

cal miles an hour, or 2.6 miles per minute; less than half the rate at which the great shocks of 1755 and 1761 crossed the Atlantic from Lisbon to Barbados, which is given by Mallet as 7.3 miles, or 6.3 geographical miles per minute.<sup>1</sup>

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#### "Partials"

IN your number of Nov. 1, p. 6, I noticed an article the object of which was to account for the existence of "partials." Were the theory therein set forth correct, we should have a constant number of "partials" for any given "fundamental" tone of constant force regardless of its source; whereas it is a well-known fact that, while the tones of some instruments are rich in "partials," those of other instruments have but few.

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#### SCIENCE AND ENGINEERING

IN the address delivered by Mr. Westmacott, President of the Institution of Mechanical Engineers, to the English and Belgian engineers assembled at Liège last August, there occurred the following passage:—"Engineering brings all other sciences into play: chemical or physical discoveries, such as those of Faraday, would be of little practical use if engineers were not ready with mechanical appliances to carry them out, and make them commercially successful in the way best suited to each."

We have no objection to make to these words, spoken at such a time and before such an assembly. It would of course be easy to take the converse view, and observe that engineering would have made little progress in modern times, but for the splendid resources which the discoveries of pure science have placed at her disposal, and which she has only had to adopt and utilise for her own purposes. But there is no need to quarrel over two opposite modes of stating the same fact. There is need on the other hand that the fact itself should be fairly recognised and accepted, namely, that science may be looked upon as at once the handmaid and the guide of art, art as at once the pupil and the supporter of science. In the present article we propose to give a few illustrations which will bring out and emphasise this truth.

We could scarcely find a better instance than is furnished to our hand in the sentence we have chosen for a text. No man ever worked with a more single-hearted devotion to pure science—with a more absolute disregard of money or fame, as compared with knowledge—than Michael Faraday. Yet future ages will perhaps judge that no stronger impulse was ever given to the progress of industrial art, or to the advancement of the material interests of mankind, than the impulse which sprang from his discoveries in electricity and magnetism. Of these discoveries we are only now beginning to reap the benefit. But we have merely to consider the position which the dynamo-electric machine already occupies in the industrial world, and the far higher position which, as almost all admit, it is destined to occupy in the future, in order to see how much we owe to Faraday's establishment of the connection between magnetism and electricity. That is one side of the question—the debt which art owes to science. But let us look at the other side also. Does science owe nothing to art? Will any one say that we should know as much as we do concerning the theory of the dynamo-electric motor, and the laws of electro-magnetic action generally, if that motor had never risen (or fallen, as you choose to put it) to be something besides the instrument of a laboratory, or the toy of a lecture-room. Only a short time since the illustrious French physicist, M. Tresca, was enumerating the various sources of loss in the transmission of power by electricity along a fixed wire, as elucidated in the careful and elaborate ex-

periments inaugurated by M. Marcel Deprez, and subsequently continued by himself. These losses—the electrical no less than the mechanical losses—are being thoroughly and minutely examined in the hope of reducing them to the lowest limit; and this examination cannot fail to throw much light on the exact distribution of the energy imparted to a dynamo machine, and the laws by which this distribution is governed. But would this examination ever have taken place—would the costly experiments which render it feasible ever have been performed—if the dynamo machine was still under the undisputed control of pure science, and had not become subject to the sway of the capitalist and the engineer?

Of course the electric telegraph affords an earlier and perhaps as good an illustration of the same fact. The discovery that electricity would pass along a wire and actuate a needle at the other end was at first a purely scientific one; and it was only gradually that its importance, from an industrial point of view, came to be recognised. Here again art owes to pure science the creation of a complete and important branch of engineering, whose works are spread like a net over the whole face of the globe. On the other hand, our knowledge of electricity, and specially of the electro-chemical processes which go on in the working of batteries, has been enormously improved in consequence of the use of such batteries for the purposes of telegraphy.

Let us turn to another example in a different branch of science. Whichever of our modern discoveries we may consider to be the most startling and important, there can I think be no doubt that the most beautiful is that of the spectroscope. It has enabled us to do that which but a few years before its introduction was taken for the very type of the impossible, viz. to study the chemical composition of the stars; and it is giving us clearer and clearer insight every day into the condition of the great luminary which forms the centre of our system. Still, however beautiful and interesting such results may be, it might well be thought that they could never have any practical application, and that the spectroscope at least would remain an instrument of science, but of science alone. This however is not the case. Some thirty years since Mr. Bessemer conceived the idea that the injurious constituents of raw iron—such as silicon, sulphur, &c.—might be got rid of by simple oxidation. The mass of crude metal was heated to a very high temperature; atmospheric air was forced through it at a considerable pressure; and the oxygen uniting with these metalloids carried them off in the form of acid gases. The very act of union generated a vast quantity of heat, which itself assisted the continuance of the process; and the gas therefore passed off in a highly luminous condition. But the important point was to know where to stop; to seize the exact moment when all or practically all hurtful ingredients had been removed, and before the oxygen had turned from them to attack the iron itself. How was this point to be ascertained? It was soon suggested that each of these gases in its incandescent state would show its own peculiar spectrum; and that, if the flame rushing out of the throat of the converter were viewed through a spectroscope, the moment when any substance such as sulphur had disappeared would be known by the disappearance of the corresponding lines in the spectrum. The anticipation, it is needless to say, was verified; and the spectroscope, though now superseded, had for a time its place among the regular appliances necessary for the carrying on of the Bessemer process.

This process itself, with all the momentous consequences, mechanical, commercial, and economical, which it has entailed, might be brought forward as a witness on our side; for it was almost completely worked out in the laboratory before being submitted to actual practice. In this respect it stands in marked contrast to the earlier processes for the making of iron and steel, which

<sup>1</sup> Mallet's Fourth Report, British Association, 1858.