ON THE SPECTROSCOPE AND ITS APPLICATIONS *

THE field of research which has been opened up by the spectroscope is one with which we have so recently become familiar, that it may almost be said that twenty years ago, a course of lectures on the spectroscope would have been an impossibility. The instrument, as we now know it, was only then in embryo, and even at the present time, although immense strides are every day

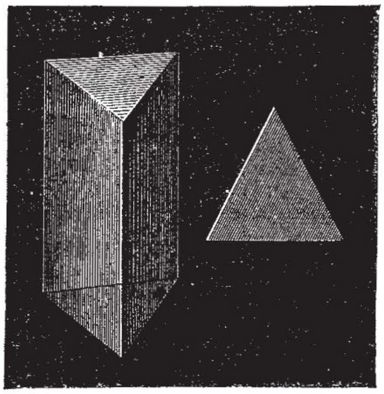

FIG. 1.—Geometrical form of the prism.

being made, the science of spectroscopy must still be considered in its infancy. And yet, so far as one can see now—it is always very easy to prophesy after the event—there seems very little reason why lectures on the spectroscope should not have been given two centuries ago; for

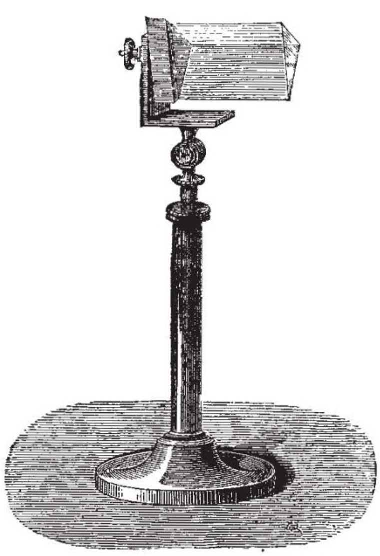

FIG. 2.—Prism mounted on a stand.

nearly two centuries have elapsed since the immortal Newton made his classical researches on the action of a prism upon sunlight. You may, perhaps, be inclined to ask, how it could take 200 years for the knowledge of the prism, and of the wonders that can be worked by it, to become part and parcel of our common stock of information? If you ask me to explain this, I tell you candidly that I cannot; but there is this grain of comfort connected with it which none of us should forget: we may almost say for certain that Newton and his successors would have brought a great deal more out of the prism than they did, if they had given a little more attention to it, and had tortured it as they did other things; that those who follow us will point to us and say the same; they possibly will say that in the 19th century, men of science, in working and experimenting, saw a great many things, and chronicled them, but did not care to go any further with them. This is very true; and the result is, that work is not done which might be done if we were more receptive and original in our methods of investigation; that is to say, if we trusted Nature more and ourselves less.

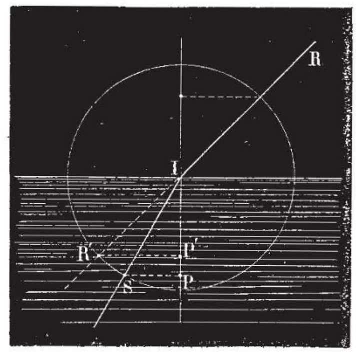

FIG. 3.—Refraction of light.

I propose that the first part of this lecture should in the main consist of an account of the prism and the principles of the spectroscope, and then of a description of the various kinds of spectroscopes which are now employed. I hope afterwards to go somewhat in detail into the applications of the spectroscope, not only with regard to terrestrial matters, but also with regard to those problems which we may possibly consider much grander, problems dealing with those celestial bodies which are sufficiently our neighbours to send us light.

Obviously, the first question we have to answer is this, What is a spectroscope? This I answer by saying that

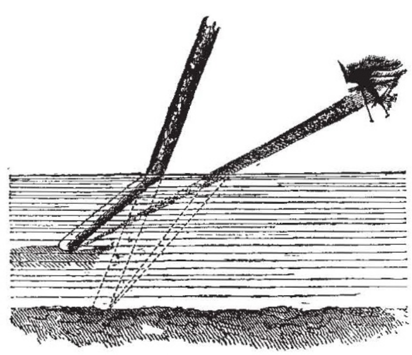

FIG. 4.—Explanation of the bent stick.

a spectroscope is an instrument in which the action of a prism or a combination of prisms is best studied. The next question, then, that arises, is, What is a prism? The accompanying figures (Figs. 1 and 2) will give a good idea of what is meant by a prism, and little time need be spent in description. It is usually a piece of glass—though it need not necessarily be so—bounded by five surfaces, two of which are parallel to each other—though they are not necessarily so—and three of which, bounded by parallel edges, cut each other at different angles; it is in reality shaped like a wedge. The importance of these different angles you will see by-and-by.

* Revised from the series of Cantor Lectures, delivered in 1869.

The discoveries of Newton, to which I have already alluded, were connected with prisms, and were based on well-known properties of light.

If a beam of light, as for instance sun-light or an artificial white light, be allowed to enter a dark room from a round hole in a shutter, it will simply travel in a straight line from its source; and to make it deviate from this straight line one of two things must be done. The beam must either be reflected or refracted.

The reflection of light is of very ordinary occurrence, for when light strikes any polished metallic surface, or in fact a surface of any kind, it is more or less reflected by it. The phenomena of reflection are so well known, the use of the mirror or looking-glass being perhaps one of

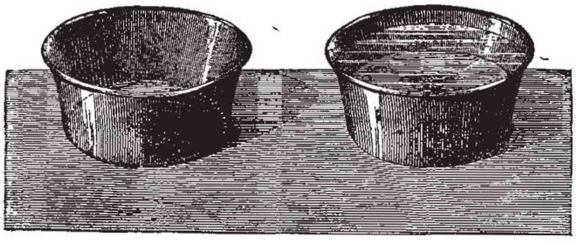

FIG. 5.—Refraction of light. Apparent elevation of the bottoms of vessels.

the most tangible, that no detailed reference need be made to them. The refraction or bending of light takes place when the ray passes obliquely from one medium to another of different density, as from air into water, or from water into air. A simple experiment may be made by passing the beam of light from above into a glass vessel containing water. If the ray strikes the surface perpendicularly, it will be seen that no visible change takes place, the ray simply proceeds directly into the water without altering its direction. If, however, the beam be allowed to fall on the surface of the water, say at an angle of about 45°, two things may be observed. In the first place a reflection will take place at the surface of the water—that is to say, the light will appear reflected at the surface, and it will be noticed incidentally that the angle at which the reflected ray leaves the water is precisely equal to that at which the incident ray strikes the surface, thus proving the rule that "the angle of incidence and of reflection

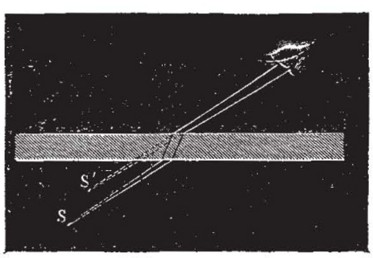

FIG. 6.—Light passing through plate of glass.

are equal." The second thing to be noticed is that on entering the water the direction of the beam of light will not be the same as it was in the air. In Fig. 3, the ray R I, striking the water at I, instead of proceeding to R′, is deflected or refracted to S; that is, the ray will be bent downwards, or, what is the same thing, towards a line, I P, perpendicular to the surface, to a definite extent, depending on the angle of the incident ray. The experiment may be varied by allowing the light to fall on the surface at various angles, when it can be shown that the angle formed by the ray refracted in the water varies in proportion to the angle of the incident ray, and that the angles formed are bound together by a regular law. Another fact may be observed, that the smaller the angl at which a ray of light strikes the surface of water, or, in fact, any transparent surface, the greater will be the proportion of light reflected at its surface.

Refraction may be clearly studied by plunging a stick into a vessel of water: the stick will appear bent at the point where it enters the liquid, as in Fig. 4, thus giving the appearance as if the stick were lifted or bent upwards. Another very instructive experiment is to place a coin at the bottom of a vessel, and then, standing so that the coin is just hidden by its edge, to gradually fill the vessel with water; the coin will appear to rise with the bottom of the vessel, and will become visible, as shown in Fig. 5.

The amount of refraction varies with the medium employed, and also with its temperature. The effect of different media can be clearly seen by passing a ray of

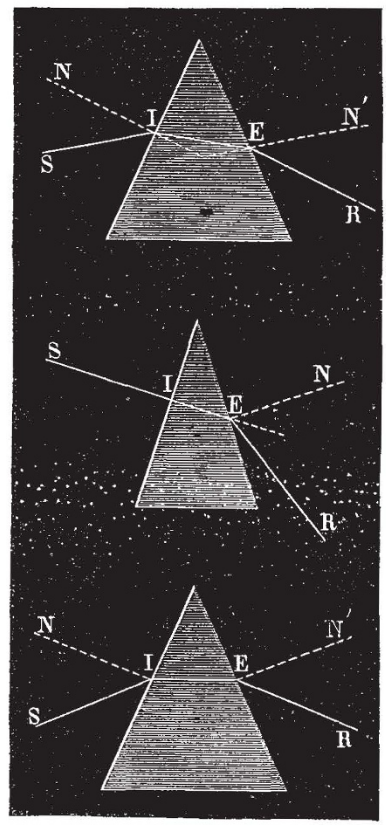

FIG. 7.—Deviation of luminous rays by prisms.

light into a vessel containing a liquid such as bi-sulphide of carbon, with a layer of water floating on the top. The ray will be seen to be bent on entering the water, and still more bent on passing from the water into the layer of bisulphide of carbon.

We have now to see what takes place when a ray of light enters a piece of glass. We will take first the case of glass with parallel sides. The ray on entering the glass at the upper surface is refracted downwards, as in the case of water, and travels through the glass until it reaches the under surface. Here we have precisely the reverse condition holding—that is, the ray of light passes from a dense medium to a rarer one. The ray is refracted upwards or away from the perpendicular line, and thus will exactly neutralise the previous refraction, and the beam of light will come out in a direction parallel to its original path, though not quite in the same straight line; as shown in Fig. 6, the ray, instead of proceeding in the direction of S′, proceeds in the direction of S.

If, then, a ray of light passes through a piece of glass, such, for instance, as a window glass, the surfaces of which are parallel, and inclined to the beam, you see when the beam passes through that the refractive effect is imperceptible. The reason of this is, that when we get the light falling on the glass from the air, then travelling through the glass and coming into the air again, under exactly the same conditions, what is done at the first surface is exactly undone at the second, so that we get pretty much the same effect as at first. But now, if instead of having the glass bounded by parallel surfaces, we use a wedge-shaped piece, or a *prism*, the sides of

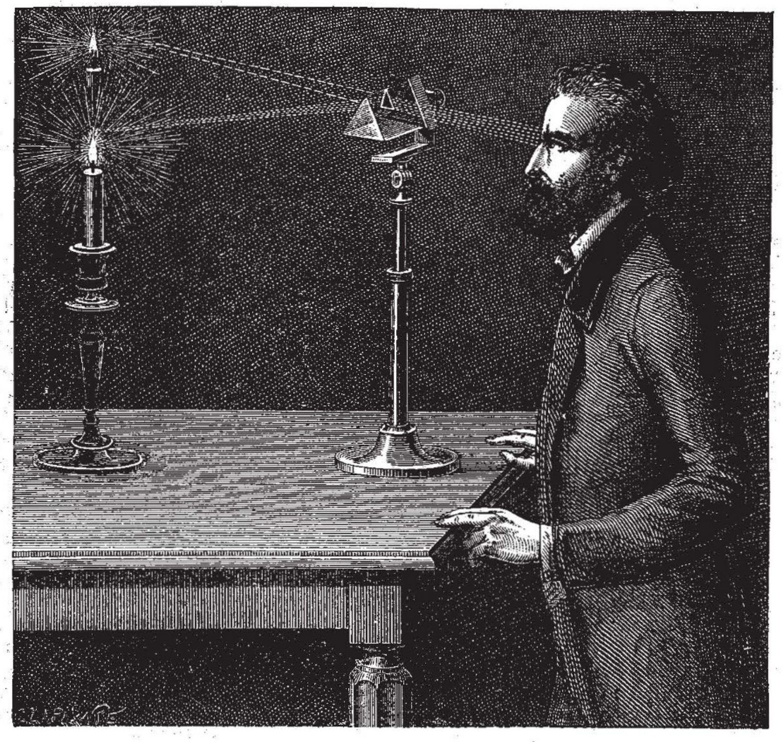

FIG. 8.—Images of objects seen through prisms.

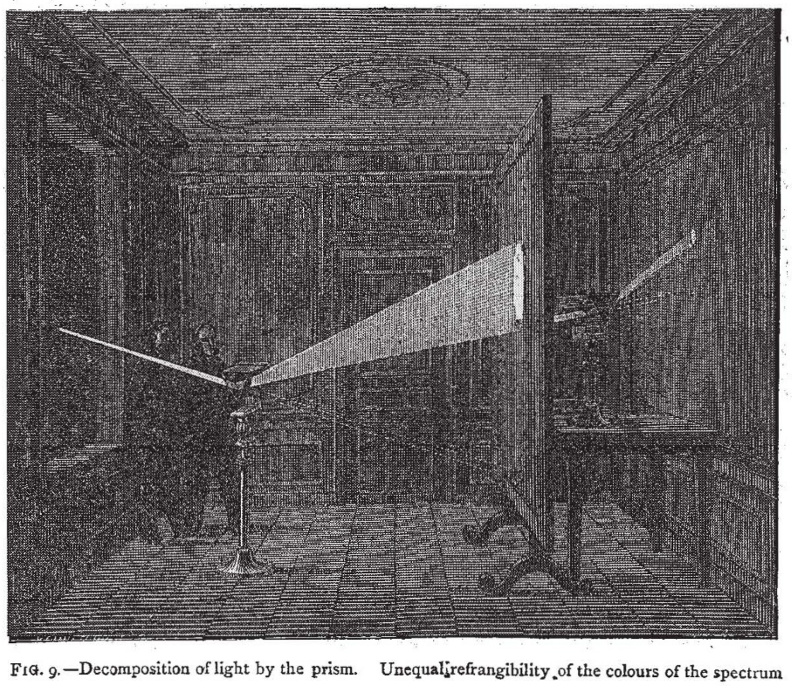

FIG. 9.—Decomposition of light by the prism. Unequal refrangibility of the colours of the spectrum

which are no longer parallel, you will see that there is a distinct alteration in the effect produced; the beam is directed to another portion of the wall altogether. The ray strikes the first side of the prism, and is bent towards the thicker part, or towards a line perpendicular to this surface, and on reaching the second side of the wedge, the ray is again bent in the same direction towards the base of the prism, for in this case the ray is bent away from the perpendicular to the second surface, and the light emerges from the second surface in a totally new direction. Fig. 7 shows the effect in three cases, the incident ray S I, the path in prism I E, and the refracted ray E R; N I and E N' being the lines perpendicular to the surfaces. An experiment may easily be tried, which will confirm this. Let a triangular piece of glass be held, with one edge pointing upwards, between the eye and a lighted candle, as shown in Fig. 8; it will be found that the candle cannot be seen; but if the prism be gradually raised, the image of the candle will appear, the amount the prism will have to be raised depending on its angle. Now, we have here obtained a deviation or refraction of light—that is to say, it has been bent out of its course; for we have to look upwards to see the candle. Another effect has also been produced: the light which was white on entering the prism is now made up of several colours, which are separated more or less from each other; the candle, as seen in the last experiment, is not white, but is fringed round with colours. If we again take our beam of light in the dark room, as in Fig. 9, and allow it to strike on one of our prisms, so placed that its edges are horizontal, and also that the beam enters it obliquely by one of its surfaces, and then receive the image on a screen, we see a band of colours which reminds us strongly of the rainbow: the lowest colour, if the base of the prism be upwards, will be red, next above orange, passing by imperceptible gradations to yellow, and afterwards green, which then passes through the shades of greenish blue till it becomes a pure blue, then indigo, and finally ends with a violet colour. The transition from one colour to another is not abrupt, but is made in an imperceptible manner, so that it can scarcely be said, for instance, where the yellow ends or the green begins. The cause of this band of colours, or *spectrum* as it is called, was first discovered by Sir Isaac Newton, who tortured this spectrum in several ways. He took one of the colours thus produced, say red, as is shown in the figure, and made it pass through a second prism, receiving the image on a second screen; the image is found to be rather longer, but the colour remains unaltered. This experiment proves that this colour of the spectrum is simple, and the same has been found of all the others. As Newton in his experiment operated with sunlight, the band of colours was in this case called the *solar spectrum*. The rainbow itself is also in reality nothing more nor less than a solar spectrum, which is caused by refraction in the rain-drops.

If, instead of getting one beam of white light, we take two of differently coloured lights, red and blue, and pass these two beams of different colour through the same prism, you will see that the action of the prism on these two differently coloured beams will be unequal; in other words, you will get the red beam deflected to a certain distance from a straight line, and the blue deflected to a certain other distance. You see by this experiment that there is a distinct difference in the amount of refrangibility—that the red light is not diverted so far out of its original direction by the prism as the blue. And this leads us to Newton's first proposition, which is this:—"*Lights which differ in colour differ in refrangibility*." I think that requires no explanation. You will be able to translate it for yourselves thus: Lights which differ in colour are differently acted upon by a prism, which, as you have seen, gives us a considerable result of the action of refraction.

J. N. LOCKYER

(*To be continued.*)

THE GEOLOGICAL EXHIBITION IN GLASGOW

THERE is probably no town or city in the United Kingdom, out of London, in which the science of Geology has been studied more extensively and enthusiastically, and to more purpose, than in Glasgow, during the last fifteen or twenty years. It is about fifteen years since the Geological Society of Glasgow was formed, and during the whole of that period the progress of the study and of the Society has never flagged, of which there was ample evidence afforded by a great exhibition of geological and mineralogical specimens which the Society held in the Corporation Galleries on the evening of Friday, December 6.

The Geological Society of Glasgow is one of the very few provincial societies, the results of whose scientific labours are permanently placed on record, and consulted by geologists elsewhere. The "Transactions" of the Society are now in the fourth volume, and in them there are embodied many valuable original memoirs bearing particularly on special departments of the geology of Lanarkshire and the West of Scotland.

The exhibition of the Society of which we are now giving a brief account, was chiefly devoted to an illustration of the fauna and flora of the Carboniferous system of the west of Scotland. Various members of the Society have worked most successfully in other departments of geological inquiry, but the function of the Society as a whole seems to have been especially the investigation of the Carboniferous system, and the elucidation of the many important physical problems connected therewith; and when we consider the fact that the exhibition in question was only a representation of the geological collections from which the specimens were obtained, we cannot help concluding that the Society's function has been performed with most surprising results to science.

Mr. James Thomson, F.G.S., corresponding member of the Royal Society of Liège, was certainly the chief exhibitor in the department of carboniferous fossils; but he was well supported by Messrs. Young and Armstrong. The first-named gentleman has done immense service during the last fifteen years, as a collector, particularly in connection with the fossil corals. His services in this respect have been extensively acknowledged at home—by the British Association and otherwise—and by Continental and American geologists, museums, &c. It is probable that, within the time named, Mr. Thomson has made sections of not fewer than ten thousand specimens of his favourite fossil corals. Besides the corals, Mr. Thomson's collection is peculiarly rich in reptilian remains, some of them quite unique and rare. Mr. Armstrong's specimens were generally representative of all the groups of animals and plants contained in the coal, ironstone, shale, and limestone series of the west of Scotland—Lanarkshire and the adjoining counties. Many of his cases excited great admiration. Besides being generally representative of the carboniferous system, Mr. Young was very strong in the Entomostraca and Foraminifera of that system, the species of which he has materially increased by his own discoveries.

In the department of Post-Tertiary shells, Mr. David Robertson, F.G.S., was without a competitor. Indeed, he has been such a devoted student of the Post-Tertiary period, that his collection is probably unrivalled. For a number of years the Rev. H. W. Crossley, F.G.S., now of Birmingham, was a zealous co-worker with Mr. Robertson. The Ostracoda and Foraminifera of the Carboniferous system, and the recent Hydrozoa and Polyzoa, were also largely represented in Mr. Robertson's cases.

Silurian fossils collected in the Girvan district, on the coast of Ayrshire, were shown by Mrs. Robert Gray, an enthusiastic naturalist; and from the Silurian system