

despised. The number of such stars is great, the number of observers small.

Next in order comes the size and shape of the earth. A relatively small difference in our position on the earth's surface makes a notable difference on the apparent position of the moon, and, in consequence, on the time of the occultation; even the height of the observer above the level of the sea has its influence. This may be well studied in the present instance; viewed from our latitude, the moon was seen to pass a little to the south of the planet Mars, whereas in the southern counties of England an occultation was seen. The oblateness of the earth has also to be taken into account. In the present instance calculations made as if the earth were spherical, would give the disappearance some eighteen seconds earlier than the above. Hence observations made on these phenomena from places in different latitudes afford a means for determining the earth's oblateness.

But, lastly, these observations are all deranged by the extreme jaggedness of the moon's edge. This jaggedness is well seen during an eclipse of the sun; it is also conspicuous against the disc of a planet. I recollect of witnessing an occultation of Saturn, some half a century ago, during which the corner of a lunar mountain was projected against the planet in such a way as to cut out a sector of about one-third of the surface. Irregularities of such magnitude cause serious variations in the times of disappearance and reappearance; and, for the purpose of estimating their possible extent, it might be useful to make concerted observations at places a few miles apart, so that the appulse may happen, here on the top of a lunar mountain, there in the hollow.

2. On Currents produced by Friction between Conducting Substances, and on a new form of Telephone Receiver. By James Blyth, M.A.

In former papers laid before this Society, I showed that when any two metals are rubbed against each other, a current of electricity is produced; and that this current agrees in direction with the thermo-electric current for the same two metals, and is greater, approximately at least, in proportion as the metals rubbed are far

apart on the thermo-electric scale,—the greatest current, as far as I have yet observed, being got from antimony and bismuth.

It is very difficult to decide as to the cause or causes of such currents. They may be (1) purely thermo-electric; (2) the currents, which are the supposed cause of friction; (3) currents produced by contact force between adhering films of air, moisture, or other substances with which the surfaces rubbed are tarnished; or (4) they may arise from all these causes combined. The following experiments were made in hopes of getting some information on these points.

My first experiment was to obtain the exact difference, as far as the production of a momentary current is concerned, between rubbing two pieces of metal together, and knocking the one against the other. For this purpose I repeated, with greater care, an experiment which I formerly described. It consisted in attaching a wire firmly to an ordinary hammer, and leading it to one of the terminals of a telephone circuit, while the wire from the other terminal was rigidly attached to a stiff bar of copper held vertically in a small table vice. When the face of the hammer was rubbed against the end of the copper bar, a very distinct grating noise was always heard in the receiving telephone; but the sound was almost inaudible when the bar was knocked by the hammer, if proper care were taken not to combine rubbing with knocking. This is, however, so difficult practically, that it is just possible that the sounds which I heard are due to faint rubs accompanying the knocking.

Should this not be the case, however, this difference of effect seems to show that the currents are not wholly, although they may be mainly, thermo-electric, as it is hard to believe that the heat produced at the junction of the surfaces by a smart blow can be less than that produced by a faint rub. Granting that the knocking is actually heard, it seems not unlikely that this effect may be due to the currents associated with rapid changes of form in matter. As has been remarked by Professor Tait (*Proc. Roy. Soc. Edin.* vol. ix. p. 552), these currents are such as would be capable of detection by the telephone.

In order to detect what effect, if any, the presence of the air had upon these friction currents, I employed the apparatus commonly called the *electric egg*. Having unscrewed the interior balls, I

fastened in their places two metallic strips, one of copper and the other of iron, so arranged that they could be made to rub against each other by moving the upper rod up and down in its air-tight socket. Before being fixed on, the metal surfaces were both well cleaned by scraping. When this apparatus was included in the circuit either of a galvanometer or telephone, no difference could be detected either in the deflection or the sound produced, by exhausting the air, as far as could be done, with an ordinary good air-pump. It is possible, however, that there may be films of air adhering to the metals which cannot be removed by pumping. Indeed, in the whole of this inquiry, the great difficulty is to be sure of what are the surfaces that are in contact.

Having ascertained that the current produced by the friction of antimony and bismuth is of some strength, and fairly constant when the friction is constant, I proceeded to make a small dynamo machine for producing currents on this principle. It consists of a cylinder of antimony 3 inches long and $2\frac{1}{2}$ inches in diameter, mounted on an axis which runs in centres. By a fly-wheel and band this cylinder is driven rapidly round against a plate of bismuth pressed tight against it by a stiff spring. Wires are led from the plate of bismuth and from one of the pivots on which the cylinder revolves to two binding screws, which form the electrodes of the machine. When this machine is included in the circuit with a microphone transmitter and a telephone, the current from it can be used for the transmission of musical sounds and even loud speaking. There is, however, heard along with the transmitted sound the noise arising from the friction of the antimony and bismuth. I have succeeded in transmitting, in this way, very distinctly, tunes played on a violin to which a microphone was attached. It is very curious, in this experiment, to hear so distinctly the music, notwithstanding the friction noise which accompanies it. It is to be noticed that the sound heard in the telephone of the rubbing of two pieces of metal together in a distant room is an effect precisely identical to this. In this case the rubbing produces the current, and the more or less loose contact of the metals acts as the microphone whereby the sound is transmitted through means of that current to the telephone.

I have also tried, with varying success, several other forms of this *friction current-producer*. In one of the most effective of these the

rubbing substances are arranged like a pair of mill-stones, the lower stone being a disc of iron laid horizontally, and the upper a disc of copper mounted on a vertical axis on which it can revolve. The surfaces are kept pressing against each other by a strong spring. When the upper disc is made to revolve rapidly, a very decided current is produced; and this I found to be markedly increased, as indicated by the telephone, by feeding in between the discs powdered antimony and bismuth combined. Of course we have here a series of rapid reversals of the current, as the direction of the current will depend upon whether particles of antimony or particles of bismuth are in contact with the lower plate. This clearly indicates a thermoelectric effect; and I have no doubt that the effect will be increased by applying a means whereby the upper surface of the copper plate and the lower surface of the iron one can be kept cold by a freezing mixture. As yet, however, I have not had time to try that. In another form I took two cylinders, the one of antimony and the other of bismuth, and placed them together end-wise, the pressure between them being regulated by a screw. The antimony cylinder was kept stationary, and the bismuth made to revolve very rapidly against it, so much so that both cylinders rapidly became hot. This also gave a pretty strong current.

Seeing that the friction between metals does certainly produce an electric current, it seemed natural to inquire whether an electric current sent from a battery across the surface between two metals would not modify the friction of the one against the other. I have tried to test this in a variety of ways, and the results leave me in doubt whether to attribute the indications which I have received to actual changes in the friction or to incipient fusion of portions of the surfaces together by the heat produced by the current, or to an effect similar to the Trevelyan rocker. In one experiment I made an inclined plane which carried a pair of parallel rails of copper about three quarters of an inch apart. The rails were hinged at the lower end, so that the plane could be set at any angle with the horizon. It was so arranged that the current from the battery could be sent up the one rail, through any conductor laid across the two, and down the other rail. The surfaces of the rails were made quite smooth. When a heavy piece of metal was laid across the rails, the angle of repose was the same both when there was and was not a

current passing. It was different, however, when a light body, such as a sewing needle, was put on. Then, when the current from three Bunsen cells was passing, the plane could be elevated considerably past the angle of repose for no current, before the needle rolled down. On examination I found that the needle was actually sticking to the copper; but that, in almost all cases, this sticking gave way without the angle being altered after the current had been taken off for some time, and the needle and copper allowed to come back to their normal temperature. In another experiment I employed a Bell telephone to enable me to detect any variation of friction when a current was passing between the rubbing surfaces. To the centre of the telephone disc was attached a long narrow strip of light wood; the object of making the strip so long being to remove the telephone as far as possible from the inductive action of the battery current which was to be used. To the other end of the strip was attached a flat piece of bismuth. This rested on the convex surface of a cylinder of antimony, which could be rapidly rotated. The battery current was sent through the antimony and bismuth by entering the antimony by the axis on which it revolved, and leaving the bismuth by a spring pressing tightly against it. In the battery circuit was included the violin with its microphone already mentioned, and the telephone with the rod attached was placed as the transmitting telephone in a telephone circuit. When the antimony cylinder was rapidly rotated, a listener in the receiving telephone watched attentively till his ear became accustomed to the sound produced by the rubbing, and transmitted along the wooden rod to the telephone disc. The battery circuit was then joined, and the violin played, the antimony cylinder meanwhile rotating at the same rate as before. No alteration in the sound was audible, which indicated no alteration in the friction. I then substituted a sharp point for the flat piece of bismuth, and immediately the violin sounds were faintly but clearly heard. This led me to think that some sticking was produced by the fusing of the sharp point, and more especially as the sound became a little clearer as the rotation became very slow.

Acting on this hint, it immediately occurred to me that a receiving telephone could be constructed depending upon this effect. I therefore took my bismuth cylinder and mounted it on a frame so that it could be made to rotate very truly on pivots. By wheels

and bands it was also made to rotate slowly. A phonograph mouth-piece, with a very thin disc of wood or mica, was next placed, so that a fine wire with a sharp point bent at a right angle, and with its other end attached to the centre of the disc just pressed with its sharp point on the convex surface of the bismuth cylinder. A current of four Bunsen cells was now passed through the wire and cylinder, and also through the violin microphone. When the violin was played the tune was heard faintly proceeding from the mouth-piece even when the bismuth cylinder was stationary. This arose simply from the loose contact of the wire and bismuth. The sound was, however, very greatly increased when the cylinder was rotated slowly,—so loud indeed, that it could be distinctly heard all over an ordinary room. I have been able to transmit singing very clearly, but not speaking clearly enough to be understood. This instrument is analogous to the loud-speaking telephone of Mr Edison; but the explanation of their action must be very different if electrolysis, as is usually supposed, be the cause of the variation in the slipping of the platinum point on the chalk cylinder, which is characteristic of Edison's instrument. Quite recently the electrolytic action has been questioned, and a different explanation given by Professor Barret of Dublin. It is evident that electrolysis can in no sense come into play when the cylinder and rubbing point are both metallic. In that case two probable explanations of the action readily suggest themselves. The one is that there is more or less of an actual sticking of the metals together, arising from their fusion by the heat of the current. If this be so, then, the loose contact is alternately made a very good one, and then one actually broken. The other is the action of the Trevelyan rocker. Here, however, we have clearly only an analogous, and not by any means an identical effect. In the Trevelyan rocker the heat passes from a large mass of hot metal through two points of contact to a cold block, whereas, in the other case the heat is only produced at the surfaces of separation, the temperature of the rest of the metals being almost unaffected. Still it appears to me that the variations of the heat at this point has a great deal to do with the actions of all microphones, and in general with all sounds transmitted from one loose contact to another. This is shown by substituting cylinders of different metals for the bismuth cylinder above mentioned, all other things remain-

ing the same. I have tried in this way, besides bismuth, cylinders of lead, tin, iron, antimony, and carbon, and find that bismuth gives by far the best result. In the other cases the sound from the simple loose contact is heard clearly enough; but there is hardly any increase of it produced by rotating the cylinder. Now this seems to be due in great part, if not entirely, to the difference between the metals as regards their specific heat and thermal conductivity. Obviously, with the same current, the greatest heat will be produced at the junction of the rubbing point and cylinder, when the specific heat and thermal conductivity are both as low as possible. Hence very probably the reason why bismuth answers so well, seeing that of all common metals it stands lowest on the list both in specific heat and thermal conductivity. In fact, if we take the product of the reciprocals of the specific heats and thermal conductivities of the above-mentioned metals, we find the product for bismuth greatly in excess of that for any of the others.

3. Note on the Present Outbreak of Solar Spots. By Professor Piazzì Smyth.

4th April 1880.

The physical activity going on in the Sun is still increasing, and worthy of all admiration. There was a very large spot had come round on the North-following limb on March 29; and was after that the subject of observation from day to day as it approached the central Solar meridian. But when it arrived there, on April 3, behold two less large but still most notable spots had burst out clear and full within the previous twenty-four hours between the great spot and the preceding limb. And on this day, April 4, there are two more notable ones very close to the greatest spot, making in all five remarkable spots not only all visible at once, but working and seething positively before our eyes.

April 5, Noon. Three of yesterday's five spots are gone. Faculæ are in their place; and that is "the end of spot-life," says Prof. Alex. S. Herschel.