Thus if he moves about from place to place within the crater, the walls on one side will come to his view, while those on the other will appear lower and lower and then disappear below the horizon, and he will hardly imagine that he is within a bowl-shaped enclosure surrounded by a wall.

Had the crater been upon the earth, whose curvature is not so large, only about 600 feet (instead of 2,200 feet) of the walls would have been invisible to him from his position at the centre. Standing at the extreme ends he would have a gradually sloping view of the walls, which would just become invisible at the opposite end.

Illumination of the Moon's Disc during a Total Lunar Eclipse.

By Dr. E. P. Harrison.

The following short note has arisen out of a discussion which occurred after the last meeting of the Society. It was subsequently thought that a few remarks on the subject of the illumination seen over the moon's disc during a total eclipse might not be without interest to some of the members. The usual diagrams given in text-books of a total Eclipse of the moon make clear the state of affairs during a total eclipse. They show the arrangement of the three bodies involved, and indicate the extent of the shadow when the earth is considered to possess no atmosphere. It is seen that the moon is completely in shadow, and apart from resultant illumination due to starlight, should be invisible from the earth.

The "radius of the shadow" may especially be noticed as being an important factor in the determination of the length of an eclipse. Its maximum value in any possible eclipse is 1° 2′ of arc.

Now suppose that, by some means or another, a portion of the light of the sun as it passes immediately over the earth's surface is bent inwards towards the centre of the moon, the effect is obviously that a certain amount of illumination is shed over the eclipsed disc, rendering the latter visible from the earth.

The existence of our atmosphere supplies us with a cause for the necessary bending, and consequently, with a perfectly satisfactory reason for the illumination observed during totality. It is only necessary now to calculate the *amount* of the refraction produced by the layer of air over the earth's surface, and to see whether the bending is sufficiently great to account for the illumination of the whole of the moon's disc.

The problem is similar to that of finding the difference between the times of real and apparent sunset.

Suppose a sunset is observed at the time of an equinox on a clear still day at sea. In actual fact the sun is below the horizon about 2 minutes and 12 seconds before it is *observed* to disappear. In other words, if the atmosphere were suddenly abolished at the moment the sun's lower limb appeared to touch the sea, darkness would be instantaneous. The fact that sunlight still reaches us after the sun is geometrically out of sight is due to this same refraction by the air, which enables the illumination of the moon's disc during an eclipse to be accounted for.

The amount of the bending will depend on the angle at which the light enters the atmosphere, and can best be calculated by experimental methods. Observations on the zenith distance of a circumpolar star at its two culminations will yield a value for the amount of refraction by the air corresponding to a particular altitude, and its value can be found by this and other methods for any altitude from 0° to 90°. At 90°, when the body observed is in the zenith, the refraction is, of course, zero ; it is at maximum when the light reaches the earth's atmosphere at grazing incidence, that is, when the altitude is 0°. This last is clearly the particular value of the refraction which we need in the eclipse problem. It is called the "Mean Horizontal Refraction," and its value is 33 minutes of arc for air at 50° F. and at a pressure corresponding to 29·6 inches of mercury.

Now, in the actual case before us, the sunlight will be refracted twice : once on entering the atmosphere, and once on leaving it, so that the total angle through which the light is deflected is *twice* the horizontal refraction, or 66 minutes, that is, 1° 6′. But the maximum "radius of the shadow" is, as we have seen, 1° 2′, so that the light refracted by the earth's atmosphere easily covers the whole of the moon's disc even in the case of a perfectly "central" eclipse.

The faint illumination observed during a total eclipse is thus accounted for. There remains the discussion of the colour of that illumination.

A Principle in Optics known as Diffraction provides the required explanation.

In the first place, it must be remembered that the light from the sun is composite. It may be described as consisting of a series of waves in the ether varying in length from

$\frac{1}{1400}$th of a millimeter which give the sensation of red light, to $\frac{1}{2500}$th of a millimeter, which give a sensation of blue.

This composite light passes through the atmosphere and becomes modified during its passage in the following way: There exist, floating in the air, a multitude of particles so small that their diameter is comparable with the length of the shorter or blue waves. These particles are in the direct path of any beam of light which enters our atmosphere, and the principle of diffraction indicates that when a beam of white light enters such a turbid medium, the short blue waves are irregularly reflected by the little particles (thus giving rise to the blue colour of the sky which is almost entirely due to this reflected light), while the longer red waves pass on unscattered.

Evidently, if the beam of light passes through a sufficiently thick layer of air, it will eventually be robbed of its blue constituents and will become correspondingly rich in reds and yellows. This is, indeed, precisely the effect observed at sunset and sunrise; when the sun's altitude is small, his light has to pass through a greater thickness of air than it does when he is in the zenith; consequently sunset tints are yellow and red. The blues have been filtered out during transmission.

For the same reason the snow of a distant peak appears yellowish in tint, and the spectrum of the earth-shine on the moon near to the time of new moon is poor in blues.

If we apply this reasoning to the problem of the eclipse, it is evident that the refracted light, having passed through a great thickness of air, will be tinged red, and that consequently, if no change in the character of the light occurs on reflection from the moon's surface, we should expect to see what we actually *do* see, that the faint illumination of the moon's disc during an eclipse is of a distinctly reddish hue.

Finally, it is interesting to try to account for the different intensity of illumination observed in different eclipses.

Observers have continually noted this variation in intensity from one eclipse to another. Indeed, in the eclipse of 1886, the moon's disc was said to have been absolutely invisible.

Probably the effect can be accounted for by assuming the existence of clouds round a large portion of the ring of air which forms the refracting medium during an eclipse. In the 1886 eclipse, a very large proportion of this ring must have been cloud-laden at the time, almost completely shutting off the refracted sunlight and giving rise to an absolute eclipse of the kind which would occur were there no atmosphere at all.

The explanation just given suggests that the intensity of illumination during an eclipse may possibly vary with the time of year; for example, it might be suspected that in June, during the beginning of the monsoon, when masses of vapour are pouring northwards from the equator, the eclipse-glow would be somewhat reduced in intensity. Moreover, since the reduction in intensity would occur principally in the plane of the earth's equator, we might expect to notice a belt of relatively faint illumination stretching across a plane parallel to this on the moon's disc.

Differences in appearance and intensity of the illumination during any one particular eclipse are most likely due to absorption of light by the layer of air *through* which we see the phenomenon of the eclipse. In Bankura, for example, a brighter illumination of the disc would be expected than that observed in Calcutta, where the air is less pure.

One more point is, I think, of interest.

The amount of refraction by those portions of air near the poles of the earth is greater than that by portions of air near the equator, owing to a difference in temperature between these regions. The Mean Horizontal Refraction for air at 50° F. and 29·6 ins. pressure is, as has been mentioned, 33 minutes of arc. The Horizontal Refraction of air at the same pressure and a temperature of 20° F. is about 40 minutes of arc. So there is a difference of 7 minutes in the amount of refraction in two planes at right angles; thus, theoretically, at all events, there should exist a short straight belt on the moon's surface parallel to the earth's polar axis which is more brightly illuminated than the rest of the disc. An observer standing anywhere on that line on the moon would observe the rim of light round the edge of the earth to be brighter there than at any other station on the satellite.

In subsequent eclipses it would perhaps be worth while for observers to look out for any indication of a relatively bright band near the centre of the disc.

Photographs of the eclipse would be most likely to show the effect, if it is to be seen at all.