LETTERS TO THE EDITOR.

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The Deflection of Light during a Solar Eclipse.

IT may be worth while to give my endeavour to obtain a rough value for the refraction effect of the atmosphere during a total eclipse of the sun. The simplest case possible is when the sun is in the zenith.

I will assume that the air density of the normal atmosphere has been removed, and that there is left the atmosphere which produces the abnormal effects in question. This is not necessary, but it makes the calculation somewhat simpler.

If O be the place on the earth's surface of maximum air density, the density ρ_0 of the residual atmosphere there will be one-seventieth of the density of the normal atmosphere if we assume that it corresponds to a fall of 4° C. in the atmosphere when in equilibrium. Take Ox in the direction opposite to that of the motion of the shadow, and Oy the vertical passing through the centre of the moon's disc. This assumes that the density is greatest at the centre of the shadow, which is almost certainly incorrect. I will take the density at any point of the residual atmosphere in the plane of xy to be given by

$$\rho = \rho_0(1 - \kappa x)e^{-\beta y},$$

where β, although it varies with temperature, is assumed to be constant and equal to $1{\cdot}3 \times 10^{-6}$, distances being measured in centimetres. If we assume that the density of the atmosphere becomes normal at 150 miles distance from O, κ will be $4{\cdot}17 \times 10^{-8}$.

With these values of the two constants, the above formula expresses that the horizontal density gradient is uniform and independent of height, and that the atmosphere has its normal density at a distance of 150 miles. None of these statements is correct. The shadow-cone in the earth's atmosphere acts like a down-draught chimney or a kind of thermal air-compression pump, increasing the density in the central region of the shadow and diminishing it in surrounding regions. Thus κ may have a very much greater value than that given above, and, indeed, the factor $1 - \kappa x$ may be quite incorrect in form.

However, taking this formula for the density, the index of refraction of the residual atmosphere at any point is

$$\mu = 1 + (\mu_0 - 1)(1 - \kappa x)e^{-\beta y},$$

where $\mu_0 = 1{\cdot}000004$.

The path of any ray in the plane of xy might be got by solving the usual differential equation for this case, but I have not succeeded in getting a solution. However, the amount of the deviation can be obtained without knowing the actual path.

If ϕ be the angle which the tangent to a curve of equal refractive index makes with the axis of x, we have

$$\tan\phi = \frac{\partial\mu}{\partial x} \Big/ \frac{\partial\mu}{\partial y} = \frac{\kappa}{\beta(1 - \kappa x)}.$$

It can easily be shown that the radius of curvature of the lines of equal density or refractive index in the neighbourhood of the axis of y is muth greater than the radius of the earth. Thus, as we have assumed the earth's surface to be plane, we can assume these lines to be straight in the portion of the atmosphere concerned. On the axis of y, $\tan\phi = 0{\cdot}032$, and for an observer at O the refraction of the light coming from a star near the edge of the sun's disc will be the same as if he were looking through an atmosphere stratified in parallel planes, making an angle ϕ with the horizon. A ray coming from such a star will make an angle of $\phi - 15'$ with the normal to these planes, and the refraction will be

$$(\mu_0 - 1)\tan(\phi - 15') = 0{\cdot}000004 \times 0{\cdot}0277 = 1108 \times 10^{-10} \text{ or } 0{\cdot}023''.$$

If the ray come from a star the angular distance of which from the sun's centre is 45′, the result is 0·0082″, which is a little more than one-third of 0·023″. But if, as I believe, κ has been greatly under-estimated, the possible values of these refractions are much greater.

If the observer be not at the origin, but at a distance along the positive direction of the x-axis, the refraction of the light from stars on the other side of the sun's disc will not be away from the sun's centre, but towards it, and *vice-versa*, if he be on the other side of the origin. But no difficulty of this kind occurs for refraction in planes perpendicular to Ox if the position of the observer be on the x-axis. Perhaps it is worth mentioning that, from the only account of the observations I have seen, it appears that, with the exception of one star, all the changes in right ascension were of the same sign, whereas the changes in declination were all in the right direction.

I ought to mention in reference to Sir Arthur Schuster's letter (NATURE, January 8, p. 468) that I never thought of a ray that, in its passage through the earth's atmosphere, lay partly inside and partly outside the umbra. And I thank him for correcting the slip that I made in the angular radius of the sun's disc. In these days of relativity, an error of fifteen minutes either of arc or of time is, perhaps, excusable.

ALEXR. ANDERSON.

University College, Galway, January 14.

"The White Water."

IT is possible that some readers of NATURE can enlighten me on the cause and nature of what the Arabs call "The White Water." This phenomenon was witnessed by me on two occasions at the entrance to the Persian Gulf in the vicinity of the Quoin. On both occasions the time was about 8 p.m. There was no moon on the first occasion, but a moon on the second.

I first observed what appeared to be a line of breakers ahead of the ship; this was not possible because we were in deep water and the position of the ship was known. As we approached, it seemed that these supposed breakers were a succession of phosphorescent waves of a period of about sixty to the minute. The waves extended, so far as could be seen, for about two miles.

In addition to these waves there were also phosphorescent Catherine-wheels, both right- and left-handed, also phosphorescent light apparently coming to the surface and radiating out in all directions.

The phenomena lasted for about half an hour, gradually fading away, apparently sinking. There were strong atmospheric disturbances at the time. Both nights were clear and the sea was calm. I could obtain no local information. I may add, in conclusion, that I was not the only person who witnessed this display.

A. R. PALMER.

Portsmouth, January 13.

I HOPE that Capt. Palmer's letter will induce officers of the Indian Marine to investigate any cases of "White Water" that come under their notice. I am