parallel lines are inconceivable. If this is not meant by our teachers, what then is meant ?

I cannot help thinking that at the back of all this apparent contradiction lies the essential common sense of science. Because of the character of the men who enunciate these seeming paradoxes, the ordinary man does not doubt. But he is puzzled when he is asked to believe, for example, that straight lines are not straight, or parallel lines parallel—even in thought. As always hitherto in science, I think it must be possible for the thinkers who seem to enunciate paradoxes to clear up the mystery by means of a few simple illustrations. It is profoundly wrong to state that the man who seeks to follow science must first believe. His belief is worthless unless he also understands. For him it is mere dogma when it is stated that clocks cannot keep time merely because one of them is in rapid motion, that straight lines curve, and that parallel lines meet. I hope H. D. will not think that I am carping at his article. I do not doubt the correctness of his opinions. But I do want to find a way through apparent contradictions, not all of which are his.

G. ARCHDALL REID.

20 Lennox Road South, Southsea.

IT is impossible in the space of a letter to deal adequately with all the points raised by Sir Archdall Reid. He has no doubt read most of the well-known expositions of relativity, but perhaps I might refer him to Professor Eddington's latest book, "The Nature of the Physical World." I know of no clearer or more generally admirable account of the relativity of space and time than that contained in its early chapters. Here I can only answer summarily the particular questions asked.

The idea that clocks in rapid relative motion do not keep time is, as a general principle, derived from not very abstruse calculations based on actual observation. In a special case it may be said, in a sense, to be derived directly from observation. If we are willing to accept an atom as a clock and its radiation as a measure of the time it keeps, then the well-known Doppler principle, verified by observations in the solar system, is a directly measured testimony to the idea. But other factors also are involved here, and perhaps it is scarcely fair to regard it as observational proof. The idea is not mystical—except in the sense in which, I suppose, every fundamental physical fact is mystical—and it certainly does not result in contradictions.

The 'curvature of space' is a symbolical expression representing the idea that if one proceeds in a certain direction he will not continue indefinitely to recede from his starting-point; he will ultimately, without changing his direction, approach it again, just as one does in travelling on what we ordinarily regard as a 'curved' surface, *e.g.*, a sphere. The idea is not a "necessary axiom of thought," although it originated, as a possibility, long before the theory of relativity. What relativity has done is to make it probable that the physical space of our experience has 'curvature.' If parallel lines are defined as lines which always keep the same distance apart, then obviously they cannot meet, but the 'parallel' lines which are said to meet if sufficiently prolonged are not so defined. The geometrical definition of parallel lines has been that they are straight lines which meet at infinity. In the space contemplated by relativity, straight lines, as ordinarily imagined, and infinity (which belongs to hypothetical, euclidean space, and is of course quite inconceivable) do not exist, and a new definition is necessary, which mathematicians, if they regard the conception of parallelism as a useful one, have no doubt provided themselves with. Subject to correction by them, I would suggest that in 'spherical' space, parallel lines might be defined as 'straight' lines which intersect at two points the distance apart of which is the greatest possible, where by a 'straight' line is understood one of which any portion lies along the shortest (or longest) distance between its ends. The portions of such lines which we, in the minute terrestrial region of space, recognise as parallel would then be analogous to the almost infinitesimal arcs of two meridians of longitude at the equator, and not to elements of two circles of latitude.

The lines of sight of Sir Archdall Reid's two observers would therefore not be 'parallel,' although, if the star were among the near ones, their deviation from parallelism would be too small to be detected. I do not know if the preceding paragraph will clear up all Sir Archdall Reid's difficulties on this point, but it should at least make it clear that the contradiction with which he is troubled does not exist. Relativity or no relativity, lines cannot both meet and never meet.

I quite agree that "It is profoundly wrong to state that the man who seeks to follow science must first believe," but this statement was not made or implied in the original article. The contention was that what is called lack of understanding of relativity is usually unbelief; the article put forward a diagnosis of a complaint, not a prescription for keeping well.

H. D.

THERE appears to be a rather interesting reversal in the direction of our minds between cause and effect in regard to some of the problems involved in relativity. The Michelson-Morley experiment was originally intended to detect the absolute movement of the earth through space; and it failed because the anticipated shift of the interference bands did not occur; and because it failed the movement through space remained undetected; and various physical theories were suggested to account for the failure.

The whole situation is now approached from the opposite end. The impossibility of observing absolute movement is elevated into a fixed fundamental principle which we are asked to accept without being too curious or insistent in demanding a physical explanation. We are free, if we like, to regard it, as we regard the point of maximum density of water, as an evidence of beneficent design, since it is on this principle that the uniformity of Nature, or the invariance of general laws, depends. The Michelson-Morley 'failure' is now recognised merely as an illustration, a direct and inevitable result, of this principle. The same principle is applied to the relativity contraction of measured lengths and the slowing of clocks as between two systems S and S'. We are discouraged from attempting to explain or explain away, on any physical basis, the apparent paradoxes which most paradoxically have accompanied the expression of Nature's invariance in mathematical form.

This new point of view for the study of relativity will be welcomed even by those who believe that a real though quite undiscoverable Fitzgerald contraction, due to absolute movement, underlies and to a large extent accounts for the relativity contractions and differences of clock rates and synchronisation which appear in the transformation formulæ. Belief or disbelief in this contraction only modifies our ideas, and does not affect experimental facts. The application of the principle that *absolute movement cannot be observed*, affords a satisfactory 'reason why' to much that must otherwise remain perplexing to the ordinary man.

H. C. BROWNE.

Dublin, Dec. 7.