mately parallel to the incident ray. Fig. 12 shows an end view of a Nicol's prism, the shorter diagonal in the direction of vibration of the emergent polarised ray.

Two such instruments, when used together, are respectively called the "polariser" and the "analyser," on account of the purposes to which they are put. These, when placed in the path of a beam of light, give rise to the following phenomena, which are, in fact, merely a reproduction in a simplified form of what has gone before.

When polariser and analyser are placed in front of one another, with their shorter diagonals parallel, that is, when the vibrations in the image transmitted by the one are parallel to those in the image transmitted by the other, the light will be projected on the screen exactly as if only one instrument existed. If, however, one instrument, say the analyser, be turned round, the light will be seen to fade in the same way as in the case of the tourmalin plates; until, when it has been turned through a right angle, or as it is usually expressed, when the polariser and analyser are crossed, the light is totally extinguished.

In the complete apparatus or polariscope, we may incorporate any system of lenses, so that we may

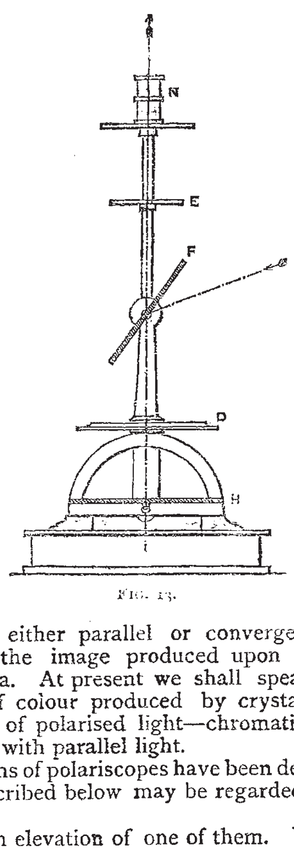

FIG. 13.

make use of either parallel or convergent light, and finally focus the image produced upon the screen or upon the retina. At present we shall speak only of the phenomena of colour produced by crystal plates in a parallel beam of polarised light—chromatic polarisation, as it is called, with parallel light.

Various forms of polariscopes have been devised, whereof the three described below may be regarded as the most important.

Fig. 13 is an elevation of one of them. When used in its simplest form, the frame F carries a plate of black glass which is capable of revolving about pivots in the uprights. The positions of the source of light and of the frame must be adjusted so that the plate will receive the incident light at the polarising angle, and reflect it in the direction of the eye-piece which contains a Nicol or other analyser. The objects to be examined are to be placed on the diaphragm E.

This instrument may be converted into another form, due to Norremberg, by placing a silvered mirror horizontally at H. The plate of black glass must be removed from the frame F, and a plate of transparent glass substituted for it, which must be so inclined that the light falling upon it shall be reflected at the polarising angle perpendicularly towards the horizontal mirror. The object may be placed on the diaphragm E as before. But it may also be placed on the diaphragm D below the polarising plate F, and in that case the eye will receive the polarised ray reflected from the mirror; and the polarised ray will have passed, before it reaches the eye, twice through the crystalline plate placed between the mirror and the polariser. The result is the same as if, in the ordinary apparatus, the polarised ray had passed through a plate of double the thickness. If the plate does not fill the entire field of view two images of the plate will be seen, the one larger, as viewed directly, the other smaller, as viewed after reflection from the horizontal mirror; the first will show the tint due to the actual thickness of the crystal, the other that due to a plate of the same crystal, but of double the thickness.

A further modification of this instrument will be described hereafter.

W. SPOTTISWOODE

(*To be continued.*)

GALILEO'S WORK IN ACOUSTICS

IN looking through the "Dialoghi delle Nuove Scienze" of Galileo, I came unexpectedly on a passage * containing two remarkable discoveries in acoustics, which I should have confidently referrred to a much later age. For the sake of such of your readers as may share the same erroneous impression, I hope you will allow me to give, in NATURE, a short account of these results.

The first is a perfectly accurate explanation of the phenomenon called "resonance." Every pendulum has a fixed period of oscillation peculiar to itself. Even when the "bob" is of considerable weight it is possible to set it swinging through a large arc by merely blowing against it with the mouth, provided the successive puffs are properly timed with reference to the pendulum's period of vibration. In the same way a single ringer can, by regular pulling, throw the heaviest bell into oscillations of such extent as to be capable of lifting half-a-dozen men who should hang on to its rope, off the ground all together. When a string of a musical instrument is struck, its vibrations set the air in its vicinity trembling, and the tremors thus set up spread themselves out through space. If they fall on a second wire in unison with the first, and therefore prepared to execute its vibrations in the same period, the effects of the successive impulses are accumulated, and the wire's oscillations can be distinctly seen to go on dilating until they have attained an extent equal to those of the wire originally struck.

Anyone who looks into the chapter on resonance in the "Tonempfindungen" will see that the account of the phenomenon given by the greatest living acoustician is, in principle, identical with that of Galileo.

The second point to which I wish to draw attention is an experiment involving the earliest direct determination of a vibration-ratio for a known musical interval. Galileo relates that he was one day engaged in scraping a brass plate with an iron chisel, in order to remove some spots from it, and noticed that the passage of the chisel across the plate was sometimes accompanied by a shrill whistling sound. On looking closely at the plate, he found that the chisel had left on its surface a long row of indentations parallel to each other and separated by exactly equal intervals. This occurred only when the sound was heard: if the chisel traversed the surface silently, not a trace of the markings remained. It was found that a rapid passage of the chisel gave rise to a more acute, a slower to a less acute, sound, and that, in the former case, the resulting indentations were closer together than they were in the latter. After repeated trials two sets of markings were obtained which corresponded to a pair of notes making

* Opere complete di Galileo Galilei. Vol. xiii. pp. 97–110. (Firenze.)

an exact fifth with each other; and, on counting the number of indentations contained in a given length of each series, it appeared that for 30 of the lower sound there were 45 of the higher, which numbers are in the exact proportion (2 : 3), which connects the lengths of two equally tense wires, giving that interval. Galileo, who had felt a tremor pass from the chisel to his hand at each experiment, inferred that what really determined a musical interval was the ratio of the numbers of vibrations performed in equal times by its constituent notes, and that that ratio was inversely as that of the lengths of the wires producing them. In order to bring out the crucial nature of his experiment, he goes on to remark, with extreme acuteness, that there was, prior to it, no reason for regarding the relations known to connect musical intervals with the *lengths* of wires as in any exclusive sense *representing* such intervals. With equal propriety might the ratio of the *tensions* under which two wires of equal lengths emitted sounds forming an interval be taken as its representative. In this case we should obtain the inverse square root of the ratio resulting from the former mode of comparison. Thus Galileo's experiment alone supplied decisive ground for concluding that the relations of *length* between similarly circumstanced wires, likewise governed those of *period* between corresponding aërial vibrations.

Prof. Tyndall, in referring to the above experiment, has described it as performed "by passing a knife over the edge of a piastre" ("Sound," 2nd ed., p. 51). This is an obvious mistake caused by incorrect translation. Galileo was scraping "una piastra d'ottone," *i.e.*, not "a piastre," but "a plate of brass." An excellent numismatist assures me that the *material* mentioned is alone decisive of the point, the piastre in Galileo's time being invariably made of *silver*.

SEDLEY TAYLOR

THE HOOSAC TUNNEL

THE following facts respecting the Hoosac tunnel, in which the borings from east and west communicated on Nov. 28, may prove of interest. The mountain penetrated is part of the chain of mountains that skirts, at a distance of two or three hundred miles inland, the Atlantic coast of the United States; of which the Blue Ridge in Virginia, the Alleghanies in Pennsylvania, the Catskills and Adirondacks in New York, the Green Mountains in Vermont, and the White Mountains in New Hampshire, are prominent examples. Hoosac Mountain has two summits, the eastern being 2,210, and the western 2,508 ft. above tide-water.

The enterprise has been the subject of various undertakings by different contractors, and the greater part of the earlier work during the years from 1848 to 1863, in length but one-twelfth of the whole distance, was on a smaller scale than the subsequent plan adopted, and had to be much enlarged and strengthened. The present contract requires a clear width of bore of 24 ft. and a height of 20 ft.; the total length of the tunnel is 25,031 ft. A central shaft pierces it from above, at a distance of 12,837 ft. from the eastern, and 12,194 ft. from the western portal. The shaft has a depth of 1,038 ft., and is of elliptical form, its major axis is 27 ft. being coincident with the line of the tunnel; its minor axis is 15 ft. The grade of the tunnel slopes up to the shaft from both ends, with a rise of $26\frac{4}{10}$ per mile. The shaft is not placed at the lowest point between the two summits of the mountains, as the exigencies of the work at the western extremity, and the presence of a stream of water at the point of lowest depression, made a site half a mile nearer the western portal preferable. The tunnel is 767 ft. above tide-water at its extremities. The temperature within averages 58° F.

The total excavation is about 1,000,000 tons of rock., requiring somewhat over 1,450,000 days' work. The boring was principally through mica schist, similar to that of the surface. The miners found it lying on the edge of the foliations and disposed to hang together after the blast. They compared the operation of working in it to pulling boards endwise from a pile of lumber. Rock of this character was found continuous until a point was reached within about 5,000 feet west of the central shaft. At that point the proportion of mica was diminished and the rock began to lose its foliated structure, becoming more homogeneous or granitic. In fact it might be characterised in general terms as granite with the ingredients differently proportioned at different localities, in some places feldspar, in some mica, and in others quartz predominating. This rock was harder to penetrate with the drills, but broke out more satisfactorily with the blast than the mica schist.

The chief trouble was occasioned by what received the name of "demoralised rock." This was rock saturated with water, which, exposed to air, disintegrated into mere mud, rendering the support of masonry absolutely necessary. The tunnel will not probably be ready for railway traffic before next July, as there is yet much work to be done, the total cost at that date, it is estimated, will not fall short of 12,500,000 dols.

NOTES

ON Monday last the French Academy of Sciences named Mr. J. Norman Lockyer, F.R.S., one of its Correspondents, to fill the place rendered vacant in the Astronomical Section by the death of Encke. We believe that the following is a complete list of the English scientific members of the French Institute at the present time:—Foreign Members—Prof. Owen, Sir C. Wheatstone. Correspondents: Geometry—Prof. Sylvester. Mechanics—Sir Wm. Fairbairn. Astronomy—Sir G. Airy, Mr. Hind, Prof. Adams, Prof. Cayley, Sir Thomas MacLear, Mr. Lockyer. Geography and Navigation—Admiral Richards, Dr. Livingstone. Physics—Dr. Joule. Chemistry—Dr. Frankland, Dr. Williamson. Mineralogy—Sir C. Lyell, Prof. W. H. Miller. Botany—Dr. Hooker. Anatomy and Zoology—Dr. Carpenter.

AT the meeting of the Paris Academy of Sciences, which took place on December 22, the places of Correspondents in the Physical Section, vacant by the death of M. Hansteen, and the election of Sir C. Wheatstone to a foreign associateship, were filled up by the election of MM. Angström and Billet.

HER MAJESTY'S Commissioners have resolved to commence, in connection with the series of international exhibitions, permanent collections which shall illustrate the ethnology and geography of the different portions of the British dominions, and ultimately form a great national museum of the empire upon which the sun never sets. They will be arranged for the present in the galleries of the Royal Albert Hall. Many portions of the empire are inhabited by aboriginal races, most of which are undergoing rapid changes, and some of which are disappearing altogether. These races are fast losing their primitive characteristics and distinguishing traits. The collections would embrace life-size and other figures representing the aboriginal inhabitants in their ordinary and gala costumes, models of their dwellings, samples of their domestic utensils, idols, weapons of war, boats and canoes, agricultural, musical, and manufacturing instruments and implements, samples of their industries, and in general all objects tending to show their present ethnological position and state of civilisation. It is proposed to receive for the Exhibition of 1874 any suitable collections, which will be grouped and classified hereafter in their strict ethnological and geographical relations. As, however, there is at present great public interest in the various tribes inhabiting the West Coast o.