Michael Faraday

The Forces of Matter

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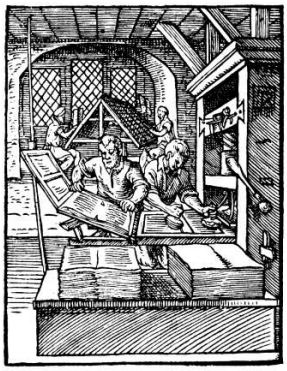

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The Force of Gravitation

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It grieves me much to think that I may have been a cause of disturbance to your Christmas arrangements,[1] for nothing is more satisfactory to my mind than to perform what I undertake; but such things are not always left to our own power, and we must submit to circumstances as they are appointed. I will to-day do my best, and will ask you to bear with me if I am unable to give more than a few words; and, as a substitute, I will endeavor to make the *illustrations* of the sense I try to express as full as possible; and if we find by the end of this lecture that we may be justified in continuing them, thinking that next week our power shall be greater, why then, with submission to you, we will take such course as you may think fit, either to go on or discontinue them; and although I now feel much weakened by the pressure of the illness (a mere cold) upon me, both in facility of expression and clearness of thought, I shall here claim, as I always have done on these occasions, the right of addressing myself to the younger members of the audience; and for this purpose, therefore, unfitted as it may seem for an elderly, infirm man to do so, I will return to second childhood, and become as it were, young again among the young.

Let us now consider, for a little while, how wonderfully we stand upon this world. Here it is we are born, bred, and live, and yet we view these things with an almost entire absence of wonder to ourselves respecting the way in which all this happens. So small, indeed, is our wonder, that we are never

taken by surprise; and I do think that, to a young person of ten, fifteen, or twenty 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 any thing 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-day 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 shell-lac [a stick of shell-lac about 12 inches long and 1 1-2 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 towards the shell-lac, and by now drawing the latter away, the paper falls over without having been touched by any thing. 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 shell-lac. The shell-lac, 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 shell-lac 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 gradually 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 terrestrial 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 for the present 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 aluminium[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 and property in the water.[4] It is now very hot; it is steaming up; and I could perhaps light phosphorus 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