Gravitation and Light.

As I said last week (p. 334), and also in the December *Phil. Mag.* (p. 737), the refractivity $\mu-1$, necessary at every point of a gravitational field to produce the Einstein deflection, is the ratio of the energy of a constant-mass particle fallen there from infinity to the energy of the same particle moving with the speed of light; but it is not permissible to say that the solar gravitational field acts like a lens, for it has no focal length. If the sun were backed by a nebula or any luminous area, the light grazing the rim all round would be brought to a focus at a place seventeen times the distance of Neptune, while light from any larger circle would focus still further off in proportion to the area of the circle. So from a uniformly luminous area there would result a focal *line* of constant brightness. The moon is, unfortunately, impotent to make an annular eclipse interesting.

For an extended solar atmosphere to produce the deflection, its density would have to vary with the inverse distance, which seems unlikely; but this is just the way in which an æther tension ought to vary in order to cause gravitation—as Newton knew. The extra æther-tension factor, μ^2-1, would be twice the refractivity.

Possibly the concluding sentence in the *Phil. Mag.* article above referred to is not expressed with sufficient clearness. Permit me to explain my points thus:—

(1) The quasi-elasticity of æther—the property which enables it to transmit light and to effect electrical discharge—is probably due to exceedingly fine-grained constitutional vorticity with high-speed circulation, as argued in my book "The Ether of Space." Consequently it would have facility for gyrostatic action, yielding a perpendicular result to an acting force.

(2) That a gravitational force acting obliquely on light would probably be unable to alter speed, but, through the co-operation of its transverse and longitudinal components, it might be expected to produce an extra dose of deflection—assuming light to be subject to gravitation, as Newton surmised. So that by the time a beam of light coming from infinity had arrived at its nearest point to the sun, it would already have been deflected as much as an ordinary heavy particle would be deflected along its whole course.

I am aware that these are only suggestions for working out.

Einstein's equations, based on the impossibility of observing motion through æther, seem powerful instruments for extracting results; just as more familiar equations, based on the impossibility of "perpetual motion," have proved themselves effective; but neither set of equations explains, nor attempts to explain, the mechanism of the consequences they deduce. Dynamics have served us so well in the past that it must be still legitimate to try, wherever possible, to apply well-established principles to new phenomena.

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Edgbaston, Birmingham, November 30.

The Displacement of Light Rays Passing near the Sun.

THE part of the earth's atmosphere within the conical shadow of the moon during a total solar eclipse may be regarded as approximately a right circular cylinder, the area of the base of which depends on the length of the shadow. Observations have shown that there are temperature and pressure gradients in this cylinder. The latter gradient at the surface of the earth is usually slight, but the temperature gradient may be considerable, so that, assuming that there is equilibrium, we have, roughly speaking, a cylinder of air the density of which decreases outwards in all directions perpendicular to its axis. When we remember that the light from stars at small angular distances from the sun's centre makes small angles with the axis of this cylinder, it is easy to see that a very small density gradient would be sufficient to account for the displacements that were observed in the total solar eclipse of the present year.

Suppose the cylinder to be made up of two parts, an inner and an outer, the common boundary being a coaxial cylinder, and let a ray of light in the outer portion inclined at a small angle α to the axis fall on the boundary, the deviation δ is given by

$$\cos\alpha=\mu\cos(\alpha+\delta),$$

where μ is the index of refraction for rays passing from the outer portion to the inner.

Since δ is very small in comparison with α, we have, approximately,

$$\delta=\frac{\mu-1}{\mu\tan\alpha}=\frac{\mu-1}{\tan\alpha} \text{ very nearly,}$$

since μ does not differ much from unity.

If $\alpha=30'$ and $\delta=1{\cdot}7''$, we get

$$\mu=1+\delta\tan\alpha,$$

δ being expressed in circular measure.

Thus $\mu=1{\cdot}00000007$, and for small values of α it is clear that δ is inversely proportional to the angular distance of the star from the centre of the sun's disc.

If we take μ_1, the absolute index of refraction of the outer portion, to be $1{\cdot}0003$, μ_2, the absolute index of refraction of the inner portion, will be $1{\cdot}00030007$, and consequently

$$\frac{\mu_2-1}{\mu_1-1}=1{\cdot}0002,$$

which will be the ratio of the density of the air in the inside portion to the density of the air in the outside portion. On the assumption that there is no gradient of pressure, this would imply a difference of temperature of about $1/18^\circ$ C., a very small amount when it is remembered that the lowering of temperature at the surface of the earth during an eclipse may be as much as 5° C.

In the actual case the path of a ray will be a curve, but the above remarks will serve to show that the density gradient would probably be sufficient to produce the observed effect. It is clear, too, that the displacement in the actual case will be inversely proportional to the angular distance of the star from the sun's centre, and that it will depend on local conditions, so that the amount of displacement will be different for different places.

I think it is quite likely that if the refraction of the atmosphere of the earth due to density changes during an eclipse could be accurately obtained and allowed for, it would be found that there is no Einstein effect at all.

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EINSTEIN'S RELATIVITY THEORY OF GRAVITATION.

I.

THE results of the Solar Eclipse Expeditions announced at the joint meeting of the Royal Society and Royal Astronomical Society on November 6 brought for the first time to the notice of the general public the consummation of Einstein's new theory of gravitation. The theory was already in being before the war; it is one of the few pieces of pure scientific knowledge which have not been set aside in the emergency; pre-