XXIV. *On Solar Light, and on a Simple Photometer.* By MUNGO PONTON, Esq.,
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In approaching the subject of solar light, the first point is to endeavour to form an idea, not altogether indefinite, with respect to its quantity and intensity, as compared with some familiar standard of artificial flame. With this view were made, in the course of last summer, the observations now to be described.

After several trials, it was found, that the most convenient mode of procedure was first to compare a definite small surface, illuminated by solar light, with a like surface illuminated by the mere light of the sky, and then to compare the latter with a similar surface illuminated by the flame of a moderator lamp. The light of the sky thus affords a middle term between the extreme lights of the sun and the lamp, which are too diverse to be directly compared.

The first difficulty to be overcome, was that arising from the difference of colour between the flame of the lamp and the light of the sky. For this purpose, it was found necessary to employ light of only one colour; and blue light was selected, as that which could be most easily obtained pure.

Various methods having been tried, it was found that the blue rays could be obtained in sufficient purity, by taking the common blue paper used by haberdashers for packing their light goods, and steeping it in a concentrated solution of sulphate of copper, and then viewing this paper through common blue glass. This glass, it is well known, transmits only the blue rays and the extreme red; but the blue paper absorbs the extreme red, and disperses only the blue and a few yellow rays, which last are absorbed by the blue glass; so that, by this combination, only the blue rays reach the eye. In the light thus obtained, no rays save the blue could be detected by prismatic analysis.

To regulate with exactness the quantity of light admitted to the eye, a number of small slips of tea-lead were perforated with holes of various diameters, from $\frac{1}{10}$ th down to $\frac{1}{100}$ th of an inch. These apertures were carefully made, the rugged edges being removed, so as to present a clean circular outline. The diameter of each hole was exactly measured under the microscope, with a power of a hundred diameters.

The next point was to secure the exclusion from the eye of all extraneous light. For this purpose two pasteboard tubes were made, about eight inches long, and one inch in diameter, and lined inside with dull black paper. These were placed parallel to each other, and fastened together in such a manner that the centres

of their diameters were two-and-a-half inches apart, but with the means of slightly varying this distance, so as to bring the apertures exactly opposite the pupils of the two eyes. At the end of the tubes next the eye was an aperture of about a quarter of an inch in diameter, in which was inserted a piece of blue glass. Outside of these were placed slides, into which the perforated slips of lead might be introduced, in such a manner as to prevent their apertures from touching the surface of the paper, for fear of the entrance of minute fibres. At the ends of the tubes farthest from the eyes were simple apertures of about a quarter of an inch in diameter. To each of these farthest ends was attached, at the inner edge, a piece of card, which, after projecting outwards, about an inch and a half, was bent round at a right angle, so as to face the end of the tube. These pieces of card were covered on the outside with black paper, and on the inside with the prepared blue paper before described. The lower part of the card was attached to the lower end of the tube by a similar piece of card, also lined with the blue paper; and there was thus formed, at the further end of each tube, a small rectangular box, open at the top and the outer side, and lined throughout with the blue paper. To each of these boxes were closely fitted covers, which could be put on and removed at pleasure. The cross piece connecting the two tubes was fastened to a telescope stand, so as to place the tubes horizontally at the level of the eyes. When so adjusted, the surfaces destined to receive the light were vertical.

In Plate VIII., fig. 1, is shown a bird's-eye view of the two tubes PQ and RS; while XY is the cross piece by which they are attached, and on which they slide horizontally, so as to adjust their distance; ee' are the ends next the eyes, and cc' , $c'c'$ are the cards fastened to the farther ends, on which the light is to fall. Fig. 2 is a central cross-section, showing how the tubes are connected by the cross piece, and the latter with the telescope stand T. Fig. 3 shows the two ends next the eyes, with the perforated slips of lead inserted in the slides. Fig. 4 shows the farther end of the tube, prepared to receive the sun-light, with the direction of the rays $r r'$. Fig. 5 shows the farther end of the other tube, furnished with a small screen s to exclude the direct rays of the sun, and leave the receiving surface illuminated by the mere light of the sky. Fig. 6 shows the end of the sun-tube, disposed for the lamp; the ring l being the argand burner, surrounded by a screen ss to confine the light. This screen was covered with black paper outside, and lined with white paper inside, so as to give the lamp-light the benefit of its reflection. There was another screen, not shown in the figure, placed over the argand, with a hole only sufficient to admit the glass chimney. By this arrangement, all light was excluded from the little box, except that of the lamp, whose flame was placed in such a position that the rays fell on the receiving surface at a horizontal angle of about 45 degrees, the surface of the flame being about two inches from the receiving surface.

When this instrument had both its receiving surfaces lighted by mere daylight, there were seen, on looking through it with both eyes, two equal round spots, one-fourth of an inch in diameter, of a very pure blue colour. If the apertures next the eyes were equal, these spots appeared of exactly the same tint and intensity; but if one of the apertures was a very little smaller than the other, the spot, viewed through the smaller aperture, appeared of a sensibly darker shade, in so much as to impress the eye with an idea of difference of colour. This peculiarity greatly aids the eye in judging when the two spots are of exactly equal brightness. It is, of course, necessary to take care that both apertures are smaller than the pupil of the eye.

In order to determine how far the results to be obtained by this instrument might be found to agree with those which may be obtained from the method of equal shadows, the instrument was first employed to compare the light of the moderator lamp with that of a wax candle (a short 6); and, after repeated trials, it was found that the results of the comparison, when made with this instrument, exactly agreed with those obtained by the method of equal shadows, the light of the lamp proving to be $3\frac{1}{2}$ times that of the candle. Indeed it is, if anything, easier to judge of the perfect equality in brightness of the two blue spots, than of the equal darkness of two shadows.

Several preliminary trials were next made, with a view to obtain a series of approximations to the relative sizes of the apertures to be employed. In making these observations, the observer should sit in an easy, half-reclining posture, with his back to the sun, so as to have the receiving surface exactly opposite to that luminary; his elbows should be rested steadily on the table; and his hands placed at the sides of his eyes, to screen them from extraneous light. Before looking into the instrument, the eyes should be closed for a little time, to render them more sensitive to the feeble blue rays; and care must be taken to have the two images simultaneously visible without effort, so as to admit of their exact comparison. For a good observation, a bright, cloudless, and perfectly calm day, should be chosen; and the sun should be at an altitude of about 45° , so as to give the mean brilliancy of sunshine.

Thursday the 10th of August 1855 having proved entirely suited for the purpose, advantage was taken of it, to make the decisive observations, which were commenced about 11 A.M., and occupied between 15 and 20 minutes.

The diameter of the aperture fitted to the sky-tube was 0.083 inch. The sun-tube was tried first with an aperture of 0.015, through which the sun-lit surface appeared a little brighter than that lighted by the sky. It was next tried with an aperture of 0.01375, and then the sky-lit surface appeared the brighter of the two. Lastly, there was applied to the sun-tube an aperture of 0.014375, and then no appreciable difference could be detected by the most steady gaze. These three apertures were changed several times, and always with the same results.

The little box at the end of the sun-tube had now its cover put on, so as to leave open only its right-hand side, to which the lamp was approached, and disposed in the manner before described. The aperture applied to this tube was now 0·1, and, after trying several approximate apertures for the sky-tube, one of 0·0275 was ultimately fixed upon, as that which rendered the two images of exactly equal brightness.

These observations were subsequently repeated, with the same results; and, on each occasion, the apertures were, after the observations, examined under the microscope and ascertained to be clear. These results may therefore be regarded as a fair approximation to the truth.

The brightness of the images being inversely as the areas of the apertures, it follows from the first observation, that a small surface illuminated by the direct rays of the sun at an altitude of 45° is 33·6 times brighter than a similar surface illuminated by diffuse day-light; while, from the second observation, it follows that a like surface illuminated by the flame of a moderator lamp, at the distance of 2 inches, and placed obliquely so that the rays might fall as nearly as possible at a horizontal angle of 45° , is 13·2 times less bright than a similar surface illuminated by diffuse day-light. Hence, the same surface when lighted by the sun is 444 times brighter than when lighted by the lamp, under the above circumstances, the blue rays only being used in each case. This exclusion of all but the blue rays, is somewhat adverse to the artificial light, which has an excess of red and yellow rays, beyond what is required for the composition of white light; but the blue rays may be held to indicate the proportion of white light, contained in the artificial flame.

As, from the preliminary observation, it was found that the moderator lamp employed was 3·5 times brighter than a wax candle (short 6 in the lb.), it follows, that a small surface, illuminated by mean sunshine, is 1554, or say 1560 times brighter than is the same surface when lit by such a wax candle placed at 2 inches from it, in an oblique direction.

Now, it is found not difficult to raise the electric light to such a pitch of intensity as to afford a light equal to that of 520 wax candles; so that, if the moderator lamp were replaced by three such electric lights, the surface would be equally bright as when illuminated by mean sunshine.

To form a conception, therefore, of the quantity and intensity of the light emanating from the sun, when it reaches a distance of 95 millions of miles from his centre, we may imagine the surface of a sphere, having that distance for its radius, to be covered all over with a very thin film, say $\frac{1}{1000}$ th of an inch in thickness, having a brightness equal to that of an electric light of the above-mentioned intensity. and that behind this there are two similar films of equal brilliancy, the three forming a thin stratum, say $\frac{1}{40}$ th of an inch in thickness; then such a stratum would represent the brilliancy of the sun's light at the earth's orbit.

Now, let us imagine this stratum to be transferred to the surface of the sun. It would there be spread over 46,275 times less area ; consequently, its thickness would be increased that number of times, and would therefore amount to about 1132 inches, or about 94 feet, embracing 138,825 layers of flame, equal in brightness to an electric light of the above-mentioned intensity, and it would at its outer surface possess a brilliancy equal to that of the surface of the sun.

It is evident, however, that there might be a very considerable addition made to the thickness of such a stratum, without affecting, in any appreciable degree, its proportion to the planetary distances. If then, the thickness of the stratum were increased 520 times, making it 49,000 feet, then it might embrace 72,000,000 layers, each of them having an individual brilliancy not greater than that of a wax candle. The real thickness of the stratum in which the luminous property of the sun resides, may be very considerably greater than the above estimate, which is somewhat over 9 miles ; and the luminosity of each individual film composing the stratum may be very considerably less, without affecting the general result.