ON ELECTRIC SPARK PHOTOGRAPHS; OR, PHOTOGRAPHY OF FLYING BULLETS, &c., BY THE LIGHT OF THE ELECTRIC SPARK.[1]

I.

WHEN I was honoured by the invitation to deliver this lecture I felt some doubt as to my ability to find a subject which should be suitable, for there is a prevailing idea that in addressing the operative classes, it is necessary to speak only of some practical subject which bears immediately upon the most important industry of the place in which the lecture is being delivered; but it seems to me that this is a polite suggestion that the audience are unable to be interested by any subject except that particular one which occupies them daily. Now though I am a comparative stranger in Scotland I have heard quite enough, and I know quite enough, of the superiority of the education of you, who have the good fortune to live in this the most beautiful half of Great Britain, to be aware that, as is the case with all highly-educated men, you are able to take a keen and genuine interest in many subjects, and that I had better choose one to which I have specially devoted myself, if I do not wish to expose myself to the risk of being corrected. I will ask you therefore in imagination to leave your daily occupation and come with me into the physical laboratory, where, by the exercise of the art of the experimentalist, problems which might seem to be impossible are continually being solved. I wish as an experimentalist to present to you an example of experimental enquiry.

Let us suppose that for some reason we wish to examine carefully and accurately some moving object travelling, if you will, at so great a speed that, observed in the ordinary way, it appears as a mere blur, or perhaps at a speed so tremendous that it cannot be seen at all. In such a case, in order to get a clear view of the moving body we may either look through an aperture which is only opened for a moment as the body passes by, or we may suddenly illuminate the object by a flash of light when it is in a position in which it may be seen. If in either of these cases the hole is open, or the illumination lasts so short a time that the object has no time to move appreciably while it is in this way brought into view, we get what may in ordinary language be called an instantaneous impression and the object appears clear, sharp, and at rest. In the same way if we wish, with the object of obtaining a permanent record, to photograph a moving body we must either allow the eye of the camera to see through a hole for a moment, *i.e.* we must use a rapid shutter, and many such are well known, or we must, keeping the photographic plate exposed and the object in the dark, make a flash of light at the right time. As before, if the shutter is open or the flash lasts so short a time that the object cannot move appreciably in the time, then, if any impression is left at all it will be sharp, clear, and the same as if the body were at rest. The first method, that of the shutter, I do not intend to speak about to-night, but as, owing to the kindness of Mr. F. J. Smith, I have with me the most beautiful example that I have seen of what can be done by this method, I thought perhaps I should do well to show it. Mr. Smith was in an express train near Taunton, travelling at forty miles an hour, and when another express was coming up in the opposite direction at sixty miles an hour, *i.e.* approaching him at one hundred miles an hour, he aimed his camera at it and let a shutter of his own construction open and shut so quickly that the approaching train was photographed sharply. There is a special interest about this photograph; it shows one of the now extinct broad-gauge engines on the road. However, this is an example of the method which we shall not consider this evening.[2]

For our purpose we require what is called instantaneous illumination,—a flash of light. It is of course obvious that it depends entirely upon the speed of the object and the sharpness required, whether any particular flash is instantaneous enough. No flash is absolutely instantaneous, though some may last a very short time.

For instance, a flash of burning magnesium powder lasts so short a time that it may be used for the purpose of portraiture, and while it lasts even the eye itself has no time to change. The lower part of the second slide (Fig. A) is a photograph of the eye of Mr. Colebrook after he had been some minutes in a dark room, taken by the magnesium flash; the upper part is the same eye taken in daylight. The pupil is seen fully dilated and the eyelid has not had time to come down, and so we might reasonably say that the flash was instantaneous; it was for the purpose practically instantaneous. Yet when I make this large clock-face four feet across revolve at so moderate a speed that the periphery is only travelling at forty miles an hour and illuminate it by a magnesium flash you see no figures or marks at all, only a blur. Thus the magnesium flash, which for one purpose is practically instantaneous, is, tested in this simple way, found to last a long time. Let me now, following Lord Rayleigh, contrast the effect of the magnesium flash with that of a powerful electric spark. At each spark the clock-face appears brilliantly illuminated and absolutely at rest and clear, and if it were not that I could at once illuminate it by ordinary light it would be difficult to believe that it was still in motion.

FIG. A.

Lower part. Upper part.

The electric spark has been often used to produce a flash by means of which phenomena have been observed which we ordinarily cannot see. For instance, Mr. Worthington has in this way seen and drawn the exact form of the splash produced by a falling drop of liquid.

Mr. Chichester Bell, Lord Rayleigh, Mr. F. J. Smith, and others have used the illumination produced by an electric spark to photograph phenomena which they were investigating. I am able to show one of Lord Rayleigh's, a breaking soap-bubble, in which the retreating edge, travelling something like thirty miles an hour, is seen with all the accuracy and sharpness that is possible with a stationary object. Mr. F. J. Smith has extended the use of sparks for the purpose of physiological enquiry, taking a row of photographs on a moving plate at intervals that can be arranged to suit the subject, and is thus putting in the hands of the much-abused experimental physiologist a very powerful weapon of research. I had hoped to show one of these series of an untechnical character, to wit, a series taken of a cat held by its four legs in an inverted position and allowed to drop. The cat, as every one is aware, seems to do that which is known to be dynamically impossible, namely, on being dropped upside down to turn round after being let go and to come down the right way up. The process can be followed by means of one of Mr. Smith's multiple spark photographs. However, his cats do not seem to like the experiments, and he has in consequence had so much trouble with them that his results,

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[1] Lecture delivered at the Edinburgh meeting of the British Association by C. V. Boys, F.R.S.

[2] I have heard that a cannon-ball has been photographed by means of a rapid-shutter, but I have no direct information on the subject.

while they are of interest, are not, up to the present, suitable for exhibition.

Let me now return to single spark photographs. We have seen that the magnesium flash, which for the purpose of portraiture is practically instantaneous, yet fails to appear so when so moderate a speed as forty miles an hour (and indeed a far lower speed) is used for the purpose of examining it. Is anything of the kind true in the case of the electric spark? Will the spark, by which we saw the clock-face absolutely sharp, after all fail to give a sharp view when tested by a much higher speed? I have taken such a spark and attempted (though I knew what the result would be) to photograph by its light the bullet of a magazine rifle passing by at the rate of about 2100 feet a second, or, what is the same thing, at about 1400 miles an hour; the result (Fig. 1) shows not a clear sharp bullet but a blur; the spark lasted so long a time that this bullet was actually able to travel half an inch or so while the illumination lasted. Thus we see, that if we wish to examine bullets, &c., in their flight, any electric spark will not necessarily do. We shall have to get a spark which while it gives enough light to act on the plate yet lasts so short a time that even a rifle bullet cannot move an appreciable distance during the time that it is in existence.

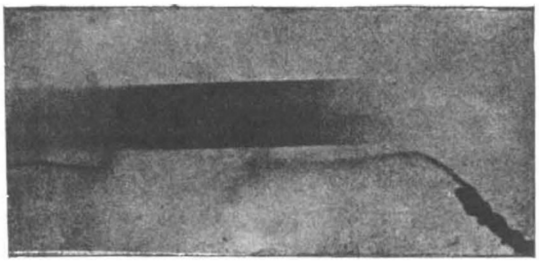

Fig. 1.

A knowledge of electrical principles enables one to modify the electrical apparatus employed to make this spark in such a manner that its duration may be greatly reduced without, at the same time, a very great sacrifice of light; but while this may be done it is important to be able to observe how long the spark actually lasts, when made by apparatus altered little by little in the proper manner. The desired information is at once given by the revolving mirror. For instance, every one is aware how, by a turn of the wrist, one may reflect a beam of sunlight from a piece of looking-glass so as to travel up the street at a most tremendous velocity; but suppose that, instead of being moved by a mere turn of the wrist, the mirror is made to rotate on an axle by mechanical means at an enormous speed; then, just as the rotation is more rapid, so will the beam of light travel at a higher speed. In the particular case that I am going now to bring before your notice, a small mirror of hardened steel was made by Mr. Colebrook, the mechanical assistant in the physical laboratory at South Kensington, mounted so beautifully that it would run at the enormous speed of 1000 turns a second (not 1000 a minute) without giving any trouble. The light from the spark was focussed by the mirror upon a photographic plate. Now if the light were really instantaneous, the image would be as clear and sharp as if the mirror were at rest; if, on the other hand, it lasted long enough for the image to be carried an appreciable distance, then the photograph would show a band of light drawn out to this distance. The mirror is now placed on the front of the platform, and a beam of electric light is focussed by it upon the screen, from which it is distant about 20 feet. Now that I turn the mirror slowly, you see the spot of light drawn out into a band reaching across the screen, and this is described over and over again as the mirror revolves. Let us suppose that the mirror is revolving once a second, then it is easy to show that the spot of light is travelling at about 250 feet a second. It is not difficult therefore to see that if the mirror is revolving 1000 times as fast, the spot of light will traverse the screen 1000 times as fast also, *i.e.*, about 250,000 feet a second, or 160,000 miles an hour—a speed which is 200 times as great as that of a Martini-Henry bullet, while such a bullet only travels 14 times as fast as an express train. You will see, then, that it is not difficult to observe how long a spark lasts when its image can be whirled along at such a speed as this. I have now started the electro-motor, and the mirror is turning more and more rapidly. Now it gives a musical note of the same pitch as that given by the tuning-fork I am bowing; it is therefore turning 512 times a second. It is now giving a higher note, *i.e.* it is turning faster and faster, until at last it gives the octave, at which time it is turning 1028 turns a second. The band of light on the screen is produced by a spot now travelling at a still higher speed than that which I have just mentioned. I had hoped to have shown with this apparatus the actual experiment of drawing out the apparently instantaneous flash of an electric spark into a band of light, but I found that while it was easy to show the experiment in a small room, the amount of light was not sufficient to be seen in a great room like this. I must therefore be content to show one or two of the photographs which were taken lately in the physical laboratory at South Kensington by two of the students, Mr. Edser and Mr. Stansfield, whom I now take the opportunity of thanking. The next slide shows the drawn-out band of a particular spark made between magnesium terminals by the discharge of a condenser of $2\frac{1}{2}$ square feet of window-glass, the spark being $\frac{1}{8}$ inch long. Below the drawn-out band I have drawn a scale of millionths of a second. If the spark had been instantaneous it would have appeared as a fine vertical line. This line, however, has been drawn sideways to an extent depending on the duration of the spark. The spark, except at the ends, is extinct in rather less than one-millionth of a second, but the ends remain alight like two stars, being drawn out in consequence into two lines, which have lasted, as measured by the scale, as long as six or seven millionths of a second. Such a light is, therefore, seen to last when tested with this very powerful instrument so long that it seems absurd to call it instantaneous. It lasts too long for the purpose of bullet photography. In order to get sparks of shorter duration it is necessary to abolish the metal magnesium, in spite of the brilliant photographic effect of the two ends of the spark between knobs of this material, it is well to avoid all easily volatile metals, such as brass, because of the zinc that it contains, and instead to employ beads of copper or of platinum. In the second place, the duration of the spark proper, which in the last case was nearly a millionth of a second, can be reduced by (1) reducing the size of the condenser, but one must not go too far, as the light is reduced also; (2) by replacing any wire through which the discharge may have taken place by broad bands of copper as short as possible, this has the further advantage of increasing the light; and (3) the light may be increased without much change being made in the duration by making a second gap in the discharge circuit, the spark in which, however, must be hidden from the plate. Fig. 2 shows the trail of the best spark for the purpose of bullet

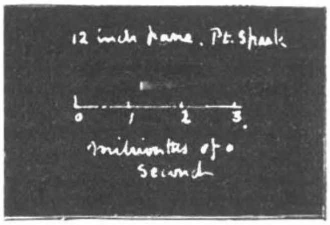

Fig. 2.

photography that I have obtained up to the present. In this case the surface of the condenser is one square foot, and the discharge is taken through bands of copper about two inches broad, and not more than about four inches long apiece. Extra good contact is made between these copper bands and the tin-foil surface by long radiating tongues of copper-foil soldered to the end of the copper bands. The knobs are platinum, but this seems no better than copper. The whole of the light is extinct in less than one-millionth of a second, while the first blaze, which is practically the whole spark, the tail being in comparison of no consequence, does not last so long as a ten-millionth of a second; in other words, it lasts so short a time that it bears the same relation to one second that one second bears to four months; or again, a magazine rifle bullet, travelling at the enormous speed that is now attained by the use of this weapon, cannot go more than one four-hundredth of an inch in this time. Other sparks of still less duration were examined, but this was chosen for the purpose of photographing bullets.[1]

Now, having obtained a suitable flash of light, I must next show how a spark may be used for the purpose of photographing a bullet in its passage This was first done by Prof. E. Mach,[2] of Prague, whose method is illustrated by the diagram Fig. 3. The squares on the right-hand side represent certain electrical apparatus by means of which a Leyden jar (J) is charged with electricity to such an extent that, while it is unable to make two sparks at B and A, it is nevertheless able to, and at once will, make a spark at B when the second gap at A is closed by a bullet or other conductor. The dotted lines represent wires through which the discharge then takes place. The spark at B, magnified by the lens *l* in front of it, then fills the field lens L with light, so that the camera K focussed upon the spark gap A will then receive an image of the bullet as it passes, and thus a photograph is secured. I am able to show two of these which Prof. Mach has kindly forwarded to me, and what I wish to point out is that in each of these photographs—and this is perhaps the most interesting feature which any of these exhibit—there are seen, besides the bullet and the wires which the bullet strikes in its journey, certain curious shades, one in advance of the bullet and one from the tail, while a trail is left behind very like that seen in the wake of a screw steamer. In fact, the whole atmospheric phenomenon accompanying the bullet is not unlike that seen on the surface of water surrounding and behind a steamship. These were seen for the first time, and their visibility by this method was, I believe, predicted by Prof. Mach before he made his first experiment.

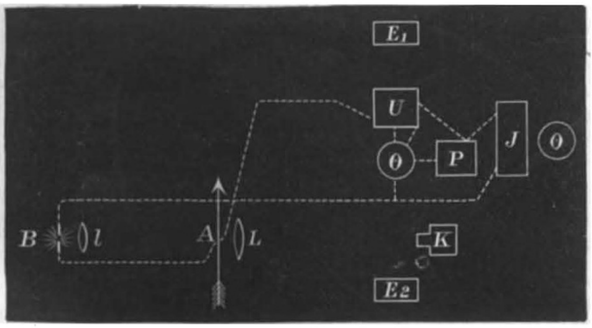

FIG. 3.

The part that I have played in this matter is after all very subordinate. I have attempted to simplify the means, and the results which may be obtained by the modified method which I have devised, are, I believe, in some respects—I don't say in all—clearer and more instructive than those obtained by the more elaborate device of Prof. Mach.

Fig. 4 is a diagram of the apparatus that I have used. C is a plate of window-glass with a square foot of tin-foil on either side. This condenser is charged until its potential is not sufficient to make a spark at each of the gaps E and E′, though it would, if either of these were made to conduct, immediately cause a spark to form at the other. *c* is a Leyden jar of very small capacity connected with C by wire, as shown by the continuous lines, and by string wetted with a solution of chloride of calcium, as shown by the dotted line. So long as the gap at B is open this little condenser, which is kept at the same potential as the large condenser by means of the wire and wet string, is similarly unable to make sparks both at B and E′, but it could, if B were closed, at once discharge at E′. Now suppose the bullet to join the wires at B, a minute spark is made at B and at E′ by the discharge of *c*, immediately C, finding one of its gaps E′ in a conducting state, discharges at E, making a brilliant spark, which casts a shadow of the bullet, &c., upon the photographic plate P. Though this is simple enough, the ends that are gained by this contrivance are not so obvious. In the first place the discharge circuit of C, via E and E′ is made of very short broad bands of copper, a form which favours both the brilliancy and the shortness of duration of the sparks; further, the double gap, of which E′ may be the longer, causes the intensity of the light of either spark to be greater than it would be if the other one did not exist—in a particular case the light of the shorter was increased six or eightfold—at the same time the duration is not greatly affected. For this reason the spark at E may be made very short, so that the shadow is almost as sharp as if the light came from a point. The spark formed at B, which is due to the discharge of *c* only, is very feeble, so that it is unable to act on the plate, whereas, had the discharge of C been carried round by B, the light at this point would hopelessly have spoilt the plate, and at the same time the light at E would have been feebler and would have lasted longer.

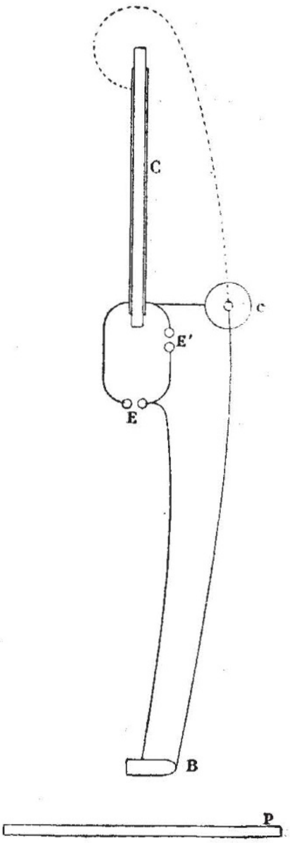

FIG. 4.

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[1] These sparks were made to go off at the time that the mirror was facing towards the photographic plate by the employment of the same device as that described below in connection with Fig. 4. On the axle of the mirror an insulated tail of aluminium was secured, so as nearly to bridge a gap in the discharge circuit of an auxiliary jar of small capacity, there being a gap common to both circuits. A self-induction coil was used instead of the wet string, as being for this purpose preferable. The length of time that the spark lasted was thus measured without taking the electricity round by the mirror, which would have been quite sufficient to modify the duration of the discharge, and it was easier than making and adjusting a second reflecting mirror, which would have answered the same purpose.

[2] See NATURE, vol. xlii. p. 250.

The wet string, while it is for the purpose of keeping the condenser *c* charged a perfect conductor, is nevertheless, when this discharges at E′ and B, practically a perfect insulator; if it were replaced by wire then C would also wholly or partially discharge itself by B and E′. Finally, in avoiding all lenses one is free from the considerable absorption of the more refrangible rays which sparks provide in great abundance, and which are largely absorbed by glass. On the other hand the photograph is a mere shadow, but this is no drawback, for the bullet itself is on either system a mere silhouette, whereas the atmospheric phenomena are more sharply defined, and their character is more clearly indicated without lenses than is possible when they are employed.

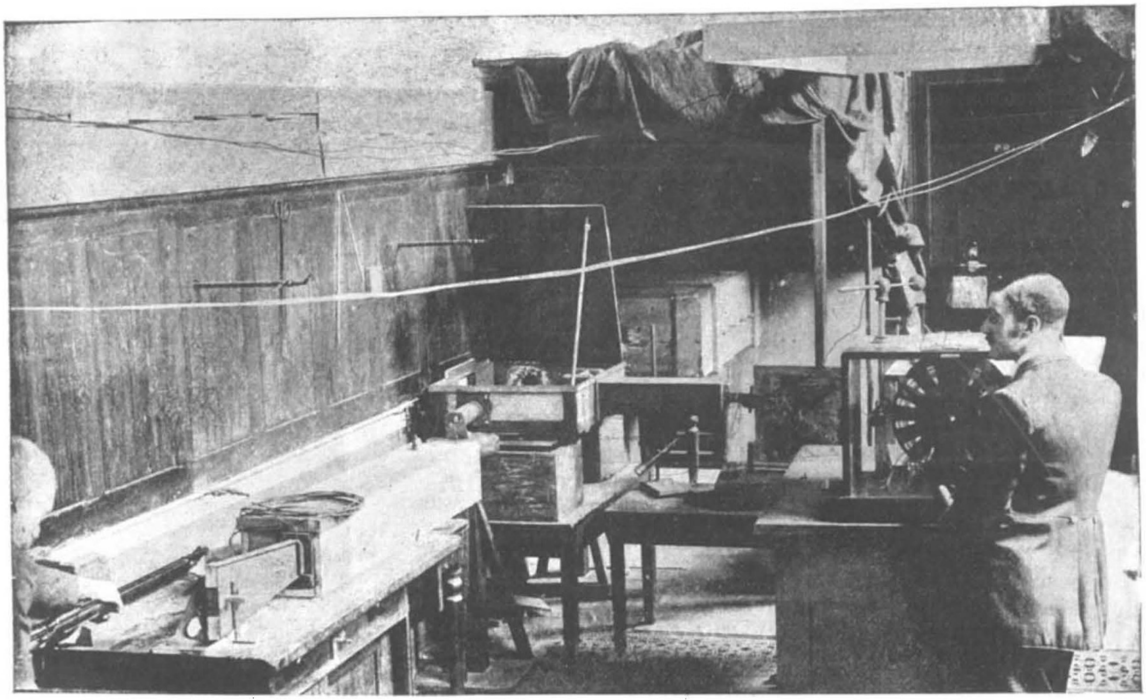

Fig. 5.

Fig. 5 is a photograph of the apparatus set up in one of the passages in the Royal College of Science, in which the experiments were made. It is apparently of the rudest possible construction. The rifle seen on the left of the figure is of course made to rest freely on six points, in order that its position every time it is fired may be the same. The bullet then traverses precisely the same course, so that wires placed in the line between holes in two cards made by one shot will be hit by the next. The two wires which the bullet joins as it passes by are set up in the box seen in the middle of the figure with the lid propped up so as to show the interior. The photographic plate is on the left-hand side and the spark when made is just within the rectangular prolongation on the right-hand side. Paper tubes with paper ends are placed on each side of the box to allow the bullet to enter and leave, and yet not permit any daylight to fall directly on the plate. All is black inside, and so the small amount of light which does enter the box through these holes is not diffused in any harmful manner. The large box at the back is a case 5 ft. long, filled with bran which stops the bullets gently without marking them. The little condenser is just below the rectangular prolongation of the photographic box, the large condenser is the vertical square sheet seen just to the right. The electrical machine used to charge the condensers is seen on the table. It is a very beautiful 12-plate Wimshurst machine made by Mr. Wimshurst and presented to the Physical Laboratory. This machine not only works with certainty but is so regular in its working that no electrometric apparatus is necessary. All that has to be done is to count the number of turns of the handle which are required to produce the sparks at E and E′ when the gap at B is not joined, and to count the number which are sufficient to produce a spark at E when the gap at B is suddenly closed. Then if the rifle is fired after any number of turns between these, but by preference nearer the larger than the smaller number, the potential will be right, the spark E, inside the box, and the spark E′, which is in sight outside the box, will be let off, and if a plate is exposed a photograph will be taken. If by chance the E′ spark is not seen then there is no occasion to waste the plate, another bullet may be fired after resetting the wires and the result will be as good as if one shot had not failed. When all is in order a failure of this kind is very rare. I also arranged a tube in the side of the box with a pocket telescope fixed in it and focussed on the wires. If a piece of white card or paper is placed in the line of vision and so as to be illuminated by a spark let off as above described but preferably much nearer the card, the bullet will be seen by any one looking through the telescope. I took this down, however, at once, as the photograph showed more than could ever be seen by the eye. The box seen just to the right of the rifle with a coil of wire upon it is the one in which the revolving mirror was fixed, and in which the trails of sparks made near the door at the end of the passage were photographed. The apparatus for photographing

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[1] Six independent points of support are required for a geometrical clamp. In this case a **V** support near the muzzle supplied two, a **V** support near the breach two more points, the rifle was pressed forward until a projection under the muzzle rested against the front **V**, thus allowing freedom of recoil, but otherwise preventing all uncertainty of position except that due to rotation in the **V**'s which is made impossible by the sixth point, that is, the lower end of the stock resting sideways against a leather covered wooden bracket fastened to the same table to which the **V**'s were attached.

the bullets was put together and set up by Mr. Barton, a student, whose very skilful help in the matter and afterwards during the experiments I found of very great value.

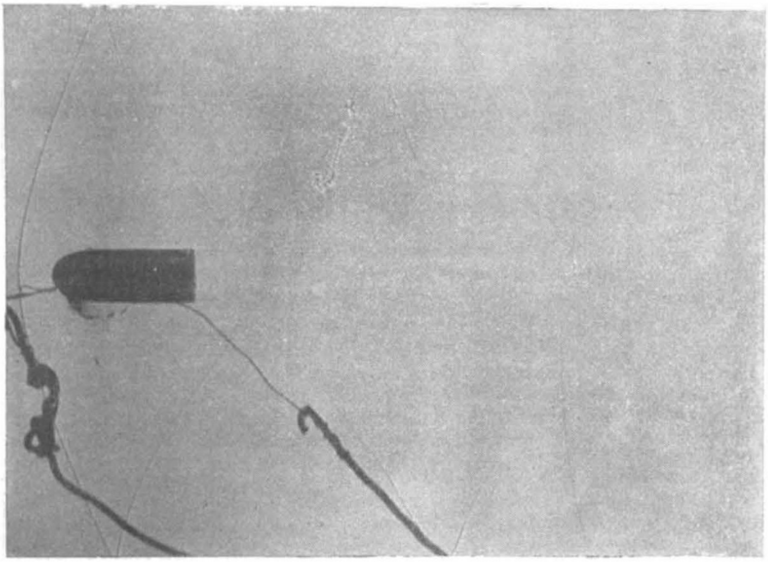

FIG. 6.

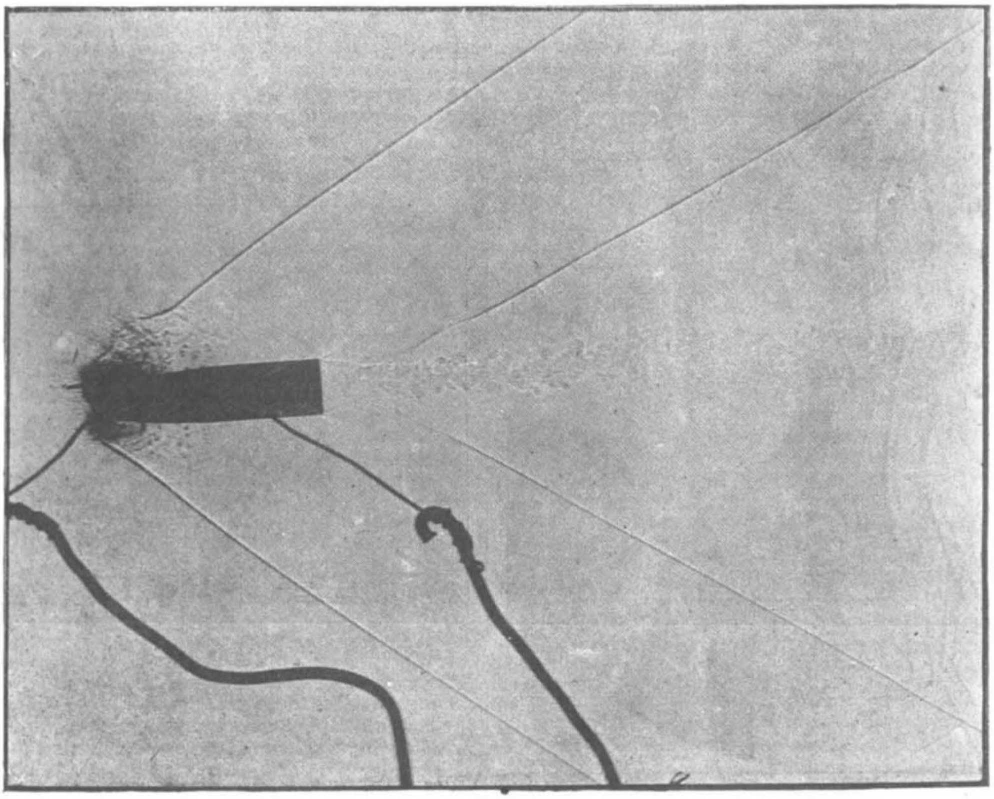

FIG. 7.

The first photograph which I am able to show was taken at Christmas, before the apparatus just described was put together. It was taken to see if the idea would practically succeed, merely using for the purpose bits of wire and other things to be found in any laboratory, which were set up in a dark room in less than an hour. The first shot was successful, but the sharpness of the photograph is not what it might be, owing to the fact that I used, for the sake of the brilliant light, a spark taken between magnesium terminals. However, the bullet is clearly enough defined, as are the wires which it has just struck. This is a photograph of a pistol bullet travelling only 750 feet a second. You will notice that unlike that taken by Prof. Mach, which represented a shot going at a much higher speed, this photograph shows no atmospheric phenomena surrounding the bullet. I would only add, in connection with this photograph, that by some accident the wad remained attached to the bullet in this case forming the enlarged tail. I do not know if this often happens; it must, if it does, seriously disturb the flight of the projectile, and introduce an anomaly that might not easily be accounted for.

The next photograph, Fig. 6, shows a bullet which has just left a Martini-Henry rifle. This is taken with the apparatus in its latest form, and the bullet appears perfectly sharp. There is no sign of any movement whatever in so far as the bullet itself is concerned.

But now that we are dealing with a higher speed, namely, 1295 feet a second, there is evidence of the movement of the bullet in the form of a wave of compressed air in front and of other waves at the side of and behind the bullet. I shall explain this in a moment, but I would rather first show another photograph, Fig. 7, of a bullet travelling at a still higher speed, a magazine rifle bullet travelling about 2000 feet a second, in which these air waves are still more conspicuous, and in which a glance is sufficient to make it evident that the waves are much more inclined to the vertical than in the previous case.

Now as it may not be evident why these waves of air are formed, why their inclination varies with the speed, or why existing they are visible at all, a short explanation may not be out of place, more especially as they form the most interesting feature in the remaining photographs that I have to exhibit, which cannot, as a matter of fact, be properly interpreted without frequent reference to them.

I would first ask you to examine some still water into which a needle held vertically is allowed to dip. If you move the needle very slowly not a ripple is formed on the surface of the water; but as the needle is moved more quickly at first a speed is reached at which feeble waves appear, and then as the speed increases a swallow-tail pattern appears, the angle between the two tails become less as the velocity gets higher. Now in the case of water-waves the velocity with which they travel depends on the distance between one and the next, and for a reason into which I must not now enter either very long or very short waves travel more quickly than waves of moderate dimensions. If they are about two-thirds of an inch long they travel most slowly—about 9 inches a second. Now so long as the needle is travelling less quickly than this no disturbance is made; but when this speed is exceeded the swallow-tail appears. Suppose, for example, the velocity of the needle to be double the minimum wave velocity for water, *i.e.* let the needle move at 18 inches a second, and let it at any moment have arrived at the point p, Fig. 8. Then any disturbance, started when it was at the point A, must have travelled as far as the circle aaa in which Aa is half Ap, similarly for any number of points BC, &c., between A and p any disturbance must have travelled as far as the corresponding circles bb, cc, &c., the result is that along a pair of lines, pL, pM, touching all the circles that could be drawn in this way, a wave will be found, and it is clear that as the velocity of the point is made greater the successive radii Aa Bb, &c., will become in proportion to Ap less, the circles will be smaller, and the angle between Lp and Mp will become less, while when the velocity is made less the reverse happens, until at last Aa Bb, &c. = Ap Bp, &c., and then when they exceed these quantities no lines Lp Mp can be drawn touching all these circles, there is no wave surface which the disturbances from all the successive points can conspire to produce, and the consequence is there is still water.

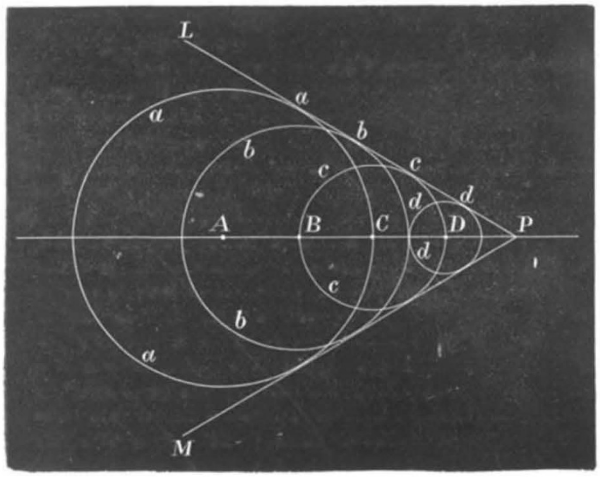

FIG. 8.

Now consider the case of a bullet moving through the air. Here again we are dealing with a case in which a wave cannot travel at less than a certain speed which is obviously the velocity of sound (1100 feet a second under ordinary circumstances), but, as in the case of surface waves on water, higher speeds are possible when the wave is one of very great intensity. The conditions in the two cases are therefore very nearly parallel; if the bullet is travelling at less than the minimum speed no waves should be formed—the pistol bullet at 750 feet a second did not show any—if the bullet is travelling at higher speeds than 1100 feet a second waves should be formed which should include a sharper angle as the speed is made to increase. This was found to be so in the case of the Martini-Henry and the magazine rifle bullet.

The curved form of the wave near the apex is due to the fact that when it is very intense, when the compression is very great, the velocity of travel is greater and, immediately in front of the bullet, the air is compressed to so great an exent that the wave at this part can travel at the speed of the bullet itself.

The reason why the waves should be visible at all is not difficult to follow. Consider a shell of compressed air though which rays of light from a point are made to traverse. These rays travel in straight lines, except where they meet a medium of different density, and the denser this is and the more nearly they meet this at a grazing incidence the more they will be bent towards the perpendicular. In comparison with water or glass a layer of compressed air has very little refractive power, and so rays which strike the shell anywhere except at the extreme edge are practically uninfluenced in their course and strike the plate practically in the same place that they would do if the shell of compressed air had not been traversed. But those rays ab, ab, Fig. 9, which strike the shell of air almost tangentially are bent inwards slightly at b and again at c, having traversed what is equivalent to a wide angle prism, and strike the plate at e, leaving the place d, where they would have gone had they not been refracted, dark; moreover at e they meet other rays which have been hardly at all refracted since they have passed actually into the shell and out again, and therefore e is doubly illuminated. The consequence is that a wave or shell of

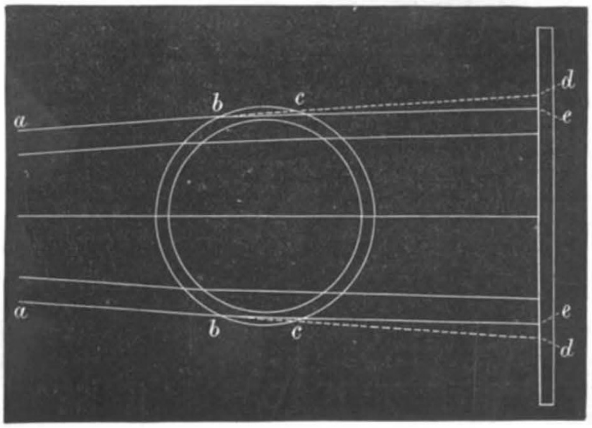

FIG. 9.

compressed air gives rise to an image on the plate, in which there is a dark line and a light line within it. Similarly a wave of rarefaction must produce a light line with a dark one within it.[1] An examination of the photograph Fig. 7 will make it evident that not only is the head wave a wave of compression, but the wave, which starts from the end of a kind of vena contracta behind the bullet, is also a wave of compression. It is a curious fact which requires explanation that the head and tail waves are not parallel to one another, and they do not show any sign that they would become parallel if they were continued indefinitely. This can only be due to either the tail of the bullet travelling considerably faster than the head, or to the actual velocity of propagation of the tail wave being less than that of the head wave. The effect observed is true and is not optical, being neither due to the refractive effect of the outer shell disturbing rays which are tangential to the inner shell, nor to an effect of perspective, for though the projection of a cone from a point upon a plane is only seen of the proper angle, when the perpendicular, dropped from the point upon the plane, passes through the vertex of the cone, yet when, as in the case of Fig. 11, where it passes within both cones, and more within the outer one than the inner one, the effect is to make the projections of both of a greater obtuseness, and of the outer one to a greater extent than the inner one; nevertheless an examination of the amount of this effect of perspective made by Mr. Barton showed that the distortion was not sufficient to be noticeable, as the difference in the acuteness of the cones certainly is.'

(*To be continued.*)

NOTES.

ADMISSION to the Croonian Lecture, which Prof. Virchow, as we have already announced, is to deliver before the Royal Society at 4.30 p.m. on the 16th inst., will be by ticket, which may be obtained from the assistant secretary by introduction of a Fellow of the Society.

THERE will be widespread regret at the announcement which we now make that the distinguished geologist, Prof. K. A. Lossen, of Berlin, died there on the 24th ult. He had been ailing for some time, and suffered severely before he entered into his rest. In spite of the deafness which necessarily restricted his intercourse with men of science, he had formed a wide circle of friends who learned to appreciate the simplicity, candour, and geniality of his character, while at the same time they came to respect and admire more and more his wide range of knowledge, and that marvellous and apparently intuitive perception of the true characters of rocks which made him probably the best field-petrographer in Germany.

WE have received news of the death of Cav. Giuseppe Antonio Pasquale, for many years professor of botany in the University of Naples, and director of the botanic garden. Prof. Pasquale was the author of numerous articles on botany and cognate subjects. His earliest works of which we have cognisance were on the flora of Capri (1840), and the flora of Vesuvius (1842). In 1869 he published a more complete "Flora Vesuviana, confronte con quella dell' isola di Capri." He appears to have been appointed to the post of director of the Naples Botanic Garden in 1866, and the following year he published a catalogue of the plants cultivated there, together with a brief history of the garden.

THE German Government has established a biological Institute on the island of Heligoland, and has appointed Dr. Kuckuck its botanical director.

PROF. SCHWEINFURTH landed at Port Said on January 7, for an expedition into Upper Egypt which is intended to extend over several months. Dr. D. Riva, who accompanied Schweinfurth on his last journey, has undertaken an expedition to Eastern Africa in the vicinity of the river Giuba.

THE moss-herbarium of Dr. Rehmann and the Hepaticæ-herbarium of Dr. Gottsche have passed into the possession of the Botanical Museum of Berlin; the Botanical Museum of the University of Vienna has acquired the moss-herbarium of Hoppe; and the Botanical Institute of the German University at Prague the greater part of the valuable library of Prof. Willkomm.

THE Reale Istituto Veneto di Scienze, lettere ed arti proposes the following prize subjects:—(1) A lithological, mineralogical, and chemical investigation of the rocky, sandy, earthy, and saline materials brought down under various conditions by one of the chief rivers of Venetia from the Alpine valleys, and deposited at various distances from the base of the Alps to the sea (prize, 3000 lire, date December 31, 1893). (2) A compendium of the history of mathematics, with a mathematical chrestomathy containing extracts from mathematical works of antiquity, the middle ages, the renaissance, and recent times down to Gauss (indicating in each case the reason for introducing the extracts), (prize and date the same). Papers may be written in Italian, Latin, French, German, or English, and are to be sent in to the secretary with motto and sealed packet.

SIR ANDREW BARCLAY WALKER, who died on Monday, did much to promote intellectual life in Liverpool. The University College of that city has good reason to remember him as one of its most generous benefactors. He assumed the entire pecuniary responsibility for the erection of the Walker engineering laboratories, which cost about £20,000.

MR. O. M. EDWARDS, who was appointed to investigate the various conditions which have to be taken into account in connection with the proposal for the establishment of a Welsh University, has completed his inquiries and forwarded his report to the Vice-President of the Committee of Council on Education. A writer in the *University Correspondent* says the report is practically a pamphlet of about eighteen octavo pages, containing a short account of the origin and progress of the educational movement in Wales, and intended to supplement the information already possessed by the Department of Education on this head. It contains a succinct epitome of the various schemes proposed—the Shrewsbury Charter, the proposals of Dr. Roberts and Prof. Evans; gives the state of efficiency of Lampeter and the three Welsh colleges; contrasts them with those at Leeds and Manchester; and points out how far, more or less, the Welsh institutions are prepared and adapted, in point of staff, students, accommodation, and appliances, to receive similar powers.

THE Municipal Council of Paris has been giving names to some new streets, and changing those by which various old streets have hitherto been known. The names selected for use are for the most part those of illustrious Frenchmen, and it is significant that among them are some well-known men of science. The Rue du Battoir, for instance, is henceforth to be called the Rue Quatrefages, in memory of the famous anthropologist; and the Rue Claude-Vellefaux becomes the Rue Charles-Robin, in memory of the great physician. A new street is called after

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[1] It may be worth while to point out that the dark and light lines are, and ought to be, parallel to one another as soon as they are so far away from the shadow of the bullet as to be practically straight lines. For if the thickness of the shell is divided up into a series of elements the ray passing through any one of these will meet with a refractive medium, which is less effective as the diameter of the part of the shell considered is greater, while the refractive angles of the elementary prisms become inclined more so as to compensate for the diminished density.