monthly temperature for five years (1903–8) varies from 9·68° F. in July to 32·54° in January, while the absolute range in the same period was 88°. The temperature variability of the seasons brings out the tendency to a winter continental and a summer oceanic climate. These values are (1904):—spring, 5·1°; summer, 1·3°; autumn, 5·4°; winter, 9·1°. The year 1904 had a mean annual temperature of 22·4°, which is 0·96° below the average mean of the five years 1903–8.

The wind directions, which were taken from the movements of the lower clouds, since the high land to the west of the observatory tended to deflect many winds, show a prevalence of north-westerly winds. Subsequent years' observations give west and south-west winds as the most frequent, which seems to show that the readings of 1904 give too high a value to north-west winds. Undoubtedly the position of Omond House is such that west and south-west winds would tend to be below what would be recorded in an unexceptional situation. In fact, on further consideration, Mr. Mossman has, we understand, come to the conclusion that the wind directions of 1904 are not wholly trustworthy. East, and especially north-east, winds are conspicuously rare, and the percentage wind frequency for each season does not materially differ from that of the year. The temperatures associated with these winds are of great interest, but unfortunately in Mr. Davis's five years' summary no thermal wind-roses are given. Very probably the high temperatures associated with some of these apparent westerly winds is partly due to Föhn effects, since in May, 1903, that is, in midwinter, an undoubted Föhn wind raised the temperature at the site of the observatory to 46°, which was only 1° lower than the absolute maximum of the year.

Associated with these prevailing west and south-west winds, which were also experienced by Dr. Nordenskjold at Snow Hill in 1902–3, there exists a low-pressure area in the Weddell Sea, furthest south in autumn and most northerly in winter, but with a centre normally about 66° S. and 30° to 35° W. The continental origin of these prevailing winds accounts largely for the low temperatures of the South Orkneys compared with their latitude. The thermal gradient on the east of Graham Land is steep, and this fact, in relation to the southward bending of the isotherms about 40° W., is strong evidence for the existence of the northward projection of Antarctica south of the South Orkneys to about the Circle. Moreover, on no other grounds is it possible to account for the very low temperatures that occur from time to time at Scotia Bay with southerly and south-easterly winds.

NATIVE WORKING OF COAL AND IRON IN CHINA.

AN interesting illustrated article on the native working of coal and iron in the province of Shansi, China, appears in *Engineering* for December 2. In the Ping Ting Chau districts the iron ore is of excellent quality. The methods of extraction are decidedly primitive; in the old workings the ground is often found honeycombed with small shafts, seldom more than 14 inches in diameter, and usually just large enough to allow a man to go down. The tools used consist of a native pick, a cast-iron hammer, a wedge, and a sort of basket-shovel, the ore being raised in the basket by a small wooden winch. The climate is healthy, but work under such conditions is sure to produce disease, and consumption is very prevalent. During the summer the mines are shut down, and all the men become farmers until the close of the harvest season. The southern district specialises in wrought-iron goods, for example, spades, picks, nails, wrought-iron bars, and general ironwork; the northern district produces the larger and rougher classes of goods, such as cast-iron pans and sections of tyres for cart-wheels. Reduction of the ore is conducted in roasting-kilns; the broken-up ore is mixed with anthracite and charged into clay crucibles, which are heated in the kilns for about four days. The iron residue is then treated in a foundry, where it is broken up and remelted in crucibles for the production of cast iron, or, if wrought iron is being produced, by melting in a crude furnace, hammering, and puddling.

The Ping Ting Chau district is one of the largest anthracite coal beds of which there is any knowledge. The natives get at the coal by adit or by shaft, as may best suit the nature of the ground. Shafts vary from 6 to 8 feet in diameter, and from 60 to 300 feet in depth; the thickness of the seam of coal varies from 4 to 18 feet. During late years native mechanics have been giving advice, with the result that collieries are coming into existence in which the coal is hoisted in baskets, and cow-hide bags are used for hauling out accumulations of water. A Canton Chinaman attempted to apply up-to-date methods to a mine just outside the Ping Ting Chau area, and sank a shaft beside the adit. He proposed to use a winch for winding up the coal, but before this could be done water was struck and the mine flooded. Boilers and pumps were erected by Chinese workmen, and the water was successfully cleared out of the first level. Shortly after starting work an explosion took place, and practically closed the shaft. At present the men are carrying the coal up the steps in bags in an excessively high temperature due to the steam-pipes, and the Cantonese has retired from the field. Pick, hammer, and wedge are the only tools used.

THE DYNAMICS OF A GOLF BALL.[1]

THERE are so many dynamical problems connected with golf that a discussion of the whole of them would occupy far more time than is at my disposal this evening. I shall not attempt to deal with the many important questions which arise when we consider the impact of the club with the ball, but confine myself to the consideration of the flight of the ball after it has left the club. This problem is in any case a very interesting one; it would be even more interesting if we could accept the explanations of the behaviour of the ball given by many contributors to the very voluminous literature which has collected round the game; if these were correct, I should have to bring before you this evening a new dynamics, and announce that matter, when made up into golf balls, obeys laws of an entirely different character from those governing its action when in any other condition.

If we could send off the ball from the club, as we might from a catapult, without spin, its behaviour would be regular, but uninteresting; in the absence of wind its path would keep in a vertical plane; it would not deviate either to the right or to the left, and would fall to the ground after a comparatively short carry.

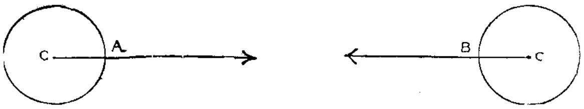

FIG. 1.

But a golf ball when it leaves the club is only in rare cases devoid of spin, and it is spin which gives the interest, variety, and vivacity to the flight of the ball. It is spin which accounts for the behaviour of a sliced or pulled ball, it is spin which makes the ball soar or "douk," or execute those wild flourishes which give the impression that the ball is endowed with an artistic temperament, and performs these eccentricities as an acrobat might throw in an extra somersault or two for the fun of the thing. This view, however, gives an entirely wrong impression of the temperament of a golf ball, which is, in reality, the most prosaic of things, knowing while in the air only one rule of conduct, which it obeys with unintelligent conscientiousness, that of always following its nose. This rule is the key to the behaviour of all balls when in the air, whether they are golf balls, base balls, cricket balls, or tennis balls. Let us, before entering into the reason for this rule, trace out some of its consequences. By the nose of the ball we mean the point on the ball furthest in front. Thus if, as in Fig. 1, C the centre of the ball is moving horizontally to the right, A will be the nose of the ball; if it is moving horizontally to the left, B will

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[1] Discourse delivered at the Royal Institution on Friday, March 18, by Sir J. J. Thomson, F.R.S.

be the nose. If it is moving in an inclined direction CP, as in Fig. 2, then A will be the nose.

Now let the ball have a spin on it about a horizontal axis, and suppose the ball is travelling horizontally as in Fig. 3, and that the direction of the spin is as in the figure, then the nose A of the ball is moving upwards, and since by our rule the ball tries to follow its nose, the ball will rise and the path of the ball will be curved as in the dotted line. If the spin on the ball, still about a horizontal axis, were in the opposite direction, as in Fig. 4, then the nose A of the ball would be moving downwards, and as the ball tries to follow its nose it will duck downwards, and its path will be like the dotted fine in Fig. 4.

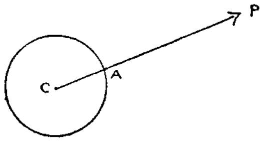

FIG. 2.

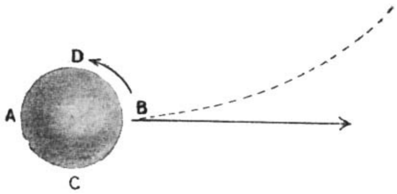

FIG. 3.

Let us now suppose that the ball is spinning about a vertical axis, then if the spin is as in Fig. 5, as we look along the direction of the flight of the ball the nose is moving to the right; hence by our rule the ball will move off to the right, and its path will resemble the dotted line in Fig. 5; in fact, the ball will behave like a sliced ball. Such a ball, as a matter of fact, has spin of this kind about a vertical axis.

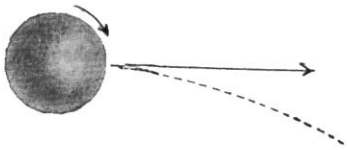

FIG. 4.

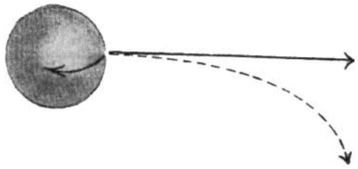

FIG. 5.

If the ball spins about a vertical axis in the opposite direction, as in Fig. 6, then, looking along the line of flight, the nose is moving to the left, hence the ball moves off to the left, describing the path indicated by the dotted line; this is the spin possessed by a "pulled" ball.

FIG. 6.

If the ball were spinning about an axis along the line of flight, the axis of spin would pass through the nose of the ball, and the spin would not affect the motion of the nose; the ball, following its nose, would thus move on without deviation.

Thus, if a cricket ball were spinning about an axis parallel to the line joining the wickets, it would not swerve in the air; it would, however, break in one way or the other after striking the ground; if, on the other hand, the ball were spinning about a vertical axis, it would swerve while in the air, but would not break on hitting the ground. If the ball were spinning about an axis intermediate between these directions it would both swerve and break.

Excellent examples of the effect of spin on the flight of a ball in the air are afforded in the game of base ball; an expert pitcher, by putting on the appropriate spins, can make the ball curve either to the right or to the left, upwards or downwards; for the sideway curves the spin must be about a vertical axis, for the upward or downward ones about a horizontal axis.

A lawn-tennis player avails himself of the effect of spin when he puts "top spin" on his drives, *i.e.* hits the ball on the top so as to make it spin about a horizontal axis, the nose of the ball travelling downwards, as in Fig. 4; this makes the ball fall more quickly than it otherwise would, and thus tends to prevent it going out of the court.

Before proceeding to the explanation of this effect of spin, I will show some experiments which illustrate the point we are considering. As the forces acting on the ball depend on the *relative* motion of the ball and the air, they will not be altered by superposing the same velocity on the air and the ball; thus, suppose the ball is rushing forward through the air with the velocity V, the forces will be the same if we superpose on both air and ball a velocity equal and opposite to that of the ball; the effect of this is to reduce the centre of the ball to rest, but to make the air rush past the ball as a wind moving with the velocity V. Thus the forces are the same when the ball is moving and the air at rest, or when the ball is at rest and the air moving. In lecture experiments it is not convenient to have the ball flying about the room; it is much more convenient to keep the ball still and make the air move.

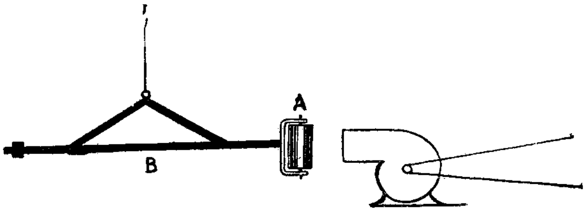

FIG. 7.

The first experiment I shall try is one made by Magnus in 1852; its object is to show that a rotating body moving relatively to the air is acted on by a force in the direction in which the nose of the body is moving relatively to its centre; the direction of this force is thus at right angles both to the direction in which the centre of the body is moving and also to the axis about which the body is spinning. For this purpose a cylinder A (Fig. 7) is mounted on bearings so that it can be spun rapidly about a vertical axis; the cylinder is attached to one end of the beam B, which is weighted at the other end, so that when the beam is suspended by a wire it takes up a horizontal position. The beam yields readily to any horizontal force, so that if the cylinder is acted on by such a force this will be indicated by the motion of the beam. In front of the cylinder there is a pipe D, through which a rotating fan driven by an electric motor sends a blast of air which can be directed against the cylinder. I adjust the beam and the beam carrying the cylinder so that the blast of air strikes the cylinder symmetrically; in this case, when the cylinder is not rotating the impact against it of the stream of air does not give rise to any motion of the beam. I now spin the cylinder, and you see that when the blast strikes against it the beam moves off sideways. It goes off one way when the spin is in one direction, and in the opposite way when the direction of spin is reversed.

The beam, as you will see, rotates in the same direction as the cylinder, which an inspection of Fig 8 will show you is just what it would do if the cylinder were acted upon by a force in the direction in which its nose (which, in this case, is the point on the cylinder first struck by the blast) is moving. If I stop the blast the beam does not move, even though I spin the cylinder, nor does it move when the blast is in action if the rotation of the cylinder is stopped; thus both spin of the cylinder and movement of it through the air are required to develop the force on the cylinder.

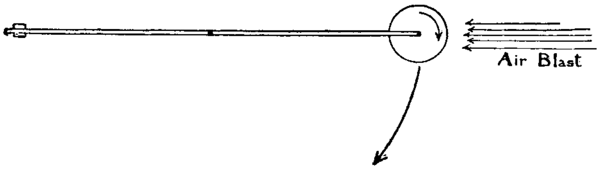

Fig. 8.

Another way of showing the existence of this force is to take a pendulum the bob of which is a cylinder, or some other symmetrical body, mounted so that it can be set in rapid rotation about a vertical axis. When the bob of the pendulum is not spinning the pendulum keeps swinging in one plane, but when the bob is set spinning the plane in which the pendulum swings no longer remains stationary, but rotates slowly in the same sense as the bob is spinning (Fig. 9).

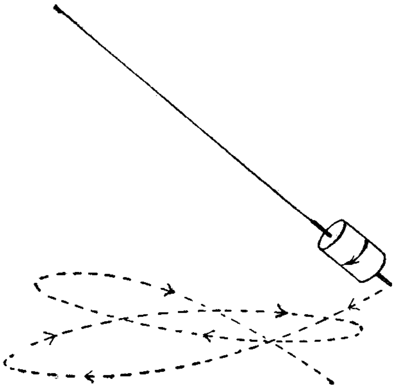

Fig. 9.

We shall now pass on to the consideration of how these forces arise. They arise because when a rotating body is moving through the air the pressure of the air on one side of the body is not the same as that on the other; the pressures on the two sides do not balance, and thus the body is pushed away from the side where the pressure is greatest.

Thus, when a golf ball is moving through the air, spinning in the direction shown in Fig. 10, the pressure on the side ABC, where the velocity due to the spin conspires with that of translation, is greater than that on the side ADB, where the velocity due to the spin is in the opposite direction to that due to the translatory motion of the ball through the air.

Fig. 10.

I will now try to show you an experiment which proves that this is the case, and also that the difference between the pressure on the two sides of the golf ball depends upon the roughness of the ball.

In this instrument, Fig. 11, two golf balls, one smooth and the other having the ordinary bramble markings, are mounted on an axis, and can be set in rapid rotation by an electric motor. An air-blast produced by a fan comes through the pipe B, and can be directed against the balls; the instrument is provided with an arrangement by which the supports of the axis carrying the balls can be raised or lowered so as to bring either the smooth or the bramble-marked ball opposite to the blast. The pressure is measured in the following way:—LM are two tubes connected with the pressure-gauge PQ; L and M are placed so that the golf balls can just fit in between them; if the pressure of the air on the side M of the balls is greater than that of the side L, the liquid on the right-hand side Q of the pressure-gauge will be depressed; if, on the other hand, the pressure at L is greater than that at M, the left-hand side P of the gauge will be depressed.

I first show that when the golf balls are not rotating there is no difference in the pressure on the two sides when the blast is directed against the balls; you see there is no motion of the liquid in the gauge. Next I stop the blast and make the golf balls rotate; again there is no motion in the gauge. Now when the golf balls are spinning in the direction indicated in Fig. 11 I turn on the blast, the liquid falls on the side Q of the gauge, rises on the other side. Now I reverse the direction of rotation of the balls, and you see the motion of the liquid in the gauge is reversed, indicating that the high pressure has gone from one side to the other. You see that the pressure is higher on the side M, where the spin carries this side of the ball into the blast, than on L, where the spin tends to carry the ball away from the blast. If we could imagine ourselves on the golf ball, the wind would be stronger on the side M than on L, and it is on the side of the strong wind that the pressure is greatest. The case when the ball is still and the air moving from right to left is the same from the dynamical point of view as when the air is still and the ball moves from left to right; hence we see that the pressure is greatest on the side where the spin makes the velocity through the air greater than it would be without spin.

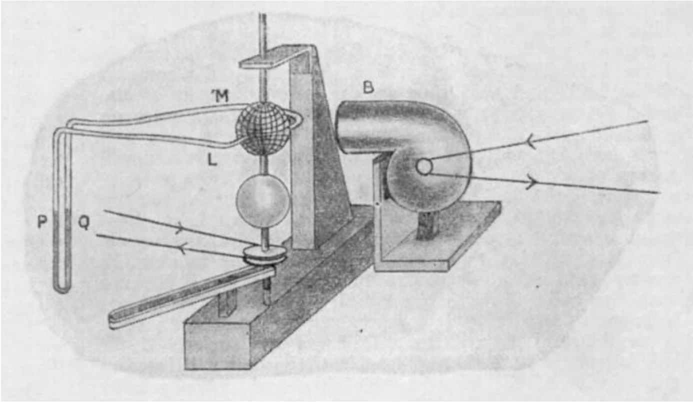

Fig. 11.

Thus, if the golf ball is moving as in Fig. 12, the spin increases the pressure on the right of the ball and diminishes the pressure on the left.

To show the difference between the smooth ball and the rough one, I bring the smooth ball opposite the blast; you observe the difference between the levels of the liquid in the two arms of the gauge. I now move the rough ball into the place previously occupied by the smooth one, and you see that the difference of the levels is more than doubled, showing that with the same spin and speed of air blast the difference of pressure for the rough ball is more than twice that for the smooth.

We must now go on to consider why the pressure of the air on the two sides of the rotating ball should be different. The gist of the explanation was given by Newton nearly 250 years ago. Writing to Oldenburg in 1671 about the dispersion of light, he says, in the course of his letter:—"I remembered that I had often seen a tennis ball struck with an oblique racket describe such a curved line. For a circular as well as progressive motion being communicated to it by that stroke, its parts on that side where the motions conspire must press and beat the contiguous air more violently, and there excite a reluctancy and reaction of the air proportionately greater." This letter has more than a scientific interest—it shows that Newton set an excellent precedent to succeeding mathematicians and physicists by taking an interest in games. The same explanation was given by Magnus, and the mathematical theory of the effect is given by Lord Rayleigh in his paper on "The Irregular Flight of a Tennis Ball," published in the *Messenger of Mathematics*, vol. vi., p. 14, 1877. Lord Rayleigh shows that the force on the ball resulting from this pressure difference is at right angles to the direction of motion of the ball, and also to the axis of spin, and that the magnitude of the force is proportional to the velocity of the ball multiplied by the velocity of spin, multiplied by the sine of the angle between the direction of motion of the ball and the axis of spin. The analytical investigation of the effects which a force of this type would produce on the movement of a golf ball has been discussed very fully by Prof. Tait, who also made a very interesting series of experiments on the velocities and spin of golf balls when driven from the tee, and the resistance they experience when moving through the air.

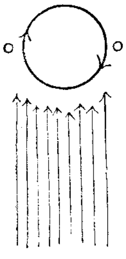

FIG. 12.

As I am afraid I cannot assume that all my hearers are expert mathematicians, I must endeavour to give a general explanation, without using symbols, of how this difference of pressure is established.

Let us consider a golf ball (Fig. 13) rotating in a current of air flowing past it. The air on the lower side of the ball will have its motion checked by the rotation of the ball, and will thus in the neighbourhood of the ball move more slowly than it would do if there were no golf ball present, or than it would do if the golf ball were there but was not spinning. Thus if we consider a stream of air flowing along the channel PQ, its velocity when near the ball at Q must be less than its velocity when it started at P; there must, then, have been pressure acting against the motion of the air as it moved from P to Q, *i.e.* the pressure of the air at Q must be greater than at a place like P, which is some distance from the ball. Now let us consider the other side of the ball; here the spin tends to carry the ball in the direction of the blast of air; if the velocity of the surface of the ball is greater than that of the blast, the ball will increase the velocity of the blast on this side, and if the velocity of the ball is less than that of the blast, though it will diminish the velocity of the air, it will not do so to so great an extent as on the other side of the ball. Thus the increase in pressure of the air at the top of the ball over that at P, if it exists at all, will be less than the increase in pressure at the bottom of the ball. Thus the pressure at the bottom of the ball will be greater than that at the top, so that the ball will be acted on by a force tending to make it move upwards.

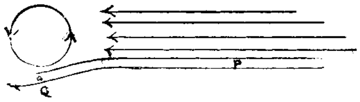

FIG. 13.

We have supposed here that the golf ball is at rest, and the air rushing past it from right to left; the forces are just the same as if the air were at rest, and the golf ball rushing through it from left to right. As in Fig. 13, such a ball rotating in the direction shown in the figure will move upwards, *i.e.* it will follow its nose.

It may perhaps make the explanation of this difference of pressure easier if we take a somewhat commonplace example of a similar effect. Instead of a golf ball, let us consider the case of an Atlantic liner, and, to imitate the rotation of the ball, let us suppose that the passengers are taking their morning walk on the promenade deck, all circulating round the same way. When they are on one side of the boat they have to face the wind, on the other side they have the wind at their backs. Now when they face the wind, the pressure of the wind against them is greater than if they were at rest, and this increased pressure is exerted in all directions, and so acts against the part of the ship adjacent to the deck; when they are moving with their backs to the wind the pressure against their backs is not so great as when they were still, so the pressure acting against this side of the ship will not be so great. Thus the rotation of the passengers will increase the pressure on the side of the ship when they are facing the wind and diminish it on the other side. This case is quite analogous to that of the golf ball.

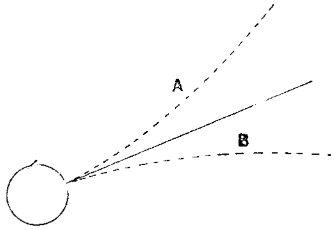

FIG. 14.

The difference between the pressures on the two sides of the golf ball is proportional to the velocity of the ball multiplied by the velocity of the spin. As the spin imparted to the ball by a club with a given loft is proportional to the velocity with which the ball leaves the club, the difference of pressure when the ball starts is proportional to the square of its initial velocity. The difference between the average pressures on the two sides of the ball need only be about one-fifth of 1 per cent. of the atmospheric pressure to produce a force on the ball greater than its weight. The ball leaves the club in a good drive with a velocity sufficient to produce far greater pressures than this. The consequence is that when the ball starts from the tee spinning in the direction shown in Fig. 14, this is often called underspin; the upward force due to the spin is greater than its weight, thus the resultant force is upwards, and the ball is repelled from the earth instead of being attracted to it. The consequence is that the path of the ball curves upward as in the curve A instead of downwards as in B, which would be its path if it had no spin. The spinning golf ball is, in fact, a very efficient heavier-than-air flying machine; the lifting force may be many times the weight of the ball.

The path of the golf ball takes very many interesting forms as the amount of spin changes. We can trace all these changes in the arrangement which I have here, and which I might call an electric golf links. With this apparatus I can subject small particles to forces of exactly the same type as those which act on a spinning golf ball.

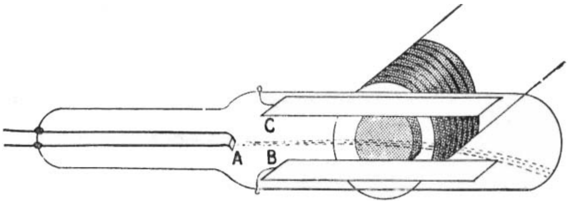

FIG. 15.

These particles start from what may be called the tee A (Fig. 15). This is a red-hot piece of platinum with a spot of barium oxide upon it; the platinum is connected with an electric battery which causes negatively electrified particles to fly off the barium and travel down the glass tube in which the platinum strip is contained; nearly all the air has been exhausted from this tube. These particles are luminous, so that the path they take is very easily observed. We have now got our golf balls off from the tee; we must now introduce a vertical force to act upon them to correspond to the force of gravity on the golf ball. This is easily done by the horizontal plates BC, which are electrified by connecting them with an electric battery; the upper one is electrified negatively, hence when one of these particles moves between the plates it is exposed to a constant downwards force, quite analogous to the weight of the ball. You see now when the particles pass between the plates their path has the shape shown in Fig. 16; this is the path of a ball without spin. I can imitate the effect of spin by exposing the particles while they are moving to magnetic force, for the theory of these particles shows that when a magnetic force acts upon them it produces a mechanical force which is at right angles to the direction of motion of the particles, at right angles also to the magnetic force, and proportional to the product of the velocity of the particles, the magnetic force, and the sine of the angle between them. We have seen that the force acting on the golf ball is at right angles to the direction in which it is moving at right angles to the axis of spin, and proportional to the product of the velocity of the ball, the velocity of spin, and the sine of the angle between the velocity and the axis of spin. Comparing these statements, you will see that the force on the particle is of the same type as that on the golf ball if the direction of the magnetic force is along the axis of spin and the magnitude of the force proportional to the velocity of spin, and thus if we watch the behaviour of these particles when under the magnetic force we shall get an indication of the behaviour of the spinning golf ball. Let us first consider the effect of underspin on the flight of the ball; in this case the ball is spinning, as in Fig. 3, about a horizontal axis at right angles to the direction of flight. To imitate this spin I must apply a horizontal magnetic force at right angles to the direction of flight of the particles. I can do this by means of the electromagnet. I will begin with a weak magnetic force, representing a small spin. You see how the path differs from the one when there was no magnetic force; the path, to begin with, is flatter, though still concave, and the carry is greater than before—see Fig. 17, *a*. I now increase the strength of the magnetic field, and you will see that the carry is still further increased, Fig. 17, *b*. I increase the spin still further, and the initial path becomes convex instead of concave, with a still further increase in carry, Fig. 18. Increasing the force still more, you see the particle soars to a great height, then comes suddenly down, the carry now being less than in the previous case (Fig. 19). This is still a familiar type of the path of the golf ball. I now increase the magnetic force still further, and now we get a type of flight not to my knowledge ever observed in a golf ball, but which would be produced if we could put on more spin than we are able to do at present. You see there is a kink in the curve, and at one part of the path the particle is actually travelling backwards (Fig. 20). Increasing the magnetic force I get more kinks, and we have a type of drive which we have to leave to future generations of golfers to realise (Fig 21).

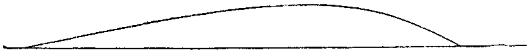

Fig. 16.

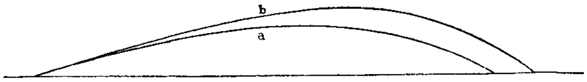

Fig. 17.

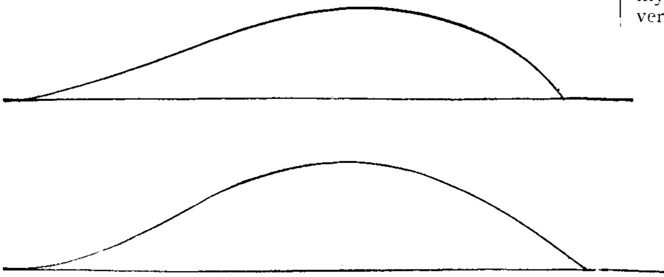

Fig. 18.

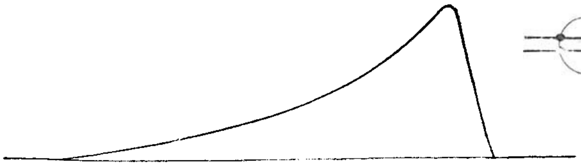

Fig. 19.

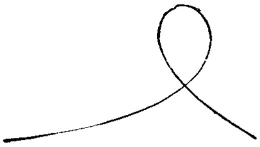

Fig. 20.

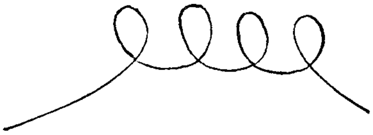

Fig. 21.

By increasing the strength of the magnetic field I can make the curvature so great that the particles fly back behind the tee, as in Fig. 22.

So far I have been considering underspin. Let us now illustrate slicing and pulling; in these cases the ball is spinning about a vertical axis. I must therefore move my electromagnet, and place it so that it produces a vertical magnetic force (Fig. 23). I make the force act one way, say downwards, and you see the particles curve away to the right, behaving like a sliced ball. I reverse the direction of the force and make it act upwards, and the particles curve away to the left, just like a pulled ball.

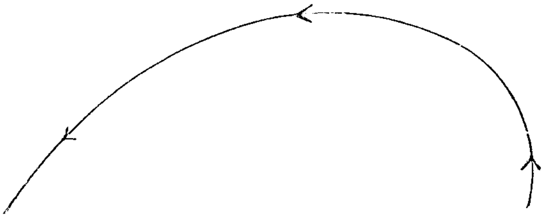

Fig. 22.

By increasing the magnetic force we can get slices and pulls much more exuberant than even the worst we perpetrate on the links.

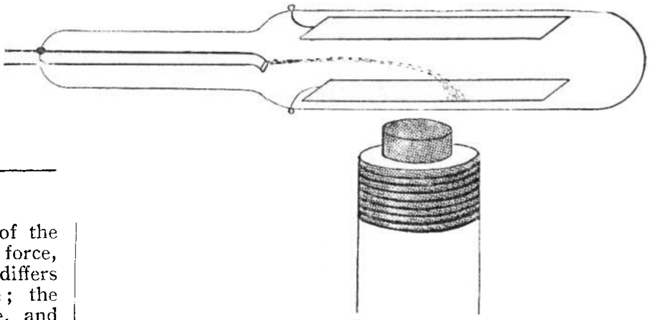

Fig. 23.

Though the kinks shown in Fig. 20 have never, so far as I am aware, been observed on a golf links, it is quite easy to produce them if we use very light balls. I have here a ball A made of very thin indiarubber of the kind used for toy balloons, filled with air, and weighing very little more than the air it displaces; on striking this with the hand, so as to put underspin upon it, you see that it describes a loop, as in Fig. 24.

Striking the ball so as to make it spin about a vertical axis, you see that it moves off with a most exaggerated slice when its nose is moving to the right looking at it from the tee, and with an equally pronounced pull when its nose is moving to the left.

One very familiar property of slicing and pulling is that the curvature due to them becomes much more pronounced when the velocity of the ball has been reduced than it was at the beginning when the velocity was greatest. We can easily understand why this should be so if we consider the effect on the sideways motion of reducing the velocity to one half. Suppose a ball is projected from A in the direction AB, but is sliced; let us find the sideways motion BC due to slice. The sideways force is, as we have seen, proportional to the product of the velocity of the ball and the velocity of spin, or, if we keep the spin the same in the two cases, to the velocity of the ball; hence, if we halve the velocity we halve the sideways force, hence, in the same time, the displacement would be halved too, but when the velocity is halved the time taken for the ball to pass from A to B is doubled. Now the displacement produced by a constant force is proportional to the square of the time; hence, if the force had remained constant, the sideways deflection BC would have been increased four times by halving the velocity, but as halving the velocity halves the force, BC is doubled when the velocity is halved; thus the sideways movement is twice as great when the velocity is halved.

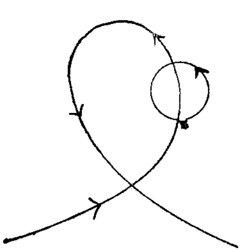

FIG. 24.

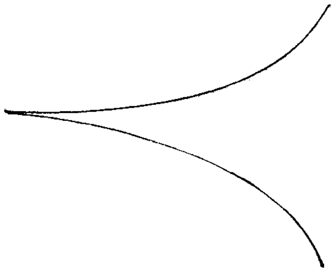

FIG. 25.

If the velocity of the spin diminished as rapidly as that of translation, the curvature would not increase as the velocity diminished, but the resistance of the air has more effect on the speed of the ball than on its spin, so that the speed falls the more rapidly of the two.

The general effect of wind upon the motion of a spinning ball can easily be deduced from the principles we discussed in the earlier part of the lecture. Take, first, the case of a head-wind. This wind increases the relative velocity of the ball with respect to the air; since the force due to the spin is proportional to this velocity, the wind increases this force, so that the effects due to spin are more pronounced when there is a head-wind than on a calm day. All golfers must have had only too many opportunities of noticing this. Another illustration is found in cricket; many bowlers are able to swerve when bowling against the wind who cannot do so to any considerable extent on a calm day.

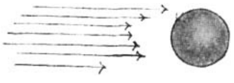

FIG. 26.

Let us now consider the effect of a cross-wind. Suppose the wind is blowing from left to right, then, if the ball is pulled, it will be rotating in the direction shown in Fig. 26; the rules we found for the effect of rotation on the difference of pressure on the two sides of a ball in a blast of air show that in this case the pressure on the front half of the ball will be greater than that on the rear half, and thus tend to stop the flight of the ball. If, however, the spin was that for a slice, the pressure on the rear half would be greater than the pressure in front, so that the difference in pressure would tend to push on the ball and make it travel further than it otherwise would. The moral of this is that if the wind is coming from the left we should play up into the wind and slice the ball, while if it is coming from the right we should play up into it and pull the ball.

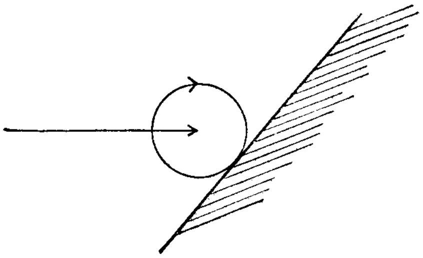

FIG. 27.

I have not time for more than a few words as to how the ball acquires the spin from the club. But if you grasp the principle that the action between the club and the ball depends only on their *relative* motion, and that it is the same whether we have the ball fixed and move the club or have the club fixed and project the ball against it, the main features are very easily understood.

Suppose Fig. 27 represents the section of the head of a lofted club moving horizontally forward from right to left, the effect of the impact will be the same as if the club were at rest and the ball were shot against it horizontally from left to right. Evidently, however, in this case the ball would tend to roll up the face, and would thus get spin about a horizontal axis in the direction shown in the figure; this is underspin, and produces the upward force which tends to increase the carry of the ball.

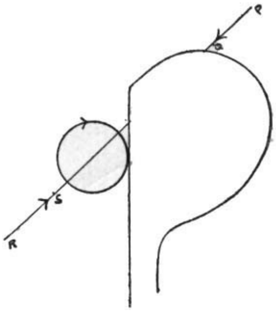

FIG. 28.

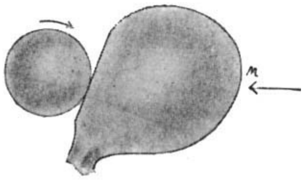

FIG. 29.

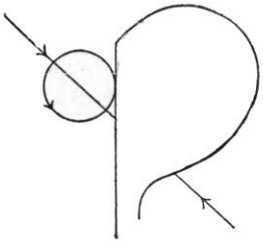

FIG. 30.

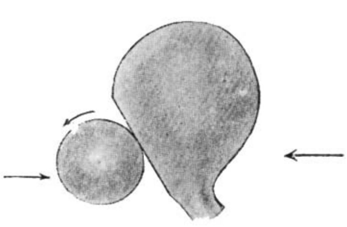

FIG. 31.

Suppose, now, the face of the club is not square to its direction of motion, but that, looking down on the club, its line of motion when it strikes the ball is along PQ (Fig. 28), such a motion as would be produced if the arms were pulled in at the end of the stroke, the effect of the impact now will be the same as if the club were at rest and the ball projected along RS, the ball will endeavour to roll along the face away from the striker; it will spin in the direction shown in the figure about a vertical axis. This, as we have seen, is the spin which produces a slice. The same spin would be produced if the motion of the club was along LM and the face turned so as to be in the position shown in Fig. 29, *i.e.* with the heel in front of the toe.

If the motion and position of the club were as in Figs. 30 and 31, instead of as in Figs. 28 and 29, the same consideration would show that the spin would be that possessed by a pulled ball.

THE SECOND FRENCH ANTARCTIC EXPEDITION.[1]

THE Antarctic is so vast as to admit of many expeditions working together with good results, and Dr. Charcot therefore resolved to return to the region which he had explored to some extent in 1903–5. His precise object was to investigate from every point of view as great an extent of the Antarctic as possible, without any considerations as to latitude. He desired to enter the region where the ice drifted furthest to the north, and he had no hope whatever of reaching the Pole. He had a three-masted vessel constructed at St. Malo, with auxiliary engine, which he named *Le Pourquoi Pas?* It was equipped with every care, and supplied with the most modern instruments for observation. The crew consisted of twenty-two men, most of whom had already accompanied Dr. Charcot on his previous expedition. The staff consisted of seven, who were experts in different departments of science. The expedition started from Havre on August 15, 1909, and on December 16 left Punta Arenas for the Antarctic.

After passing Deception Island Dr. Charcot made for Port Lockroy, in Gerlache Strait, where the work of the expedition began. Some days later the expedition arrived at Wandell, which was found to be a very unsatisfactory harbour, and therefore the expedition moved on to Petermann Island. Dr. Charcot with two of his companions set out to discover if it was possible to pass between the Biscoe Islands and the coast. As they expected to return the same day they did not take any provisions or change of garments. Their return was blocked by the ice, and it was four days before they were able to reach the ship, narrowly escaping death from hunger and cold. From Petermann Island a journey was made towards the south along the coast, the mapping of which, begun during the previous expedition, was completed. A hydrographical survey was made of Adelaide Island, which was found to be seventy miles long instead of eight, as had previously been stated. To the south of Adelaide, in a region which had not previously been visited, a great gulf was discovered which was entitled Marguerite Bay. Here the greatest difficulties were met with from the ice and from icebergs, but these were successfully overcome. In spite of all the difficulties the expedition discovered and studied the hydrography of 120 miles of unknown coast to the south.

At last, after two attempts, the expedition succeeded in traversing the ice and reaching Alexander Land, which was mapped, and the hydrography of which was investigated. It was found absolutely impossible to winter here, however, and the expedition was compelled to return to Petermann Island. Observations, however, were carried on with great perseverance, numerous soundings and dredgings were made, and many photographs taken. The house which had been constructed here on the previous expedition was still available, and after three days' work was put into condition for being able to be used during the winter. In the autumn numerous and long excursions were made on the glaciers. The winter, though mild, was almost continuously stormy, a formidable north-east wind blowing during nine months. An immense quantity of snow fell. The terrible season was very trying to the members of the expedition, some of whom had been attacked with scurvy.

An attempt was made to traverse Graham Land. The members of the expedition who carried out the work returned with many interesting observations, but without having been able to overcome the impassable perpendicular wall of granite and of ice which lines the whole of the coast where a landing was attempted to be made. Many other excursions were made in the neighbourhood. With great difficulty, owing to the state of the ice, Deception Island was reached at the end of November, and the expedition received the greatest hospitality from the whalers who are settled on the island. Many observations were here made in seismography, on the tides, on hydrography, in natural history and geology, and many soundings and dredgings were carried out.

After the expedition had been refitted it visited Bridgman Island, Admiralty Bay, the south coast of the South Shetlands, at all of which places good work was done. After this another attempt was made to penetrate southwards. In spite of the unfavourable condition of the ice and the weather, the expedition succeeded in passing beyond all the latitudes previously reached to the southwest of Alexander Land. It was hoped that the expedition would be able to make further discoveries to the south and the west of Alexander Land, but the formidable condition of the pack rendered this extremely difficult. The route, however, was continued along the edge of the pack, when Peter 1st Island was discovered in the place at which it is usually charted. After this the icebergs became so numerous as to be embarrassing and dangerous. Dr. Charcot reckons that they counted something like 5000 of these in one day. However, they succeeded in reaching 126 degrees west longitude, and so reached two or three degrees further south than the route followed by Cook and Bellingshausen. As the supply of coal was now almost exhausted, and the health of the expedition had become alarming, it was decided to make for the north. The icebergs gradually diminished, and at last disappeared, and, thanks to an uninterrupted series of strong winds, varying from south-west to N.N.W., rapid progress was made. In ten days the Straits of Magellan were reached, and on February 12 the expedition anchored at Punta Arenas. The *Pourquoi Pas?* behaved admirably in spite of the many trials to which it was subjected, and the crew was all that could be desired, while the scientific staff worked incessantly, and from the scientific point of view the programme was scrupulously carried out. It will take many months to work out the observations which have been made during the expedition, to study and arrange the rich collections obtained, and therefore it is somewhat difficult to give more than a brief *resume* of the results obtained.

From the geographical point of view the expedition has proved that the west coast of what may be called the South American Antarctic is cut up by deep fjords, and the coast studded with islands and reefs. Graham Land is continued to the south by a land to which Dr. Charcot has given the name Terre Loubet; this is continued by the Terre Fallières. Alexander Land, which has only been seen by Bellingshausen, is a large island, but the lands discovered by the expedition to the south and west of that very probably join on Terre Fallieres. Outside of Peter 1st Island the expedition did not obtain sight of any other land, but their soundings in continuation of those of the Belgian expedition, the configuration of the icebergs and their movements, seem to indicate that there exists a continual line, which most probably joints the Graham Land section of the Antarctic to King Edward VII. Land. Dr. Charcot considers that the further exploration of this land is very desirable, although the difficulties from the state of the weather and the formidable nature of the ice here will render such an enterprise extremely difficult.

In spite of the difficulties which had to be faced, the observations made in the various departments of science are extremely rich. Careful mapping of the lands visited was carried out throughout; numerous gravity observations were made; earthquake phenomena recorded; an eclipse of the sun on December 23, 1908, was observed; important geological observations carried out, proving that the same dioritic and granitic forms which are to be found in Graham Land are continued further to the south. Of the existence of a continental plateau there can be little doubt from the observations that were made. Numerous excursions were made on the glaciers into the interior; careful continuous meteorological observations were re-

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[1] Summary of a paper by Dr. J. B. Charcot read before the Royal Geographical Society on December 19.