SCIENCE MADE POPULAR.

PROFESSOR FARADAY'S LECTURES ON THE PHYSICAL FORCES.

LECTURE 1.—THE FORCE OF GRAVITATION.

Let us consider, for a little while, how wonderfully we stand upon this world. Here it is we are horn, bred and live, and yet we view these things with an almost entire absence of wonder to ourselves respecting the way in which this all happens. So small, indeed, is our wonder, that we are never taken by surprise; and I do think that, to a young person of 10, 15 or 20 years of age, perhaps the first sight of a cataract or a mountain would occasion him more surprise than he had ever felt concerning the means of his own existence; how he came here, how he lives, by what means he stands upright, and through what means he moves about from place to place. Hence, we come into this world, we live, and depart from it, without our thoughts being called specifically to consider how all this takes place; and were it not for the exertions of some few inquiring minds, who have looked *into* these things, and ascertained the very beautiful laws and conditions by which we *do* live and stand upon the earth, we should hardly be aware that there was anything wonderful in it. These inquiries, which have occupied philosophers from the earliest days, when they first began to find out the laws by which we grow and exist and enjoy ourselves, up to the present time, have shown us that all this was effected in consequence of the existence of certain forces, or abilities to do things, or powers, that are so common that nothing can be more so; for nothing is commoner than the wonderful powers by which we are enabled to stand upright—they are essential to our existence every moment.

It is my purpose to make you acquainted with some of these powers; not the vital ones, but some of the more elementary, and what we call *physical* powers; and, in the outset, what can I do to bring to your minds a notion of neither more nor less than that which I mean by the word *power* or *force?* Suppose I take this sheet of paper and place it upright on one edge, resting against a support before me (as the roughest possible illustration of something to be disturbed), and suppose I then pull this piece of string which is attached to it. I pull the paper over. I have therefore brought into use a power of doing so—the power of my hand carried on through this string in a way which is very remarkable when we come to analyze it; and it is by means of these powers conjointly (for there are several powers here employed) that I pull the paper over. Again: if I give it a push upon the other side, I bring into play a power, but a very different exertion of power from the former; or, if I take now this bit of shellac [a stick of shellac about 12 inches long and 1½ in diameter], and rub it with flannel, and hold it an inch or so in front of the upper part of this upright sheet, the paper is immediately moved toward the shellac, and by now drawing the latter away, the paper falls over without having been touched by anything. You see, in the first illustration I produced an effect than which nothing could be commoner; I pull it over now, not by means of that string or the pull of my hand, but by some action in this shellac. The shellac, therefore, has a power wherewith it acts upon the sheet of paper; and, as an illustration of the exercise of another kind of power, I might use gunpowder with which to throw it over.

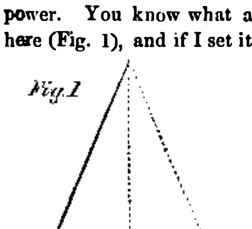
Now I want you to endeavor to comprehend that when I am speaking of a power or force, I am speaking of that which I used just now to pull over this piece of paper. I will not embarrass you at present with the *name* of that power, but it is clear there was a *something* in the shellac which acted by attraction and pulled the paper over; this, then, is one of those things which we call power or force; and you will now be able to recognize it as such in whatever form I show it to you. We are not to suppose that there are so very many different powers; on the contrary, it is wonderful to think how few are the powers by which all the phenomena of nature are governed. There is an illustration of another kind of power in that lamp; *there* is a power of heat—a power of doing something, but not the same power as that which pulled the paper over; and so, by degrees, we find that there are certain other powers (not many) in the various bodies around us; and thus, beginning with the simplest experiments of pushing and pulling, I shall proceed to distinguish these powers one from the other, and compare the way in which they combine together. This world upon which we stand (and we have not much need to travel out of the world for illustrations of our subject; but the mind of man is not confined like the matter of his body, and thus he may and does travel outward, for, wherever his sight can pierce, there his observations can penetrate) is pretty nearly a round globe, having its surface disposed in a manner of which this terrestial globe by my side is a rough model; so much is land and so much is water; and, by looking at it here, we see in a sort of map or picture how the world is formed upon its surface. Then, when we come to examine farther, I refer you to this sectional diagram of the geological strata of the earth, in which there is a more elaborate view of what is beneath the surface of our globe. And, when we come to dig into or examine it (as man does for his own instruction and advantage, in a variety of ways), we see that it is made up of different kinds of matter, subject to a very few powers; and all disposed in this strange and wonderful way, which gives to man a history—and such a history—as to what there is in those veins, in those rocks, the ores, the water-springs, the atmosphere around, and all varieties of material substances, held together by means of forces in one great mass, 8,000 miles in diameter, that the mind is overwhelmed in contemplation of the wonderful history related by these strata (some of which are fine and thin, like sheets of paper), all formed in succession by the forces of which I have spoken.

I now shall try to help your attention to what I may say by directing, to-day, our thoughts to one kind of power. You see what I mean by the term *matter*—any of these things that I can lay hold of with the hand, or in a bag (for I may take hold of the air by inclosing it in a bag)—they are all portions of matter with which we have to deal at present, generally or particularly, as I may require to illustrate my subject. Here is the sort of matter which we call *water*—it is *there* ice [pointing to a block of ice upon the table], *there* water [pointing to the water boiling in a flask], *here* vapor—you see it issuing out from the top (of the flask). Do not suppose that that ice and that water are two entirely different things, or that the steam rising in bubbles and ascending in vapor *there* is absolutely different from the fluid water; it may be different in some particulars, having reference to the amounts of power which it contains; but it is the same, nevertheless, as the great ocean of water around our globe, and I employ it here for the sake of illustration, because if we look into it we shall find that it supplies us with examples of all the powers to which I shall have to refer. For instance, here is water—it is heavy; but let us examine it with regard to the *amount* of its heaviness or its gravity. I have before me a little glass vessel and scales [nearly equipoised scales, one of which contained a half-pint glass vessel], and the glass vessel is at present the lighter of the two; but if I now take some water and pour it in, you see that that side of the scales immediately goes down; that shows you (using common language, which I will not suppose that you have hitherto applied very strictly) that it is *heavy*, and if I put this additional weight into the opposite scale, I should not wonder if this vessel would hold water enough to weigh *it* down. [The lecturer poured more water into the jar, which again went down.] Why do I hold the bottle above the vessel to pour the water into it? You will say, because experience has taught me that it is necessary. I do it for a better reason—because it is a law of nature that the water should fall toward the earth, and therefore the very means which I use to cause the water to enter the vessel are those which will carry the whole body of water down. That power is what we call *gravity*, and you see *there* [pointing to the scales] a good deal of water gravitating toward the earth. Now *here* [exhibiting a small piece of platinum(2)] is another thing which gravitates toward the earth as much as the whole of that water. See what a little there is of it; that little thing is heavier than so much water [placing the metal in opposite scales to the water]. What a wonderful thing it is to see that it requires so much water as that [a half-pint vessel full] to fall toward the earth, compared with the little mass of substance I have here! And again: if I take this metal [a bar of aluminum(3) about eight times the bulk of the platinum], we find the water will balance that as well as it did the platinum; so that we get, even in the very outset, an example of what we want to understand by the words "forces" or "powers."

I have spoken of water, and first of all, of its property of falling downward; you know very well how the oceans surround the globe—how they fall round the surface, giving roundness to it, clothing it like a garment; but, besides that, there are other properties of water. *Here*, for instance, is some quicklime, and if I add some water to it, you will find another power or property in the water.(4) It is now very hot—it is steaming up; and I could perhaps light phosphorous or a lucifer-match with it. Now that could not happen without a force in the water to produce the result; but that force is entirely distinct from its power of falling to the earth. Again: here is another substance [some anhydrous sulphate of copper (5)] which will illustrate another kind of power. [The lecturer here poured some water over the white sulphate of copper, which immediately became blue, evolving considerable heat at the same time.] Here is the same water with a substance which heats nearly as much as the lime does—but see how differently. So great, indeed, is this heat in the case of lime, that it is sufficient sometimes (as you see here) to set wood on fire; and this explains what we have sometimes heard, of barges laden with quicklime taking fire in the middle of the river, in consequence of this power of heat brought into play by a leakage of the water into the barge. You see how strangely different subjects for our consideration arise when we come to think over these various matters—the power of heat evolved by acting upon lime with water, and the power which water has of turning this salt of copper from white to blue.

I want you now to understand the nature of the most simple exertion of this power of matter called *weight* or *gravity*. Bodies are heavy; you saw that in the case of water when I placed it in the balance. Here I have what we call a *weight* [an iron half cwt.]—a thing called a weight, because in it the exercise of that power of pressing downward is especially used for the purposes of weighing; and I have also one of these little inflated India-rubber bladders, which are very beautiful although very common (most beautiful things are common), and I am going to put the weight upon it to give you a sort of illustration of the downward pressure of the iron, and of the power which the air possesses of resisting that pressure; it may burst, but we must try to avoid that. [During the last few observations, the lecturer had succeeded in placing the half cwt. in a state of quiescence upon the inflated india-rubber ball, which consequently assumed a shape very much resembling a flat cheese with round edges.] There you see a bubble of air bearing half a hundred-weight, and you must conceive for yourselves what a wonderful power there must be to pull this weight downward to sink it thus in the ball of air.

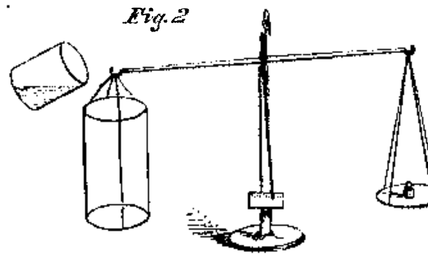
Let me now give you another illustration of this power. You know what a pendulum is. I have one here (Fig. 1), and if I set it swinging, it will continue to swing to and fro. Now I wonder whether you can tell me why that body oscillates to and fro—that "pendulum bob," as it is sometimes called. Observe, if I hold the straight stick horizontally, as high as the position of the ball at the two ends of its journey, you see that the ball is in a higher position at the two extremities than it is when in the middle. Starting from one end of the stick, the ball falls toward the center, and then rising again to the opposite end, it constantly tries to fall to the lowest point, swinging and vibrating most beautifully, and with wonderful properties in other respects—the time of its vibration, and so on—but concerning which we will not now trouble ourselves.



If a gold leaf or piece of thread, or any other substance, were hung where this ball is, it would swing to and fro in the same manner, and in the same time, too. Do not be startled at this statement; I repeat it, in the same manner and in the same time, and you will see by-and-by how this is. Now that power which caused the water to descend in the balance—which made the iron weight press upon and flatten the bubble of air—which caused the swinging to and fro of the pendulum, that power is entirely due to the attraction which there is between the falling body and the earth. Let us be slow and careful to comprehend this. It is not that the earth has any *particular* attraction toward bodies which fall to it, but that *all* these bodies possess an attraction every one toward the other. It is not that the earth has any special power which these balls themselves have not; for just as much power as the earth has to attract these two balls [dropping two ivory balls], just so much power have they in proportion to their bulks to draw themselves one to the other; and the only reason why they fall so quickly to the earth is owing to its greater size. Now, if I were to place these two balls near together, I should not be able, by the most delicate arrangement of apparatus, to make you or myself sensible that these balls did attract one another; aud yet we know that such is the case, because if, instead of taking a small ivory ball, we take a mountain, and put a ball like this near it, we find that, owing to the vast size of the mountain as compared with the billiard ball, the latter is drawn slightly toward it, showing clearly that an attraction *does* exist, just as it did between the shellac which I rubbed and the piece of paper which was overturned by it.

Now it is not very easy to make these things quite clear at the outset, and I must take care not to leave anything unexplained as I proceed; and, therefore, I must make you clearly understand that all bodies are attracted to the earth—or, to use a more learned term, *gravitate*. You will not mind my using this word, for

Fig. 2



when say that this penny-piece gravitates, I mean nothing more nor less than that it falls toward the earth, and, if not intercepted, it would go on falling, falling, until it arrived at what we call the *center of gravity* of the earth, which I will explain to you by-and-by.

I want you to understand that this property of gravitation is never lost; that every substance possesses it; that there is never any change in the quantity of it; and, first of all, I will take as illustration a piece of marble. Now this marble has weight, as you will see if I put it in these scales; it weighs the balance down, and if I take it off, the balance goes back again and resumes its equilibrium. I can decompose this marble, and change it in the same manner as I can change ice into water and water into steam. I can convert a part of it into its *own* steam easily, and show you that this steam from the marble has the property of remaining in the same place at common temperatures, which *water* steam has not. If I add a little liquid to the marble and decompose it(6), I get that which you see [the lecturer here put several lumps of marble into a glass jar, and poured water and then acid over them; the carbonic acid immediately commenced to escape, with considerable effervescence], the appearance of boiling, which is only the separation of one part of the marble from another. Now this [marble] steam, and that [water] steam, and all other steams, gravitate just like any other substance does; they all are attracted the one toward the other, and all fall toward the earth; and what I want you to see is, that *this* steam gravitates. I have here (Fig. 2) a large vessel placed upon a balance, and the moment I pour this steam into it you see that the steam gravitates. Just watch the index, and see whether it tilts over or not. [The lecturer here poured the carbonic acid out of the glass in which it was being generated into the vessel suspended on the balance, when the gravitation of the carbonic acid was at once apparent.] Look how it is going down. How pretty that is! I poured nothing in it but the invisible steam or vapor or gas which came from the marble; but you see that part of the marble, although it has taken the shape of air, still gravitates as it did before. Now will it weigh down that bit of paper? [placing a piece of paper in the opposite scale.] Yes, more than that; it nearly weighs down this bit of paper [placing another piece of paper in]. And thus you see that *other* forms of matter besides solids and liquids tend to fall to the earth; and, therefore, you will accept from me the fact that all things gravitate, whatever may be their form or condition. Now here is another chemical test which is very readily applied. [Some of the carbonic acid was

Fig. 3

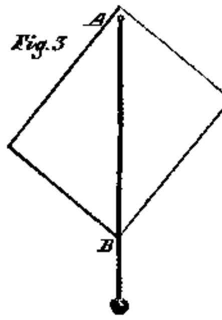
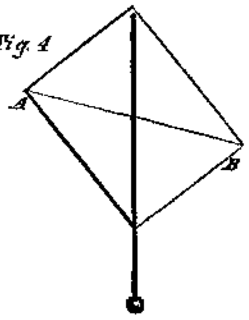


Fig. 4



poured from one vessel into another, and its presence in the latter shown by introducing into it a lighted taper, which was immediately extinguished.] You see from this result, also, that it gravitates. All these experiments show you that, tried by the balance, tried by pouring like water from one vessel to another, this steam or vapor or gas is, like all other things, attracted to the earth.

There is another point I want, in the next place, to draw your attention to. I have here a quantity of shot; each of these falls separately, and each has its own gravitating power, as you perceive when I let them fall loosely on a sheet of paper. If I put them into a bottle, I collect them together as one mass, and philosophers have discovered that there is a certain point in the middle of the whole collection of shots that may be considered as the one point in which all their gravitating power is centered, and that point they call the center of gravity; it is not at all a bad name, and rather a short one—the "center of gravity." Now suppose I take a sheet of pasteboard, or any other thing easily dealt with, and run a brad-awl through it at one corner, A (Fig. 3), and Mr. Anderson hold that up in his hand before ns, and I then take a piece of thread and an ivory ball and hang that upon the awl, then the center of gravity of both the pasteboard and the ball and string are as near as they can get to the center of the earth; that is to say, the whole of the attracting power of the earth is, as it were, centered in a single point of the cardboard, and this point is exactly below the point of suspension. All I have to do, therefore, is to draw a line, A B, corresponding with the string, and we shall find that the center of gravity is somewhere in that line. But where? To find that out, all we have to do is to take another place for the awl (Fig. 4), hang the plumb-line, and make the same experiment, and there [at the point C] is the center of gravity—there where the two lines which I have traced cross each other; and if I take that pasteboard, and make a hole with the

Fig. 5

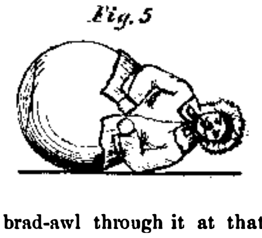
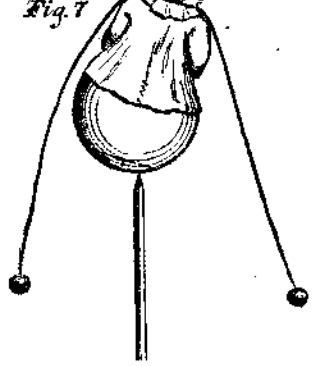


Fig. 6

brad-awl through it at that point, you will see that it will be supported in any position in which it may be placed. Now, knowing that, what do I do when I try to stand upon one leg? Do you not see that I push myself over to the left side, and quietly take up the right leg, and thus bring some central point in my body over this left leg? What is that point which I throw over? You will know at once that it is the center of gravity—that point in me where the whole gravitating force of my body is centered, and which I thus bring in a line over my foot.

Here is a toy I happened to see the other day, which will, I think, serve to illustrate our subject very well. That toy *ought* to lie something in this manner (Fig. 5), and would do so if it were uniform in substance; but you see it does not; it will get up again. And now philosophy comes to our aid; and I am perfectly sure, without looking inside the figure, that there is some arrangement by which the center of gravity is at the lowest point when the image is standing upright; and we may be certain when I am tilting it over (see Fig. 6) that I am lifting up the center of gravity, *a*, and raising it from the earth. All this is effected by putting a piece of lead inside the lower part of the image and making the base of large curvature, and there you have the whole secret. But what will happen if I try to make the figure stand upon a sharp point? You observe I must get that point *exactly* under the center of gravity, or it will fall over thus [endeavoring, unsuccessfully, to balance it]; and this, you see, is a difficult matter; I cannot make it stand steadily; but if I embarrass this poor old lady with a world of trouble, and hang this wire with bullets at each end about her neck, it is very evident that, owing to there being those balls of lead hanging down on either side, in addition to the lead inside, I have lowered the center of gravity, and now she will stand upon this point (Fig. 7); and, what is more,

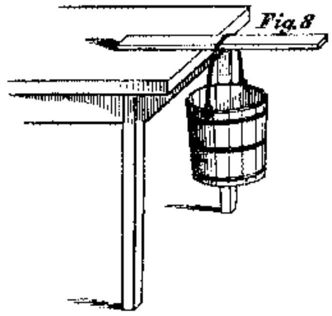
Fig. 7



she proves the truth of our philosophy by standing sideways.

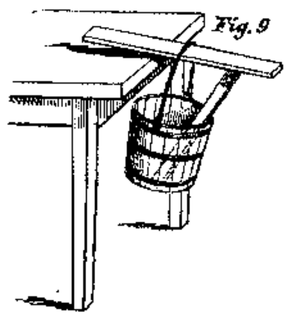
I remember an experiment which puzzled me very much when a boy. I read it in a conjuring book, and this was how the problem was put to us:—"How," as the book said, "how to hang a pail of water, by means of a stick, upon the side of a table" (Fig. 8). Now I

Fig. 8



have here a table, a piece of stick and a pail, and the proposition is, how can that pail be hung to the edge of this table? It is to be done; and can you at all anticipate what arrangement I shall make to enable me to succeed? Why, this. I take a stick, and put it in the pail between the bottom and the horizontal piece of wood, and thus give it a stiff handle, and there it is; and, what is more, the more water I put into the pail, the better it will hang. It is very true that before I quite succeeded, I had the misfortune to push the bottoms of several pails out; but here it is hanging firmly

Fig. 9

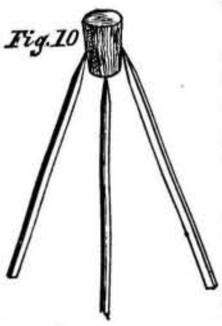


(Fig. 9), and you now see how you can hang up the pail in the way which the conjuring books require.

Again: if you are really so inclined (and I do hope all of you are), you will find a great deal of philosophy in this [holding up a cork and a pointed, thin stick, about a foot long]. Do not refer to your toy-books, and say you have seen that before. Answer me, rather, if I ask you, have you *understood* it before? It is an experiment which appeared very wonderful to me when I was a boy. I used to take a piece of cork (and I remember I thought at first that it was very important that it should be cut out in the shape of a man; but, by degrees, I got rid of that idea), and the problem was to balance it on the point of a stick. Now, you will see that I have only to place two sharp-pointed sticks, one on each side, and give it wings, thus, and you will find this beautiful condition fulfilled.

We come now to another point. All bodies, whether heavy or light, fall to the earth by this force which we call gravity. By observation, moreover, we see that bodies do not occupy the same time in falling; I think you will be able to see that this piece of paper and that ivory ball fall with different velocities to the table [dropping them]; and if, again, I take a feather and an ivory ball, and let them fall, you see they reach the table or earth at different times; that is to say, the ball falls faster than the feather. Now that should not be so; for all bodies do fall equally fast to the earth. There are one or two beautiful points included in that statement. First of all, it is manifest that an ounce, or a pound, or a tun, or a thousand tuns, all fall equally fast, no one faster than another: here are two balls of lead, a very light one and a very heavy one, and you perceive they both fall to the earth in the same time. Now, if I were to put into a little bag a number of these balls, sufficient to make up a bulk equal to the large one, they would also fall in the same time; for if an avalanche fall from the mountain, the rocks, snow and ice, together falling toward the earth, fall with the same velocity, whatever be their size.

Fig. 10



I cannot take a better illustration of this than that of gold leaf, because it brings before us the reason of this apparent difference in the time of the fall. Here is a piece of gold leaf. Now, if I take a lump of gold and this gold leaf, and let them fall through the air together, you see that the lump of gold—the sovereign or coin—will fall much faster than the gold leaf. But why? They are both gold, whether soverign or gold leaf. Why should they not fall to the earth with the same quickness? They would do so, but that the air around our globe interferes very much where we have the piece of gold so extended and enlarged as to offer much obstruction on falling through it. I will, however, show you that gold leaf *does* fall as fast when the resistance of the air is excluded; for if I take a piece of gold leaf and hang it in the center of a bottle, so that the gold and the bottle and the air within shall all have an equal chance of falling, then the gold leaf will fall as fast as anything else. And if I suspend the bottle containing the gold leaf to a string, and set it oscillating like a pendulum, I may make it vibrate as hard as I please, and the gold leaf will not be disturbed, but will swing as steadily as a piece of iron would do; and I might even swing it round my head with any degree of force, and it would remain undisturbed. Or I can try another kind of experiment: if I raise the gold leaf in this way [pulling the bottle up to the ceiling of the theater, by means of a cord and pulley, and then suddenly letting it to fall within a few inches of the lecture table], and allow it then to fall from the ceiling downward (I will put something beneath to catch it, supposing I should be *maladroit*), you will perceive that the gold leaf is not in the least disturbed. The resistance of the air having been avoided, the glass bottle and gold leaf all fall exactly in the same time.

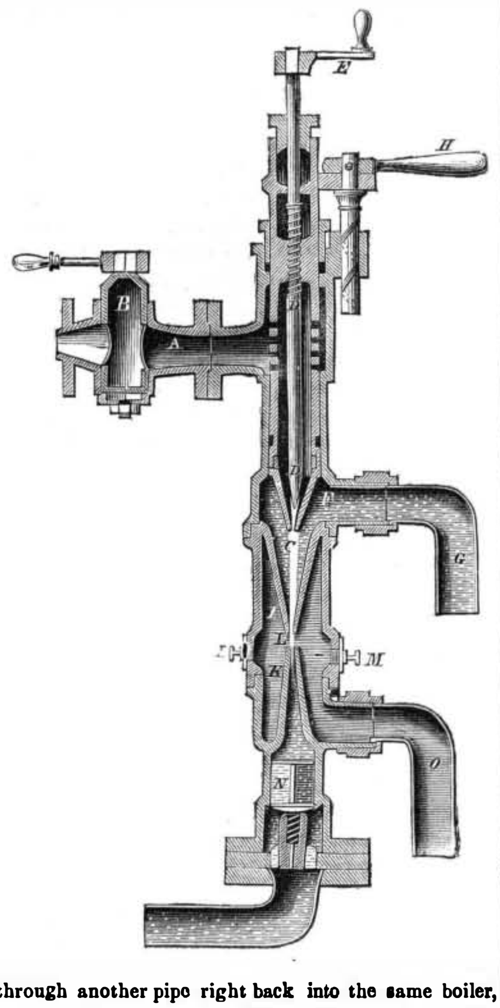
Here is another illustration: I have hung a piece of gold leaf in the upper part of this long glass vessel, and I have the means, by a little arrangement at the top, of letting the gold leaf loose. Before we let it loose, we will remove the air by means of an air-pump, and, while that is being done, let me show you another experiment of the same kind. Take a penny-piece, or a half-crown, and a round piece of paper a trifle smaller in diameter than the coin, and try them side by side to see whether they fall at the same time [dropping them]. You see they do not—the penny-piece goes down first. But now place this paper flat on the top of the coin, so that it shall not meet with any resistance from the air, and upon *then* dropping them, you see they *do* both fall in the same time [exhibiting the effect]. I dare say, if I were to put this gold leaf, instead of the paper, on the coin, it would do as well. It is very difficult to lay the gold leaf so flat that the air shall not get under it and lift it up in falling, and I am rather doubtful as to the success of this, because the gold leaf is puckery, but will risk the experiment. There they go together [letting them fall], and you see at once that they both reach the table at the same moment.

We have now pumped the air out of the vessel, and you will perceive that the gold leaf will fall as quickly in this vacuum as the coin does in the air. I am now going to let it loose, and you must watch to see how rapidly it falls. There [letting the gold loose]; there it is, falling as gold should fall.

I am sorry to see our time for parting is drawing so near. As we proceed, I intend to write upon the board behind me certain words, so as to recall to your minds what we have already examined, and I put the word FORCES as a heading, and I will then add beneath the names of the special forces, according to the order in which we consider them; and, although I fear that I have not sufficiently pointed out to you the more important circumstances connected with the force of GRAVITATION, especially the law which governs its attraction (for which, I think, I must take up a little time at our next meeting); still, I will put that word on the board, and hope you will now remember that we have, in some degree, considered the force of gravitation—that force which causes all bodies to attract each other when they are at sensible distances apart, and tends to draw them together.

GIFFARD'S INJECTOR.

Let no man hereafter conclude, by mere reasoning, that anything cannot be done. That a pipe coming out of the top of a steam boiler should be able, by the mere force of the steam rushing out of it, to blow water



through another pipe right back into the same boiler, without the intervention of any machinery, and thus keep up the supply of water in the boiler, would, most assuredly, have been pronounced impossible by all the philosophers in the world. And yet there are large numbers of steam engines running at this time, the boilers of which are supplied by this process. We gave a description of the apparatus on page 162 of the current volume; but it is so very novel and peculiar that, finding an engraving of it in its most improved form, in the London *Mechanics' Magazine*, we have decided to reproduce it for the benefit of our readers.

The steam from the boiler is admitted through the pipe, A, furnished with a cock, B, and passes down through the perforated cylinder or tube, C, which is made conical at the bottom; the area of the aperture being regulated by the conical rod, D, adjusted by the screw and handle, E. The jet of steam issuing from the orifice of the tube, C, encounters the feed-water in the chamber, F, which enters either from a head of water, or by the aspiration of the apparatus itself, from a tank placed near; from the feed-pipe, G, the supply of feed-water is regulated by raising or lowering the tube, C, by means of the handle, H, and screw of quick pitch. The stream of feed-water propelled by the steam jet issues from the upper orifice, I, and passes into the mouth of the lower pipe, K, leading into the boiler; the intervening space, L, being open to the atmosphere, so that the stream of water can be seen through the sight-holes, M, at this part of the passage. While the injector is at work, a check valve is inserted at N, to prevent the return of water from the boiler when the injector is not working. The overflow pipe carries off any overflow occasioned in starting the injector to work, and the sight-holes, M, are covered by a circular slide.

In starting the injector to work, the handle, H, is first turned into the position suited to the pressure of steam in the boiler; this permits the access of water to the instrument, and regulates its admission. The steam cock, B, is then opened, and the handle, E, turned slightly, so as to elevate the screwed rod, D, which admits a small quantity of steam to the conical opening, I; a partial vacuum is thus produced in the chamber, F, by the rush of steam through the opening, I, and the water flows into it. As soon as this happens, which can be seen by the issue of water from O, the screwed rod, D, is gradually raised until the overflow ceases; thus giving full liberty to the steam to act upon the water at L, and drive it into the boiler through the pipe, K, and the valve, N.

There has been much discussion as to the theory of the action of this wonderful apparatus. Our own explanation is simply this: as the steam in the pipe comes in contact with the cold water, it is condensed, forming a vacuum, into which the steam, under high pressure in the boiler, rushes with tremendous velocity, acquiring sufficient momentum not only to carry itself back into the boiler, but also to carry along with it any particles of water with which it may come in contact on its way.

THE SUBTLETY OF POISONS.—At a recent discussion before the Society of Arts in London on the detection of arsenical poisoning, Dr. Letheby traced the progress of toxicological research from the trial of Donald, in 1815, up to the present time. A little while before that period, *ten grains* of arsenic were required to make a metallic test satisfactory in a court of law. Afterwards, Dr. Black improved the process till he could detect the poison if he had *one grain* to operate upon. It was then thought a marvel of toxicological skill when Dr. Christison said he only required the sixteenth of a grain; but now we can trace the presence of the 250,000,000th of a grain of arsenic! It is to be feared that the detection of this particular poison has reached an almost dangerous degree of delicacy, and extreme caution is necessary in examination for its criminal administration. We live surrounded by means of unconsciously absorbing traces of arsenic; we breathe arsenicated dust from the green wall papers of our rooms; the confectioners supply it wholesale in their cake ornaments and sweetmeats; the very drugs prescribed for our relief are tainted with arsenic; nay, more, even our vegetable food, as Professor Davy has lately pointed out, may be contaminated with arsenic; and there is probably no drinking water containing iron without a trace of arsenic as well. The poison may thus be stored up in the system till, in the course of years, the amount becomes appreciable.