higher than that of lead-207·72. No attempt has as yet been made to determine with great accuracy the absolute value of the transition points, which are slightly above 7·2° K. The resulting power of $M(0\cdot 73 \pm 0\cdot 05)$ thus appears to be somewhat higher in our experiments than that predicted by Fröhlich (0·5).

Lead-207·72 (extracted from Ceylon thorite)[10] was kindly lent to us by Prof. F. Soddy, and spectrographically analysed by Mr. G. H. Palmer, of the Atomic Energy Research Establishment, Harwell.

We are grateful to Mr. C. H. Collie for lending us the uranium lead sample (lead-206·15) which was obtained from the Eldorado Mining Company of Canada. I wish to thank Dr. K. Mendelssohn for his interest and advice, and my husband, J. L. Olsen, for his help with the experiments.

MARIANNE OLSEN

Clarendon Laboratory,
Oxford.
June 5.

[1] Maxwell, E., *Phys. Rev.*, **78**, 477 (1950).
[2] Serin, B., Reynolds, C. A., and Nesbitt, L. B., *Phys. Rev.*, **78**, 487 (1950).
[3] Onnes, H. K., and Tuyn, W., Comm. Kamerlingh Onnes Lab., Leyden, 106 *b* (1922).
[4] Justi, E., *Phys. Z.*, **42**, 325 (1941).
[5] Maxwell, E., *Phys. Rev.*, **79**, 173 (1950).
[6] Lock, J. M., Pippard, A. B., and Shoenberg, D., *Nature*, **166**, 1071 (1950).
[7] Bär, M., Mendelssohn, K., and Olsen, J. L., *Nature*, **166**, 1071 (1950).
[8] Fröhlich, H., *Proc. Phys. Soc.*, A, **63**, 778 (1950); *Phys. Rev.*, **79**, 845 (1950).
[9] MacDonald, D. K. C., and Mendelssohn, K., *Proc. Roy. Soc.*, A, **200**, 66 (1949); **202**, 103 (1950).
[10] Soddy, F., Ann. Rep. Chem. Soc., **13**, 247, 272 (1916).

The Clock Paradox in Relativity Theory

THE clock paradox discussed by Prof. McCrea in his letter in *Nature* of April 28 is, as he says, no paradox at all. It exists only for observers who have been asleep during the changes of direction of motion of the clocks.

A stumbling-block to handling the problem by using the Lorentz transformations is that these apply only to uniform motion, not to a clock reversing its direction of travel. This difficulty may be avoided if we make use of auxiliary moving clocks, to which the epochs of the original clocks are communicated as they pass each other.

Consider two identical railway trains in uniform motion at different rates; call them A and B. Observers on these trains make indistinguishable observations of uniform separation or approach. For convenience, locate our co-ordinate system on A, that is, consider it stationary. At some point in the progress of B let another identical (auxiliary) train C pass it going in the opposite direction at such a rate that it ultimately passes A. Let the epoch on the clock on B be flashed to a clock on C as they pass. Then as C passes A (B meanwhile passing off into space), a comparison of the epochs of the clocks on A and C shows the clock on C—since B and C have both been in motion with respect to A—to be behind the clock on A. The observer on A sees a clock pass him in one direction, and if he has not seen the transfer operation, sees the clock returning, having lost time in the process.

For an observer on B the similar experience is presented, when at some point A is passed by a train D travelling at such a speed that it ultimately overtakes B. It reaches B by *travelling at a higher velocity* than B; the epoch of its clock, originally flashed from A, is retarded over B because of this higher velocity in travelling over the same distance.

The argument is as follows: Designate by L the distance between A and B when D catches up with B. The time is then L/v, where v is the velocity of B. Because of the slowing down of B's clock, this time will be read:

$$t'_B = \frac{L}{v}\sqrt{1 - \frac{v^2}{C^2}} \cong \frac{L}{v} - \frac{1}{2}\frac{Lv}{C^2}.$$

Now D traverses the distance L in time L/V, where V is D's velocity. This will be read by D's clock as:

$$t'_D = \frac{L}{V}\sqrt{1 - \frac{V^2}{C^2}} \cong \frac{L}{V} - \frac{1}{2}\frac{LV}{C^2}.$$

D, however, received its epoch from A when B had already travelled some distance l, that is at the time l/v, so that the time read on D will be:

$$T'_D = t'_D + \frac{l}{v}.$$

Now $\frac{L-l}{v} = \frac{L}{V}$, or $\frac{l}{v} = \frac{L}{v} - \frac{L}{V}$;

so that we have:

$$T'_D = t'_D + \frac{l}{v} = \frac{L}{V} - \frac{1}{2}\frac{LV}{C^2} + \left(\frac{L}{v} - \frac{L}{V}\right)$$
$$= \frac{L}{v} - \frac{1}{2}\frac{LV}{C^2};$$

which is to be compared with t'_B above. Since V is greater than v, the time by D's clock is less than the time by B's clock.

Thus, B also observes a clock moving away from him, and later (not having observed the process of transferring epoch from A to D) sees 'the clock' returning, having lost time. Both observers conclude that it is the other's clock that has slowed down.

If in the first case an observer on B is (in a state of unconsciousness) trans-shipped from B to C at the same time that the interchange of clock readings is made, when he awakes he observes A approaching him. When he passes A he finds *his* clock is behind A's clock, contrary to his expectation that since A has receded and approached it will be A's clock that has lost. He thus discovers that he has been 'Shanghaied' while unconscious. The observer on A, as described above, similarly unconscious while the B—C transfer occurs, agrees with the B—C observer, when they meet, that the latter's clock has lost time —there is no clock paradox. The observer on A is also reassured, if he has followed this argument, that he has stayed on the same train during his nap.

HERBERT E. IVES

32 Laurel Place,
Upper Montclair, N.J.

A Toroidal Geiger Counter

A TOROIDAL Geiger counter has been constructed in an attempt to produce a γ-ray sensitivity detector with a response independent of the position of the γ-ray source over a small region of space. The counter was made from two U-shaped half-sections (radius ½ in.), one of which is shown in the photograph, pressed from 24 S.W.G. oxygen-free copper. The counter was designed in the first instance for experiments in which it was necessary to pass the counter freely