KOLHÖRSTER.

Höhenstrahlungslaboratorium des
Meteorologisch-Magnetischen Observatoriums,
Potsdam. Aug. 10.

¹ *Naturwiss.*, 16, 10; 1928.

² *Berl. Ber.*, 1933, in press.

³ *Berl. Met. Institut*, 1931, p. 34; Berlin, 1932.

⁴ *Z. Phys.*, 74, 433; 1932.

* cf. Schweidler, "Probl. kosm. Physik, XV". Hamburg, 1932.

Development of the Lightning Discharge

It is generally believed, though direct evidence has so far been lacking, that the first stage in the preliminaries to spark break-down is the passage from cathode to anode of an electron avalanche. It has been suggested that the real break-down occurs after the passage of this avalanche and proceeds from anode to cathode as a thermally ionised tongue.

We have recently obtained what appears to be very clear evidence of the reality of these effects in the case of the lightning flash, which we have studied with a revolving lens camera of the type invented by Prof. C. V. Boys. An example of the results obtained is shown in Fig. 1, where the two distorted pictures of the same lightning stroke have been mounted side by side with the directions of the lens movements outwards. Those corresponding points on the two

photographs which are nearer together therefore actually occurred earlier in time.

It will be seen that the first event was the production of a faint track of uniform thickness which began near the base of the cloud and moved downwards. The uniform width of this track shows that its luminosity was such as would be produced by a downward-moving fireball or dart. The mean vertical velocity was $7.2 \times 10^8 \text{ cm./sec.}$ and the width of the track is such as to make the maximum possible length of the luminous dart 36 metres.

This downward dart, on arriving at or near the ground, caused the development of an upward moving discharge with a more brilliant track, the distortion of the inside edges of which indicates a mean upward vertical velocity of $5.3 \times 10^8 \text{ cm./sec.}$ The fact that this track is not of uniform thickness but is drawn

FIG. 1.

out more at its lower than its upper end, shows that the strong luminosity persisted at the base for some time after the discharge had moved upwards. The total length of the discharge was 2.1 km. and the luminosity at the base continued strongly until the head of the upward moving tongue was 1.2 km. above the ground. After this the luminosity at the base changed to a different form, with a shaded appearance on the photograph, which persisted until long after the discharge had reached the cloud.

We have found this combination of a downward-moving 'leader' with a stronger upward stroke to be very frequent. In the eleven discharges photographed by one of us (H. C.), there occurred 45 separate lightning strokes, of which 24 definitely were of this nature. The proportion would be much higher (24 out of 27) if we excluded those strokes which were not recorded under favourable conditions for seeing the leaders. Dr. E. C. Halliday has also very kindly shown us a photograph taken by him in which 4 out of 5 strokes show the same effect.

The upward stroke in the illustration is unbranched, but we have found others in which the branching is downwards, or directed away from the cloud, as previously reported by Halliday².

A full discussion of these photographs will shortly be published. We would identify the downward leader stroke with the electron avalanches, the cloud base acting as the cathode in the discharge. The subsequent discharge from the earth is considered to progress by a process of thermal ionisation.