Letters to the Editor.

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Atmospheric Refraction.

THE proposition that "the course of a nearly horizontal ray of light in the lower part of the atmosphere is a circular arc having a radius of 14,900 geographical miles" has been stated by Mr. Mallock in a letter in NATURE of June 9, p. 456. Mr. Mallock states later on in the same communication that rays that are pointed a few degrees up or down will still be arcs of a circle of 14,900 miles radius.

It has been customary for many years in all survey departments to assume that the angle of refraction on a ray bears to the angle subtended at the centre of the earth a ratio denoted by k, which is called the "coefficient of refraction," assumed to be constant at a given point for all rays. It is easy to see from this that the ratio of the curvature of the ray—tacitly assumed to be circular—to the curvature of the earth is $2k$; and that if $2k=1$ a horizontal ray would circle the earth. According to Mr. Mallock's result, $2k=3960/14{,}900$, taking the earth's radius as 3960 miles, which leads to $k=0 \cdot 133$. Now this is *not* a value ordinarily met with in practice. In Clarke's "Geodesy" values of k derived from observations of the Ordnance Survey are given as 0·0809 for rays over water and 0·0750 for rays over land. These values are not far different from values obtained from other surveys.

Mr. Mallock's reasoning is based on the equation

$$v_h = v_0\left(1 - a\frac{H-h}{h}\right).$$

When $h=0$ this becomes $v_0(1-0 \cdot 00029)$, or v_0/μ, where μ is the refractive index of air at standard pressure and temperature. While this is correct, it appears to me to be quite erroneous to consider the equation as giving the correct velocity at heights of a few thousand feet. It may not be incorrect to state for a limited range of height that the velocity varies as the height; but surely it is incorrect to deduce the factor of this variation from an assumed law which gives the velocity at height H (the height of the homogeneous atmosphere = 8·3 km.) equal to the velocity *in vacuo*?

If the refracted ray is circular and of the same radius of curvature for rays deviating several degrees from the horizontal, it would follow that the value of k at two considerably different levels would be the same. Now the refraction depends on $\mu-1$, which varies as the density of the air. It is manifest that k is smaller at a considerable height than at sea-level in the proportion of the densities at the two heights. The value of k varies not only with the height, but also with the angle of elevation of the ray. The most convenient plan so far evolved is to speak of the "coefficient of *horizontal* refraction," k_0, and to give values for this quantity at various heights. Under certain average conditions for a ray from A to B, points the heights of which are h_a and h_b, the refraction may be computed by using the coefficient of horizontal refraction appropriate to height $1/3(2h_a+h_b)$, while for the reverse ray $1/3(h_a+2h_b)$ should be used. The values of k_0, which follow from purely theoretical considerations if a temperature gradient of 3° F. per 1000 ft. be assumed, vary from 0·08 at sea-level to 0·05 at 19,000 ft. for temperatures and pressures 82°, 30 in., and 25°, 15 in., respectively. These values are found to account very well for refraction in numerous Indian observations.

Refraction is not, in general, constant throughout the twenty-four hours. It is usually smallest in the afternoon at about 3 p.m., and the minimum value then reached is approximately the same from day to day. On this account observations are often restricted to the hours between 2 and 4 p.m. It may easily happen that the refraction at 8 a.m. is double that at 2 p.m. The values of k given above refer to minimum refraction. Recent research has shown that the diurnal change is due mainly to the changes of temperature in the first 300 ft. of the atmosphere; in that region the form of the ray of light is by no means circular. Beyond a height of 300 ft. temperature changes in the air due to conduction practically disappear. For rays of light which remain most or all of their length within a distance of 300 ft. from the ground, highly anomalous values of k may, and generally do, exist. In such cases afternoon refraction is smaller than is indicated by values of k already given, and in some cases is zero, or even negative. Such rays require special consideration.

Results of a good many observations will be found in my "Formulæ for Atmospheric Refraction and their Application to Terrestrial Refraction and Geodesy" (Professional Paper 14, Survey of India, Dehra Dun, 1913); and a more recent article in "The Dictionary of Applied Physics" (Macmillan and Co.), now under publication, may also be consulted.

J. DE GRAAFF HUNTER.

Dehra Dun, United Provinces, India, July 13.

THE only points in Dr. Graaff Hunter's letter to which I need refer are (1) the objection raised against taking the refractive-index gradient for the lower levels of the atmosphere as being identical with that which would make $\mu=1$ at the height of the homogeneous atmosphere, and (2) the statement that "conduction" of heat extends to a height of 300 ft. above the ground.

With regard to (1), the pressure gradient near the ground, and the density and refractive-index gradients also, decrease linearly at such a rate that if the linear relation continues to hold, the pressure and density would be zero and the refractive-index unity at the height H, and this is the gradient which should be used in correction for refraction to such heights, as the linear relation is a sufficient representation of the facts. How far depends on the order of accuracy aimed at.

Temperature effects may make a difference of 1 or 2 per cent. per 1000 ft., but in such an uncertain correction as that for terrestrial refraction this is scarcely worth notice.

The presence of water-vapour will have an effect as well as variation of temperature, and it will generally be impossible at any particular time and place to know for certain what the refraction really amounts to, especially if the course of the ray is long.

(2) It is scarcely correct to speak of the irregular distribution of temperature near the ground as being due to conduction. True conduction in the air is quite insensible compared with diffusion by eddies and the general instability of flow.

A. MALLOCK.

The X-ray Structure of Potassium Cyanide.

WRITING in the current number of the Proceedings of the Royal Society, Prof. A. O. Rankine concludes from determinations of the viscosity of cyanogen gas that the cyanogen molecule "behaves in collision like a hard body formed by two overlapping hard spheres, each of which has the kinetic properties of a nitrogen molecule." He gives as the distance between the centres of these overlapping spheres $2 \cdot 3 \times 10^{-8}$ cm. Prof. Rankine also remarks: "It is significant that the crystals of potassium cyanide and those of the potassium halides are usually stated to be iso-