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819TH ORDINARY GENERAL MEETING,

HELD IN COMMITTEE ROOM B, THE CENTRAL HALL, WESTMINSTER, S.W.1, ON MONDAY, APRIL 4TH, 1938, AT 4.30 P.M.

R. E. D. CLARK, ESQ., M.A., PL.D., IN THE CHAIR.

The Minutes of the previous meeting were read, confirmed and signed and the HON. SECRETARY announced the election of H. E. Fitzgibbon, Esq., B.A., B.A.I., Assoc.M.Inst.C.E., M.Inst. M. & C.Y.E., M.A.T.Inst., as an Associate.

The CHAIRMAN then called on Albert Eagle, Esq., B.Sc., A.R.C.Sc., to read his paper entitled "Difficulties underlying the Einstein-Eddington Conception of Curved Space."

DIFFICULTIES UNDERLYING THE EINSTEIN-EDDINGTON CONCEPTION OF CURVED SPACE.

By ALBERT EAGLE, ESQ., B.Sc., A.R.C.Sc.
(Lecturer in Mathematics, University of Manchester.)

IN the last twenty years all the world has heard of a very remarkable theory—Einstein's Theory of Relativity—which is chiefly associated with the names of Einstein and Eddington. This theory is supposed not only to have corrected all scientists of former ages, like Newton, whose ideas on the Universe could not possibly be the last word, but also all ancient geometers, like Euclid, who dealt with matters of pure thought which had nothing to do with the external physical Universe.

No theory has ever, in so few years, been put before the general public in such a furore of books, lectures, articles in scientific journals, magazines, and even newspapers. Scores of books, learned, semi-popular and popular, have been produced. Both Einstein and Eddington have thought it necessary to produce books of the latter class while one publisher alone has produced over a dozen books, mostly of the semi-popular class for novices or elementary students, which occupied two pages in his general catalogue.

One aspect only of this theory I will deal with to-night; and that is the "curved space" aspect. According to this view, space is only Euclidean in the absence of gravitating matter. Round any star, and to a less an extent round any particle of matter, space no longer obeys the laws of Euclid as exemplified in the famous result of Euclid I, 47, of which a particular case is that the length of the diagonals of a square is $\sqrt{2}$ times the length of the sides.

What curved space is, Sir James Jeans has explained to nearly half the homes in the country in a broadcast on astronomy on November 28th, 1934. He pointed out that an aviator who started out successively in different directions from the same point, with an aeroplane of a certain cruising radius, sees a certain circular area of the earth's surface; and that if he does the same with another aeroplane of double the cruising radius he will see approximately four times the area of the earth's surface, and so on till the cruising radius gets comparable with the earth's radius; while, when the cruising radius is equal to half the circumference of the earth, he finds the boundary circle which he has reached has become reduced to a point instead of being a circle of ten times the circumference of the boundary circle when his cruising radius was only one-tenth as large. According to Sir James Jeans, curved three-dimensional space differs from flat three-dimensional space exactly as the curved surface of a sphere differs from a plane. That is to say, that if we started successively in opposite directions and go far enough, we may reach the same point in absolute defiance of the capability of our intellects to understand how that can possibly be. This makes it clear that the gravitational field which curves or distorts space must have played a still greater havoc with our minds; for we are prevented from thinking correctly as the facts have given the lie to our ideas of the truth, or the possible.

But the curved spacist may object that when we travel a steered straight line of about 12,500 miles over the surface of the earth we reach the same point irrespective of the direction in which we set out. Quite so. But that is easily comprehended: we know that it is because the earth's surface curves away from us beneath our feet, and if we want to keep the same distance above it we must curve our path downwards too.

So curved space means, of course, that if we consider a sphere void of matter, and then put a sun or planet inside it, the points in this now distorted sphere cannot be made to coincide with the

points of the same sphere before the mass was introduced except that the two systems of points could be made to coincide for some particular radius; for a Euclidean sphere and a non-Euclidean sphere can intersect in a *spherical surface* just as the spherical surface of the earth and a plane can have a *circle* of intersection.

Now, unless we can form some mental conception of where these points in this non-Euclidean sphere *are*, when practically all of them are somewhere different from the positions of all the points in the Euclidean sphere occupying the same space before the gravitating particle came into its neighbourhood, our talking about curved space may be pure nonsense, as we may be deluding ourselves and misleading other people by pretending that certain things exist which do not exist.

Where have these distorted-away points gone to? They do not seem to have gone to anywhere different. Perhaps a relativitist might reply that Einstein's theory distorts time as well as space and these distorted points have gone into a different time. But this explanation only makes matters worse. It is as much as to say that these points are not there when we want to think about them but only when we do not want to think about them!

Let us leave Sir J. H. Jeans on curved space and go to a higher authority, his teacher, Sir Arthur Eddington. Sir Arthur says, in his well-known book, *Space, Time and Gravitation*, p. 104:

> "Thus if we draw a circle, placing a massive particle near the centre so as to produce a gravitational field, and measure with a rigid scale the circumference and the diameter, the ratio of the measured circumference to the measured diameter will not be the famous number 3·14159265.... but a little smaller . . . Placing the particle near, instead of at, the centre, avoids measuring the diameter through the particle and so makes the experiment a practical one . . . It is of value to put the result in this way, because it shows the relativitist is not talking metaphysics when he says that space in the gravitational field is non-Euclidean. His statement has a plain physical meaning . . ."

Now, in the above, Sir A. Eddington seems to me to be talking like a pure geometer infatuated with the idea of curved space, and not at all like a physicist should talk about a physical experiment.

Let us consider this experiment as any physicist like myself would like to consider it. We will take Sir Arthur's figures of a ton inside a circle of five yards radius. A ton of lead would make two solid hemispheres each about 22 in. in diameter. Let us place these with, say, a $\frac{1}{4}$-in. air gap between their plane faces. Between these hemispheres place a thin metal disk somewhat over 10 yards in diameter. On this disk let a circle of 5 yards radius, together with a diameter, be scratched with a diamond point. Let us also have a small piece of the same metal with some fine graduations on it to form our measuring rod. Now ordinary materials are elastic ; and so, if we hold our measuring rod by the further end when it is pointing *to* the mass it will be in tension and therefore lengthened. To get over this difficulty let us suppose the metal of the measuring rod has an infinite modulus of elasticity ; so that it is what we may call perfectly rigid. Now it is quite conceivable for the measuring rod and disk to a change their dimensions in a gravitational field even if perfectly rigid. For elasticity depends on the fact that the atoms of a solid are not in actual contact, but are held in equilibrium positions *near* each other by the forces of cohesion, and so the distance apart of the atoms is altered by an applied tension or compression. But even if perfectly rigid, a solid would necessarily change dimensions if some influence altered the *size* of the atoms. To do this only requires that the radius of the atomic orbits of the electrons in the atom should be altered. And, since it is now accepted by physicists that the *time* of revolution of electrons in their atomic orbits is increased in gravitational field, a change in the *radius* of the atomic orbits is almost inevitable, since the time of revolution and the radius of the orbit are so intimately connected with one another. Also we know pretty conclusively that all bodies, when in motion, undergo what is called the Lorentz-FitzGerald contraction in the direction of their motion. This contraction is very simple. If v is the velocity of the body, and V is the velocity of light, then all dimensions in the direction of motion are reduced in the ratio of 1 to $\sqrt{1 - v^2/V^2}$.

Theoretically, one would expect any change of dimensions in a gravitational field to be about the same as the Lorentz-Fitz-Gerald contraction for a velocity equal to that acquired by the body falling from a great distance to its position *in* the field. This is about one part in 1,400 million parts for bodies in the earth's gravitational field.

Now return to our sheet of metal between the two lead hemispheres. What is going to happen to it if the atoms gradually increase in size nearer to the centre of the disk? Clearly the disk must become saucer-shaped. If, on the other hand, the atoms become smaller nearer the centre of the disk, the outside edge will be too large for the inside portion and consequently it will go into puckers. If now we measure the length of the scratched circle and its diameter we shall obviously get the same ratio as we should if the lead hemispheres were removed, since at every point we move the measuring rod to, the material of the disk will have expanded or contracted just as much as the measuring rod. So we have failed to detect "curved space." But we have not been measuring a plane circle and its straight line diameter. To do so we must prevent the disk from buckling; so let us make a large number of fine radial cuts in the disk, not quite going as far as the centre, which would divide the disk into many pieces. This will keep the disk in one plane. And now, if the atoms near the centre of the disk have become larger, the width of our cuts will become wider near the edge than near the centre; while the reverse will happen if the atoms near the centre become smaller. *Now* it is very obvious that if we measure the length of our scratched circle (including the gaps) we shall not get a ratio which is exactly equal to π. It will be greater than π if the gaps are wider near the circumference than near the centre; and less than π in the opposite case. How very simple this is to understand! There is obviously no question of the ratio not being exactly equal to π meaning that the *space* surrounding the ton of lead has become curved in some unconceivable manner.

The above assumes that a small sphere of matter would change its dimensions equally all round in a gravitational field. There is no reason why this should be so. There might be a change of dimensions in one ratio in the direction of the field, and in quite another ratio in directions at right angles, just as the Lorentz-FitzGerald contraction only exists in the direction of motion and is nothing in the perpendicular directions. If this more complicated law is followed it will need a simple mathematical expression to state whether the cuts in our disk are wider or narrower near the edge than near the centre.

The above consideration show how very differently a physicist looks at a physical experiment than a pure geometer; and shows how diffident such geometers should be in expressing an opinion

on anything which is really a matter of physics and not of geometry. For the geometer, as such, neither knows, nor cares, anything about the trillions of complicated systems called chemical atoms of which the disk is composed, and the unknown influence to which these may be subjected in a gravitational field.

Let us now turn to the mathematics of curved space. Every student, who knows a little of both co-ordinate geometry and the differential calculus, knows that if P is the point whose co-ordinates are r and θ, and if Q is the point whose co-ordinates are $r + dr$ and $\theta + d\theta$, then the distance PQ^2 is given by

$$PQ^2 = (dr)^2 + (r\,d\theta)^2. \quad . \quad . \quad . \quad . \quad . \quad (1)$$

According to relativitists, this equation is no longer true in a gravitational field; but instead, if we have a mass m at the origin, the distance PQ is given by

$$PQ^2 = \frac{(dr)^2}{1 - \frac{2\,Gm}{V^2 r}} + (r\,d\theta)^2; \quad . \quad . \quad . \quad . \quad (2)$$

where V is the velocity of light as before, and G is the Newtonian constant of gravitation. That is to say, that if $dr = 0$, so that P and Q are at the same distance from the origin, their distance apart is $r\,d\theta$ as it obviously is; but if $d\theta = 0$, so that P and Q are on the same radius, their distance apart is not dr but dr divided by the square root of $1 - \frac{2\,Gm}{V^2 r}$. That is to say, that when PQ is radial, the *measured* distance PQ, between the points P and Q, is not equal to the *physical* distance between them, which is dr, but is greater than dr; while in the perpendicular directions the measured distance and the physical distance are equal.

Now how can the distance in one direction be the distance measured by the measuring rod and the distance in a direction at right angles not be the distance given by the measuring rod? Very easily if we admit that the measuring rod changes its true length when we turn it through 90°. What *other* conclusion, than this very obvious explanation, could any clear thinker possibly come to if he was compelled to accept the correctness of the equation (2) as the correct expression for the square of the measured distance PQ? So we can readily admit that the

relativitists' formula for the distance between two points in a gravitational field is correct provided we believe that the measuring rod preserves its length unaltered when it is at right angles to the field but that it has become shorter in the ratio of 1 to $\sqrt{1 - \frac{2Gm}{V^2 r}}$ when it is pointing in the direction of the field; for then the measured distance corrected by the relativitists' formula gives exactly the same result as would have been given if we had been able to perform the measurements with a rod which was not affected by a gravitational field. Now this change of length is rather interesting. If the measuring rod was of unit mass and *fell* into the gravitational field from a large distance, thereby acquiring a velocity v, it would have acquired kinetic energy of $\frac{1}{2}v^2$; but it would have lost an equal amount of potential energy Gm/r. So substituting $\frac{1}{2}v^2$ for Gm/r we see that the supposed contraction in length is in the ratio of 1 to $\sqrt{1 - v^2/V^2}$ when the rod is pointing to the particle, but is nothing when pointing in a perpendicular direction. So this supposed contraction is exactly as if the Lorentz-FitzGerald contraction, acquired during the fall, was supposed to be preserved after the velocity had been arrested.

This might be so. No one knows enough about the manner in which physical matter may change its dimensions in a gravitational field to say it is not so. It does not seem to me to be the most likely manner in which matter may be expected to change its dimensions in a gravitational field; but it must be remembered that anything which does not involve a contradiction in thought must be admitted as an *a priori* possible thing to happen in a matter on which we are quite ignorant.

Now if a measuring rod in a gravitational field does behave in this manner, so that the relativity formula for the distance is correct, it completely takes all the curvature out of their curved space; for all the points round their gravitating particle are still in the ordinary three-dimensional flat space round the particle!

But if this extraneous factor multiplying the dr is not required to compensate for a recognised deformation of the measuring rod in a gravitational field, whatever excuse is there for its insertion in this high-handed manner without any reason being given us for its insertion? "Curved space demands it," relativitists would reply; "if it was not there space would have no curvature; and, since we know that space is curved in a gravitational field, this factor must be there."

If we ask *how* they know that space is curved they fall back on the fact that light is found to be slightly deflected when passing near the sun, and on one or two other minute astronomical phenomena so that the only justification for this factor is an *a posteriori* justification. As there is no *a priori* justification for it, the agreement obtained between relativity mathematics and physical phenomena stands exactly on the same basis as any other empirical formula, devoid of theoretical basis, which experimentalists often find extremely useful in representing their results when they do not understand the operating causes sufficiently well to produce a formula with some theoretical justification.

If mathematicians want to mix up distances in one direction with distances in another direction multiplied by a factor, they should coin a new name for their product, and not still call it " space " as if it *was* the space of external reality ; and then pretend that the space of external reality is distorted. If a distinctive suitable name for the quantity in equation (2) was coined I should not have the slightest desire to dispute the fact that this thing *is* distorted in a gravitational field.

Is it possible that this variable change of length of bodies in different directions in a gravitational field is what relativitists mean by their curved or distorted space ?

I could give many quotations from Einstein, Eddington and other relativitists to show most emphatically that they do ***not*** mean this. They mean that the distance is correctly given by the formula (2), above, when measured with a rigid rod which undergoes no internal change in a gravitational field which could affect its length ; which possible change, apparently, they never even thought about. To assert that formula (2) could be correct in this case is surely pure nonsense ; and is quite as erroneous as the assertion that $2 \times 2 = 5$. In my humble opinion it is a sheer delusion to pretend otherwise. Yet the Bishop of Birmingham, in a letter, has told me that I have not " understood " curved space, and tells me that " curved space, though finite, is the whole of space : it is not set in a three-dimensional void."

Where in earth or heaven these points in the neighbourhood of a gravitating particle *are*, which do not coincide with any of the points of the three-dimensional space which existed there before the particle was introduced, no one has ever enlightened me. Surely it is very plain that we cannot come to the conclusion that three-dimensional space can be curved without at the same

time coming to the conclusion that our brains are of no use at all for thinking; or for coming to *any* truthful conclusions; for we have made ourselves believe in something in flat defiance of the ability of our brains to comprehend how it is possible. We have, in fact, done intellectual violence to ourselves of a very damaging kind.

The truth is, of course, that Einstein and Eddington did not reach the conclusion that space was curved as the result of any reasoning; it was the result of an infatuation for a mathematical idea. Now anyone is quite welcome to prefer his infatuation as a guide to truth to his reason; if he likes to do so. But he must not lose his reason to such an extent as to think that other people ought to rate his infatuation above *their* own reason. We must tell relativitists emphatically that the reason why we disagree with their curved space is not because we possess defective brains, and so cannot understand it (and all curved spacists seem to look on disbelievers with a supercilious contemptuous pity for the possessors of brains of such limited powers) but because we emphatically dislike their curved space idea as being indistinguishable from a self-contradiction.

Relativitists have fallen into a mistake which no competent practical physicist would ever have fallen into. They think that when they use a symbol, say s, for distance, that that represents *a physical distance in external reality.* It does nothing of the sort; the mathematician's s is merely a *pure number* representing the number of times the *physicist's* unit measuring rod goes into the distance being measured. One can know nothing about the *physical distance* in external reality until one *knows* all about the physics of the measuring rod when it is moved about in a gravitational field; and neither physicists nor mathematicians have any such omniscient knowledge.

If relativitists want to improve upon Euclid; instead of trying to find fault with Euclid's pure thought, by attacking Euclid's theory of parallels, they should have attacked Euclid's naïve physics, on which subject the poor man was completely ignorant. Now a large part of Euclid—all his metrical theorems for instance—depends upon the assumption that one can *transfer* a measuring rod to different parts of a geometrical figure, or can transfer one geometrical figure and superpose in it on another, without their undergoing any change of magnitude during the transfer. Now this is emphatically not so. One cannot have a geometrical figure consisting of filaments of nothing existing in a

stark void. In this world a geometrical figure must consist of a diagram scratched on the surface of a piece of *physical matter*. Poor Euclid simply did not know that practically all substances, save invar, which had not been invented by his day, changed their dimensions appreciably with only a few degrees' rise in temperature; nor did he know that any measuring rod, held vertically by its upper end, was longer than when held vertically by its lower end. Still less could he have known anything about gravitational fields and realised that in all probability all bodies changed in dimensions on being moved about in one. Most of us will say: "Thank heavens, Euclid did not know anything about such things. What a difficulty he would have found with the foundations of his subject if he had known!"

But of course my saying that three-dimensional space may obey the mathematics of curved space, merely because measuring rods alter in dimensions when they are moved about in it, completely denies that Einstein has, in any manner *explained* gravitation. No one could be so illogical as to imagine that the fact that bodies change in dimensions in a gravitational field can be the *explanation* of the gravitational pull of attraction between the bodies. Obviously both the pull and the change of dimensions must both be due to some unknown underlying cause. So that all claim that Einstein has *explained* gravitation falls to the ground, until he has given an intellectually clear explanation of how a three-dimensional stark void, in which there is nothing present, can possess a curvature.

I will now give two or three further illustrations of the absurdities that accepting this idea of curved three-dimensional space, which, of course, requires that more than three spatial dimensions exist, can lead people into.

Everyone can imagine any three-dimensional body rotating about an axis. Let us listen to Sir Arthur Eddington explaining rotation in four dimensions. He says:*

> "although the mathematician visualises four dimensions, his picture is *wrong* in essential particulars—at least mine is. I see our spherical universe like a bubble in four dimensions; length, breadth, and thickness, all lie in the skin of the bubble. Can I picture this bubble rotating Why, of course I can. I fix on one direction in the four dimensions as axis, and I see the other three dimensions whirling round

* *The Expanding Universe*, p. 32.

it. Perhaps I actually never see more than two at a time ; but thought flits rapidly from one pair to another, so that all three seem to be hard at it. Can *you* picture it like that ? If you fail, it is just as well. For we know by analysis that a bubble in four dimensions does not rotate that way at all. Three dimensions cannot spin round a fourth. They must rotate two round two ; that is to say, the bubble does not rotate about a line axis but about a plane. I know that is true but I cannot visualise it."

Were such incomprehensible ideas ever soberly put forth as rational explanations in science before the days of Einstein and Eddington ? Yet in the face of the above contradictions Sir Arthur has not the common sense to see that he is trying to make his mind believe in the impossible *because it involves a contradiction.* Cannot he see that when his mind " flits rapidly " from one pair of dimensions to another that he is trying to imagine something, which, in its completeness as he wants to imagine it, cannot exist because it involves an inherent contradiction ? What possible better evidence could one have that one is trying to imagine the impossible than this that one's mind refuses to visualise it but only flits frantically about first over one part of the desired vision and then over another part ? How in the world can anyone so allow their infatuation for a geometrical idea to depose their rational thinking passes my comprehension.

I will now give another quotation which I should forgive anybody who said they considered it a bit of priceless nonsense. It seems so much like it that I think it will be a kindness if I do not divulge the author's name ; but it is by one of the leading writers on relativity. This writer says :—

" By Einstein's law of gravitation matter causes a curvature of the space that it occupies. If you try to put too much matter in one lump, space curves round so much that it closes up. That is what happens to the large globe of water ; when it reaches a diameter of 400,000,000 miles, space has closed up tightly all round. You cannot increase the globe, because there is nowhere to put any more water. All space is within the sphere ; what is outside is—nothing."

Now a globe of water of this diameter would contain about 70 million times as much matter as there is in our sun. Yet the Galactic System, of which our sun is a member, contains about 4,000 or 5,000 times as much matter as this. All this matter is

kept from falling together by the rotation of the Galaxy in about two or three hundred million years. Suppose something slowed down the rotation and the stars began to fall together in different groups. There would be enough matter to make 4,000 of the above described spheres each of which would " contain all space " while outside each of them there was just " nothing." And yet somehow, not only would there be the 3,999 of these spheres outside any one of them, but there are all the many millions of other galactic systems known as the spiral nebulæ which would be quite unaffected by the catastrophe which had overtaken ours ! Yet somehow these could not then still be in existence since " all space " is inside any *one* of the 4,000 spheres formed by the coalescing of about 70,000,000 suns !

Although there is nothing in the above quotation which can possibly be taken seriously we can seriously ask ourselves why anyone should express such views ; and what ideas made them do it. As I showed a few minutes ago, the relativitists' formulæ for curved space are satisfied if we suppose that any piece of matter in a gravitational field has its radial dimension shortened, but not the other dimensions. Now the formulæ are such that it turns out that at the surface of this large sphere that our author is talking about, the radial dimension of any piece of matter would have been reduced exactly to zero. In this case obviously one could keep on putting fresh matter into the sphere without its getting any larger ; for as soon as any piece of fresh matter has reached the surface it has been reduced to zero volume ; so, of course, its entrance into the sphere cannot increase the latter's volume. What could possibly be more obvious ! In fact, if this were true, such a sphere could not only contain the mass of 70,000,000 suns, it could contain the whole of the matter in the Galaxy, and even all the matter in all the other millions of spiral nebulæ too !

But granted that matter may possibly contract in volume in a gravitational field, what an absurdity it is to think that the formula which holds for a very minute contraction can be trusted to hold till the volume has been reduced to zero !

For instance, sea water decreases in volume by about one part in 144 parts at a depth of one mile. But what should we think of a popular writer who, on the strength of this, declared that at a depth of 150 miles the volume of sea water would be absolutely zero ; and that, consequently, if one bored a hole one inch in diameter to a depth of 150 miles and let the oceans drain into it,

all the water in all the oceans could flow into that hole without filling it up! Of course it could if the water at the bottom was compressed to an *absolutely zero* volume; for as more water flowed in, more water would be compressed to zero volume.

After the way in which I have ridiculed curved space many of my audience must want to ask me *why* anyone should *want* to believe in curved space. The reason is that by so doing we can get a blind and purposeless explanation of gravitation which does not depend in any manner on any of the properties of matter.

Now all sensible physicists, and all sane thought, realises that phenomena in the inorganic world are as they are because matter has been created with certain properties and the observed behaviour is simply the consequence of these properties. This common-sense view is substantiated ever more and more, in all directions, the more accurate and detailed our knowledge of the properties of matter becomes. Everyone realises that the properties of chemical compounds are due to the properties of the chemical atoms present and to the way in which they are combined with one another to form a molecule of the compound. Even the properties of the extremely minute atoms and atomic nuclei are now fast being found to be due to the properties of the electrons and protons constituting them and the manner in which they are arranged inside the respective atoms and nuclei. No sensible person can doubt, I think, that the explanation of gravitation must lie in some unknown properties of matter and of the medium in which it is immersed. But relativitists care nothing for such knowledge and ideas. They recall to us that when a particle is projected on a curved surface, to which it is confined, its path depends not at all upon any of its properties; but is what it is out of necessity from the nature of the surface. So, they claim, the apparent phenomena of gravitation do not depend upon any of the properties of matter, but arise simply as a necessity from the nature of the curved space-time in which a piece of matter moves. To be able to give the explanation of the behaviour of a thing without knowing anything about its nature seems to some mathematicians to be a glorious triumph, and a wonderful testimony to their powers of mathematical analysis. This way of thinking tries to abstract from reality everything that is tangible, and tries to reduce the physical universe to a purely geometrical universe—to a kind of distorted Euclid.

Even Einstein, who started this way of thinking, finds his soul so revolts against the ideas as they have been developed by

Sir Arthur Eddington that he has declared that if he thought for a moment that Eddington's ideas were true he would never spend another day over the study of physics. Is any further condemnation necessary than such an opinion from such a source ?

In my opinion, the curved space idea has been the most deplorable episode of absurdity in the history of science or of human thought. Great as are the objections, as I have just shown, to curved space on purely physical grounds, the psychological and philosophical grounds against the theory are even greater. It would be beyond the scope of the present paper to deal with these grounds here. I must content myself with remarking that the whole conception does such violence to the whole nature of our minds, and to all our rational thinking, that we instinctively feel the whole idea must be a lie, and therefore we cannot do other than revolt against it. It is noticeable that nearly all the writers on relativity have been (or seemed to me) quite ignorant of psychology.

One of the most famous of living psychologists, who has a very wide understanding of many sciences, tells me that I have only said in my attack on the theory in my book* what he would have liked to have said but had not the scientific standing to say ! And one of the greatest scientific thinkers in Germany, Prof. Hans Driesch, the famous vitalist biologist, tells me that he " endorses every word I have said " in my 60-page attack on the theory, and he added, " curved space, what nonsense it is."

Messrs. Einstein and Eddington have challenged the whole sanity of human thought and the worth-whileness of sensible thinking as they have never been challenged before ; and all serious thinkers who wish to preserve their God-given faculty of thinking rationally must reject absolutely their curved-space ideas until they have made them appear rational.

Sir Arthur Eddington demands that we shall surrender our own thinking and reasoning faculties to him, and believe as he believes, because he knows more about the mathematics of curved space than other people. He will tolerate no disbelief in his curved space from anyone. He has replied to any would-be disbelievers that " curvature is simply a technical property which we find space possesses." I must have the courage, I think, to declare that that statement is completely untrue. No competent physicist or astronomer has ever found a tiny bit of experimental

* *The Philosophy of Religion* versus *the Philosophy of Science.* From Simpkin Marshall, 5*s*.

evidence for requiring to believe in such an intellectual obscurity as that three-dimensional space can possess a curvature. It is, I must say, only mathematicians, dabbling in physics and astronomy, in which subjects they have had no adequate first-hand experimental experience, who are thrusting these ideas into the sciences of physics and astronomy.

It is, I am afraid, not easy for Sir Arthur Eddington to change his mind on this matter of curved space for he has declared most emphatically that " there can be no doubt in my mind " about the truth and reality of curved space. I can only feel regretful about Sir Arthur's mind and hope that this peculiarity will long be confined to only a small fraction of the human race.

To attack the theory of curved space is a most thankless and almost impossible task. It was so energetically and skilfully popularised at the moment when popular interest in it was aroused by the discovery of the deflection of light passing near the sun at a solar eclipse that it is now widely regarded as an established truth, although the public interest in it is now dead because the theory was uncomprehendable. So no public interest can now be aroused by any attacks on the theory. Moreover, the chief believers in the theory preserve a dumb-mutism attitude towards any attacks on it, comforting themselves apparently with the idea that whoever attacks the theory is beneath their dignity to notice. The public should judge for themselves the probable value of a theory whose chief defenders treat intelligent criticism of it in this manner.

Some people may think that I have more moral indignation, perhaps amounting even to animosity, against the theory of curved space than can be justified against any mere theory, no matter how erroneous or misleading it is. Perhaps some people, including editors, think the theory is scarcely worth attacking. But popular books on the theory, with titles like : " Relativity for Dick, Tom and Harry," are still appearing. And it is still widely accepted and believed in in academic circles. In some universities even, " The Elements of the Theory of Relativity " appears as a subject taught to students taking an Honours Degree in Mathematics. One cannot help feeling a little bit indignant that young brains should be injured over this brain-addling theory which, in my opinion, harms the brains of all who try to understand it. On these grounds I do not think protest against the theory is superfluous—however little other people may pay attention to it.

Another point is that abstract justice would seem to demand that the discrediting of the theory should be as extensive as its popularisation ; since it swept nearly the whole of our intellectual classes off their feet of common sense as if they were so many ninepins. Not only did nearly all our mathematical physicists fall before it ; but also many philosophers like Professor Samuel Alexander and religious thinkers like Dr. Barnes—they, too, all fell down before it. So much so that I have sometimes felt like sighing " Only I, of mathematical physicists, am left who think rationally." And then it dawns upon me that there may be, after all, perhaps 7,000 more or less obscure mathematical physicists who have not bowed the knee to curved space.

And all this intellectual catastrophe has been due merely to the fact that relativitists, in a rather high-handed manner, insist that in a gravitational field radial distances, as measured, must be multiplied by a factor, which factor is not necessary for distances measured in directions at right angles ; and that this extraneous factor is not required to compensate for the behaviour of the measuring rod in the gravitational field, but is there because the space is " curved." It is, of course, nothing but the insertion of this factor, and their high-handed dogmatic assertion that doing so *gives* the " space " an external reality, in a gravitational field, which makes that space appear curved and distorted. It would indeed be strange if it did not do so. In this assertion of theirs they were uncritically believed by nearly everybody, with the result that the intellectual life of the last quarter of a century has been befooled as never before. Surely after this revelation of the manner in which relativitists have produced their curved space any further exposure of the theory would be very much superfluously unnecessary.

This action of relativitists is one of those arresting strokes of genius which some people find hard to distinguish from those sudden irrational impulses which afflict most mortals at times in their unguarded moments. Fortunately, it is not often that the basis of a fundamental scientific theory, which receives world-wide popularisation under the driving force of an immense infatuated enthusiasm, is so insecure.

Sir Arthur Eddington closes his well-known book, *Space, Time and Gravitation*, with words which I must quote here as they are obviously words which he was inspired to write by some Higher Power. " We have found," he says, " a strange footprint on the shore of the unknown. We have devised profound theories

one after another, to account for its origin. At last, we have succeeded in reconstructing the creature that made the footprint. And Lo ! it is our own." How profoundly true it is that the footprint of curved space which Sir Arthur thinks he has discovered in external reality is not there at all but has simply been manufactured by his own brain by the proceeding which I have described above !

But need I say any more about curved space ? for it has already fallen flat ; and therefore, at present, at any rate, it apparently cannot be curved.

Discussion.

Dr. R. E. D. Clark (in the chair) said : I feel great responsibility in being in the chair this afternoon, especially as Mr. Albert Eagle has described as fantastic nonsense some of the very ideas which our President put before this Society in 1928 ! Clearly, it is my duty to make the peace.

I believe that the present misunderstanding arises solely from the use of words as, indeed, Mr. Eagle has pointed out this afternoon. He has told us that mathematicians have no right to mix up distances in one direction with distances in another which have been multiplied by a factor, and then use the ordinary word " space " for the last named. But relativitists think they are quite right in using the old word for the simple reason that the new " space " is just the same as the old except in very rare conditions. In this they follow the example of the ordinary man who never hesitates to estimate the distance between one place and another on the assumption that the earth is flat, though he knows very well it isn't ! And to their credit, be it said, the relativitists willingly admit that the word " space " is used by them in other senses than the ordinary. Mr. Eagle ought to have reminded us that Professor Eddington, whom he criticises so strongly, has candidly stated that he used the word " space " in four different senses in one of his books !

The truth is that space of every-day experience is never curved, and Professor Dingle has recently told us that he doubts whether any relativitist has ever really conceived of its being so. Misunderstandings have chiefly arisen because newspapers have printed such headlines as " Space Caught Bending," while certain optimists go

on maintaining that relativity must bring " a new epoch in the intellectual and social life of mankind." (A. A. Merrill.)

However, I think we must agree with Mr. Eagle's main contention. He urges very rightly that some relativitists do not care for facts but only for mathematics. This is exactly the complaint that a large number of scientists and mathematicians are making at the present time. There has recently been a long discussion of the matter in *Nature*, but I cannot give an outline of it here, though I would particularly like to commend the contribution of Dr. H. Jeffreys to your notice. Suffice it to say that many scientists and mathematicians (such as Levy) believe that some people are to-day vesting mathematics with a kind of mystical " reality," instead of regarding it as a mere tool for calculation. In the case of relativity, the very careful consideration given to the matter by Dingle, Chari and others has shown that the " t " of physics differs widely from the time of experience, and this fact removes Minkowski's claim that space and time have been blended—for the " t " of physics is itself a measure of *space* and not of time.

By far the most illuminating account of relativity I have seen is that of J. Mackaye. He argues that relativitists and non-relativitists attack physical problems by the method of dimensions and by the physical understanding of what is happening, respectively. The physical basis of relativity, he shows, is simply the Doppler effect (involving motion through the ether), but by treating the problem dimensionally, this physical meaning is hidden and, of course, denied. He shows that any physical phenomenon can be treated in the " relative way " by the simple use of multiplying factors, and that in this way the physical meaning can be hidden. But the " space," " distance," " velocity," " time," " energy," " momentum," " now," " future," " past," etc., of relativity have different meanings from those in common usage. Thus, if light from a distant star reaches you now, the star's distance is very large in the ordinary sense of " distance," but in the relativity sense the " distance " is precisely nothing! Unfortunately, Professor Eddington would probably express this idea by saying that it was " true " the star was a great way off, but not " really true." But then, you see, Professor Eddington delights in paradoxes!

In recent years the theory of relativity has been attacked vigorously. Silberstein has contested the general theory. Bridgman,

like Mackaye and Mr. Eagle, claims that relativity is mere mathematics obscuring a physical meaning, while Drysdale, Lodge, D. C. Miller, and many others have questioned the whole notion of the impossibility of measuring an ether drift.

Let us hope that if the theory of relativity emerges from the crucible of criticism, it will do so in such a form that it will no longer seem at variance with common sense. I am sure you will agree with me that the paper we have heard this afternoon marks a step in this direction.*

Brigadier N. M. McLEOD said: The lecturer has told us a lot about Einstein's curved space, but I thought that curved space had rather gone out of the picture in recent years.

Did not Einstein and his colleague de Sitter, after their visit to Mount Wilson about six years ago, come to the conclusion that space need not necessarily be curved after all?

Let me quote from a letter in *The Times* of May 26th, 1932, signed G. Peace, F.R.A.S., etc.:

> "As a result of collaboration at Mount Wilson, they (Einstein and de Sitter) state that they conclude that it is possible to represent the facts of observation without assuming a curvature of three-dimensional space, and to insert into the equations of Einstein relativity Euclidean three-dimensional space of the old-fashioned type."

Will the lecturer tell us if Einstein has gone back to his curved non-Euclidean space?

(LECTURER replied he thought both Einstein and even Eddington were already getting rather tired of their curved space.)

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* Fleming, A. (Sir), *Trans. Vict. Inst.*, 1928, **60**, 248 ff. Eddington, A. S (Sir), *New Pathways in Science*, 1935, p. 279. Dingle, H., *Roy. Institution Lect.*, Nov. 26, 1937. Merrill, A. A., *Jour. Franklin. Inst.*, 1936, **222**, 212, Jeffries, H., *Nature*, 1937, **139**, 1004. Levy, H., *The Universe of Science*, 1932. Dingle, H., *Through Science to Philosophy*, Chap. xi. Chari, C. T. K., *Mind*, 1937, **46**, 159 ff. Minkowski, H., *The Principles of Relativity*, by Lorentz, Einstein, etc., 1923, p. 75. Mackaye, J., *Jour. Franklin Inst.*, 1934, **218**, 343. Eddington, A. S. (Sir), *Nature of the Physical World*, 1929, p. 33. Silberstein, L., *Univ. Toronto Studies. Phys. Ser.*, 1936. (See *Nature*, 1936, **138**, 1012). Bridgman, P. W., *The Logic of Modern Physics*, N.Y., 1928, pp. 167–172. Drysdale, C. V., *Nature*, 1934, **134**, 796, 833. Lodge, O. (Sir), Many works, *The Ether of Space*, 1909, *My Philosophy*, 1933, etc. Miller, D. C., *Rev. of Modern Physics*, 1933, **5**, 203.

I do not understand relativity and do not know anyone who does. But I wish to attack the very foundation of the theory.

Have not all the scientific publicists, including Sir James Jeans, who have told us about the Einstein theory, stated clearly and definitely that the basis of the relativity theory was the *null* result of the famous Michelson-Morley experiment, and have not the most eminent mathematicians, headed by the late Henri Poincaré, laid down that the theory must stand or fall by the result of the Michelson-Morley experiment ?

Professor Picard also said : " It vanishes as soon as the Michelson-Morley experiment comes within the scope of known physical effects."

Now I have studied the 1933 report on the Ether Drift (Michelson-Morley) experiments carried out at Ether Rock, Mount Wilson, over a period of more than 30 years, by Professor Dayton C. Miller, and I find that these physical effects have been observed and measured, and *from these results* have been calculated the direction and speed of the movement of the solar system through the ether of space, the speed being approximately 208 km. per second in the direction of a point about 6° from the S. ecliptic pole. Now, how can the theory stand when it was based on the fallacious assumption that the ether does not exist and that, therefore, movement through it cannot be detected, especially when this assumption depended upon the wrong reading of the result of such an all-important experiment ?

Mr. H. S. SHELTON thought it would interest the meeting if he read them an extract from an article he published as long ago as 1914, in which the arguments were not unlike those used by the lecturer.

> " In Riemann's space a line returns on itself. In the space of Lobatschewsky, ' parallel ' lines bend apart. Does either of these or Euclidean space represent actual space ? To this question there is only one possible answer. The line returning on itself is not straight, and the bending parallel straight lines are neither straight nor parallel. No possible experiments can alter or modify this fundamental. It may be that non-Euclidean geometry is applicable to real existent conditions. It may

be that parallaxes of very distant stars are negative, and there may be means of proving that stars which, by astronomical measurement, are found to be nearer, should ultimately be discovered to be farther. On such a question it is possible to admit evidence. A non-Euclidean ether is as metaphysically possible as a centaur or a hippogriff. A non-Euclidean space is as contradictory as a round square. Our material lines may bend; our rays of light may bend; but our straight lines are not straight unless they are straight. It may be that we always see crooked, but that is no reason why we should not think straight. The writer would urge that not only we go back to or remain with Newton, but that we go back to or remain with Euclid. Non-Euclidean geometry, non-Newtonian mechanics, and the Principle of Relativity are admirable examples of the coherence of thought whatever may be the material supplied to it as foundation, but they must not be mistaken for reality."*

The lecturer would therefore see that he was not alone in objecting to curved space, or peculiar in the reasons that he gave.

Mr. Shelton went on to say that the strength of the Theory of Relativity, which enabled it to carry with it a good deal that seemed to him to be nonsense, was to be found in the fact that it not only explained the previously unexplained irregularity in the orbit of mercury, but enabled Einstein to predict the existence and amounts of the bending of rays of light by gravitation, and the displacement of spectroscopic lines in a gravitational field. The latter prediction had been strikingly verified when astronomers were able to take the spectrum of the companion of Sirius—a white dwarf with an enormous gravitational field.

It seemed to him that there was a field open to the mathematicians to calculate from other and more admissible data the amounts of these three effects. The mere pointing out of the absurdities that arose from certain deductions from the Principle of Relativity was hardly sufficient. The problem was how to account for known facts in some other way. He hoped that experts in mathematical physics would give their attention to this problem.

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* "The Philosophy of Science." (*Science Progress*, January, 1914, pp. 415–6.)

W. E. LESLIE said: The first part of the paper is technical. What is the layman to make of these arguments? If Mr. Eagle were denying the curvature of the earth's surface, the layman would reflect—"This man has the world against him. That does not prove him wrong, but it does suggest that I should receive his arguments with cautious reserve." That, if he is wise, will be his attitude toward the technical arguments of this paper.

Next, Mr. Eagle argues repeatedly that the curvature theory is beyond the capability of our intellects, that we cannot form a mental conception of it, and so forth. But there is a vital distinction between that which violates the laws of thought, and so destroys tself, and propositions of which it may be difficult or impossible to form a mental picture. Further, the Theory of Gravitation which Mr. Eagle accepts is as hard to understand as the General Theory of Relativity. The layman can believe that the theories of mathematical physicists are beyond his picture-forming powers, but he will not readily believe that they have all (with the exception of Mr. Eagle) violated the laws of thought.

For the rest, we have a series of sweeping statements that have little beyond their dogmatism to commend them. The curvature theory has won the universal acceptance which Mr. Eagle deplores, first because it is the logical outcome of the sweeping changes in the theory of the physical sciences during the last few years, and then because it has stood the test of observation. A ray of light passing the sun has behaved as Einstein said it would—and not as it should on Mr. Eagle's view. Our author will, one fears, continue to sigh that he only is left to think rationally—he is not likely to find 7,000 mathematical physicists to think with him!

LECTURER'S REPLY

The author agrees with Dr. Clark, and would especially commend Mr. Mackaye's amusingly ironical exposure of relativitists' ambiguities. I know that Professor Eddington says that he uses the word "space" in four different meanings. How then can he expect anyone to know what he means? Unless by "curved space" he means "curved *Raum*" (German), he is misleading people.

I endorse Brigadier-McLeod's remarks. Professor Miller's results emphatically do not give "no fringe shift" which both relativity

and the Lorentz-FitzGerald contraction require. His results are most consistent with a contraction of 95% of the L.-F. amount; the 5% deficiency making it theoretically possible to determine (but with poor accuracy) the earth's motion through the ether. And this, roughly, agrees with that deduced from the rotation of the Galaxy.

Relativitists dare not look at these results, as belief in the slightest fringe shift is a complete experimental destruction of their whole theory, which incidentally is also founded on an erroneous definition of simultaneity in a moving system; this definition being made so that the velocity of light relative to the system will appear to be the same in both directions. The dishonesty of this question-begging definition has only gone unchallenged because a direct experimental test is impracticable—any practicable experiment requiring the light to be reflected back to its source.

The author cannot understand relativitists' ideas on the L.-F. contraction.' Thus Eddington describes it as "true (*i.e.*, apparently true), but not really true." This would be the dictum of someone ignorant of electromagnetism. The contraction is a theoretical *necessity** unless some quite unknown cause neutralises it; and if the contraction has only 95% of its theoretical value, then some unknown cause is neutralising 5%.

The author was very interested in the quotation from Mr. Shelton's 1914 article, and congratulates him on thinking so "straight" when many physicists were beginning to think crookedly.

In reply to Mr. Leslie, the deflection of light does not prove the curvature of space. It proves that light travels more slowly through the ether in a gravitational field—a very likely thing to happen. This produces the curved path just as it does in light rays through the atmosphere in which all horizontal rays have a camber of about 0·4 inch per mile due to the fact that the lower side, travelling through a denser atmosphere, travels more slowly than the upper side. A decrease in the velocity of light in a gravitational field would almost inevitably cause spectrum lines to be displaced towards

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* See last sentence in H. M. Macdonald's *Electromagnetism* (Bell), in which he quietly remarks, "this contraction [proved above] accounts for the *null* result in the Michelson-Morley experiment."

the red. This makes an understandable *physical* explanation as against a purely mathematical one.

I do not see how relativitists can possibly escape the charge that their " curved space " is really a contention that " ' nothing ' can possess a curvature," to quote from Professor Dingle. With these words the theory should, in the interests of clear thinking, be finally dismissed by everyone.