oil of cloves are used, to which a little tincture of musk can be added. This tincture is to be bought at every druggist's, ready prepared, but any one can make it by pouring a little spirit on some musk. The cheapest way is to buy the shrivelled pods of musk, and when cut in small pieces, steeped in spirit for a fortnight, which will communicate the odor to it. Much soap perfumed by this method is found in commerce.—*Kurten.*

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Progress of Locomotion Since 1834.

When, in 1834 (says the London *Examiner*), the Duke of Wellington despatched Mr. Hudson to Rome to inform Sir Robert Peel that he had been called upon by King William IV. to form a ministry, it was thought a marvel that the messenger was able to complete his journey on the twelfth day after that on which he left London. Bound on an analogous mission, a Mr. Hudson of the present day would give but a poor account of his journey, if he said that he was occupied upon it even a fourth of that time. By the old roads the distance was a little under one thousand three hundred.miles. By railway, the distance over Mont Cenis passage of the Alps is one thousand three hundred and fifty-five miles. In 1834 the cost of Mr. Hudson's journey was about £250. Had he occupied eighteen days instead of twelve, and travelled by the ordinary postal conveyances of the period, he would have paid about £30. The first class fare between London and Rome now does not exceed £13.

The traveller who leaves London on any morning, let us say Monday, at half past seven o'clock, can reach Turin, seven hundred and ninety-nine miles, including a sea passage of twenty-two miles and fifty of ordinary road conveyance, across the Mont Cenis, as the chimes of the Duomo are striking the quarter before twelve on Tuesday night. When the Mont Cenis railway is open, the saving in the passage across the mountain will enable him to push on to Florence the same night; but until then he must repose at Turin until a quarter before eight the following morning. Resuming his journey, he will be in the capital of Italy, three hundred and twenty-three miles further south, at eight that evening, and he can start an hour afterwards, for the Eternal City. The distance from Florence to Rome, two hundred and thiry-three miles, can be accomplished in nine hours and twenty minutes, in which are included frontier *visa* both of luggage and of passport. After a break of four hours he may start again for Naples, one hundred and sixty-three miles further than Rome and fifteen hundred and eighteen from London, and here he arrives at 6:30 P. M. on Thursday evening, three days and eleven hours from the time he left home. When the Mont Cenis railway is completed, the time will be shortened by nearly twelve hours.

In 1834 the *Malle Poste* journey from Paris to Marseilles took eighty hours, the roadway being distance five hundred and thirty miles. In 1867 we leave Edinburgh at seven o'clock in the evening, the next evening at six we are in Paris—six hundred and ninety-seven miles—and the following day at noon we are at Marseilles. Yet Edinburgh and Marseilles are one thousand two hundred and thirty-nine miles apart—our pace, including breaks and stops, has been thirty miles an hour while traversing the whole distance; exclusive of the breaks and stops, five-and-thirty.

Roughly estimated, the number of persons who travelled by mail coaches throughout the United Kingdom in 1837, the year before the partial opening of the railways between London, Birmingham, Liverpool and Manchester, was 2,688,000. If to these be added twenty-five per cent, as representing travellers with post horses, in wagons and canal boats, we have a gross total of land and canal travellers of about 3,360,000; or an eigth of the total population of the kingdom at that time. In 1865, the latest year for which the Board of Trade returns have as yet been issued, the number of passengers carried on railways (including an allowance of one hundred journeys for each annual ticket holder), was 261,577,415, more than eight times the total population of the kingdom. The number of persons traveling on public roads to and from railways is believed to be fully as great as it was by roadway conveyances in 1837. In other words, land traveling in the United Kingdom has *de facto* increased nearly ninety fold in eight and twenty years. Comparing the population at the two periods the increase has been sixty-four fold.

In 1865, the number of third class travellers by railway, in England, was 151,416,269. There is something marvellous about the development of this third class traffic. In the seven years between 1859 and 1865, both inclusive, the yearly average increase of first class passengers was 1,494,122; of second class, 3,775,905, but the average yearly increase of the third class was 9,316,432. This increase must, however, be looked at in another way. In the four years, 1858 to 1862, its average was 4,893,310, but the increase of 1863 over 1862 was 15,617,917; of 1864 over 1863, 15,229,183; of 1865 over 1864, 15,114.688.

At the end of 1865 there were 7,414 locomotives in working order, and during that year they ran 139,527,127 miles with trains behind them. They evaporated as much water as would supply both Manchester and Liverpool with thirty gallons per inhabitant for each day in the year. In the generation of steam only they consumed about 2,625,000 tuns of coal.

The progression of the railway system of Great Britain has been as follows: On the 1st of January, 1843, 1,857 miles were open for traffic; at the same date in 1849, they had increased to 5,007 miles; on the 1st of January, 1855, there were 8,054 miles; eight years afterwards, that is, on the 1st of January, 1863, 11,551; that day twelve months they were 12,322; on the 1st of January, 1866, they were 13,289.

The latest statistics show that there are about 53,000 miles of railway in Europe. The following were the lengths open in different countries at the commencement of the present year: The United Kingdom, 13,382; France, 8,989; Prussia, 5,483; the Austrian dominions, including the non-German provinces of Austria, 4,001; Bavaria, 5,208; Saxony, 1,587; Belgium, 1,910; Italy, 3,040; Spain, 3,216; Russia, 2,893; North and South America, 37,886 (of these 32,896 belong to the United States, and about 16,000 miles are in course of construction there); India, 4,070; Australia, 669. Railways are completed for opening all over the world, at the rate of 10,000 miles per annum; thirty-five miles for each working day throughout the year.

Science Familiarly Illustrated.

HEAT AND COLD.

We present for our young readers (and it may be for older readers) a verbatim report of a familiar lecture by Prof. Tyndall on the above subject, illustrated by engravings. It is a subject of great importance and is very imperfectly understood by people generally, although of value to both old and young. The genial style in which the information is given will commend itself to all our readers:

Now, I suppose all of us twenty times a day—perhaps more—make use of the word "I." Every boy here present says, "I eat," "I drink," "I sleep," "I feel;" but perhaps very few boys or girls either ever ask themselves, "Who is this *I* that does all these things?" and if you went to the biggest man in the world, or the greatest philosopher, you would puzzle him exceedingly if you asked him "Who is this *I* that sleeps, and drinks, and eats, and feels?" In fact, philosophers, great as they may be—and great they are—find that there are things altogether beyond their power to understand, and this wonderful human *I* is one of those things. Hence, I do not want you to be able to answer me if I ask, Who is this *I*—what is this *I*—that sleeps, and drinks, and eats, and feels, and makes use of its senses? In fact, as I have said, the best of us know very little about it; but we know a great deal of that peculiar instrument by which the *I* operates upon the world, and by which it understands the things that are going on in the world, and that instrument is the wonderful human body. When we examine that body, looking into its interior parts, we find bones and muscles and tissues of various kinds; and passing through these muscles we find strings of whitish matter—strings going from the spinal marrow, and going from a mass of matter that rests in this wonderful cavity called the head. I say those strings of white matter go through the body, and they are called the *nerves*; and it is by the intervention of these nerves and this wonderful brain that we human beings are able, so to say, to hold converse with the world round about us. Now, these nerves transmit the impressions from without. If I prick my finger a nerve is affected: it is lacerated by the pricking of the pin or the penknife, and that nerve thus lacerated sends intelligence through itself up along the arm to the brain; and until it arrives at the brain you do not feel anything. It travels up to the brain at the rate of about 180 feet in a second. This is one of these wonderful things that have been measured by able men. You do not feel the exact moment your finger is pricked.

Now, what the nerves in all these cases convey to the brain is something in the nature of motion; and in order to enable you to form an idea of this motion I have arranged a little experiment. And here I must call upon that power which every boy and girl here possesses—that wonderful power which is sometimes called "imagination"—the power of picturing things before the mind. I would ask you to picture one of these nerves going through the body to the brain; and I would ask you to figure that nerve burned, we will say. Now, how are you to conceive of this nerve? The nerve is made up of very minute particles to which we give the name of "molecules" or "atoms." They are sometimes called atoms. In fact a molecule is an aggregate of atoms. But what I want you to clearly realize, and which is perfectly in your power to realize, is that these nerves are composed of little particles—(I do not care about the name, whether "atoms" or "molecules"): and if you disturb the end of any nerve—if you burn it—if you prick it—what you do there is that you impart *motion* to the body. This motion runs along the nerve, and when it reaches the brain it declares itself in some form—of pain, or, it may be, of pleasure. Now, how is this done? You may, in fact, consider those nerves to be like the telegraphic wires that go through the streets. You have seen them passing through the air of London; and these telegraphic wires carry messages to and fro through various parts of London. I say, you may consider the nerves as being represented by those telegraphic wires, and you may consider the brain a great central station, so to say, with which the nerves communicate—to which they communicate their messages, and from which they receive their messages. In order to make this plain I have here arranged a little experiment—very simple indeed. You can make it yourselves with the glass balls used in the game of solitaire. You see I have there a series of these balls, and I want to enable you by these balls to conceive how motion is propagated through the nerves. There is nothing shot through the nerves: the motion is communicated from particle to particle. Observe, here. If I take hold of this ball and strike it against the first ball of this series, you will observe what occurs. The motion will be transmitted through all the series of balls. Each ball will take up the motion given to it by the preceding one, and pass it on to its neighbor, and thus the motion will go through the entire series so that the last ball of the series will be the only one affected. Observe how the last ball is detached. There it goes away. The moment I hit this first ball the terminal ball flies off. Now, in some such way—in a way somewhat analogous to this—is motion propagated to the brain. Allow this bell to represent the brain. Now, if we take our series of balls thus, and strike, as I have said, the first ball, the blow will be communicated to the terminal ball, and that, liberated, will strike against the bell. The sound of that bell is something like a signal given in the brain. [The bell was sounded in the manner indicated.] Here you have the motion transmitted from the first ball, and finally the bell is thus affected. In the way somewhat rudely and roughly represented by this experiment the motion is transmitted to the brain, and when it reaches the brain it evidences itself, as I have said, as pleasure or pain, as the case may be.

Now, having exercised your imagination upon those particles which I have called atoms or molecules, I think we may go on to consider the character of this power that we have to deal with in this course of lectures; that is, this thing that we call "heat." Long reflection and many experiments on this important subject have caused men of science—learned men who investigate such things—to the notion that this thing that we call heat is a kind of motion. And now I should like every, even my youngest hearer (and that is a large demand) to figure, by this power of imagination, what I describe. Take any substance,—for instance, this body which I hold in my hand. This, like our nerves, is composed of little particles or atoms. It is not absolutely cold at the present time. Of course it may feel cold to my hand, but it is really not cold. Those particles that I have been speaking of are in a state of motion. Although they are too small to be seen. and although the motion is entirely too small to be seen even by our best microscopes, still we have every reason to believe that the particles of that body at the present time are vibrating. The little particles, remember—(picture them to your mind)—are vibrating to and fro; and the warmer the body is, the more intense is this motion; and, in point of fact, it is this motion of the smallest particles of the body to which, when communicated to the nerves, and through the nerves to the brain, we give the name of heat. Now, although I am dealing with some of the deepest things in science, still I expect all the boys and girls here to clearly figure to their own minds this substance as an assemblage of small particles, and those particles oscillating—vibrating; and the warmth that I feel when I take this in my hand is due to the multitude of these small motions that are going on within the body. Well, now, this motion of the particles of a body can be excited in various ways, and one of the most ordinary ways of exciting it is by friction. If you take, say a flat brass button, in your hand, and if you rub this button upon a surface of wood, as I am doing this which I hold in my hand, very soon, by rubbing this body [a short rod of metal] I make it so hot that I don't like to bear it against the skin of my face. In point of fact, the friction exerted against this substance produces the motion we call heat, and I very nearly burn myself. The rubbing throws the particles into this furious motion. If I place this body, before rubbing it, upon a flat piece of white wax, there it stands; but let me rub the end of the piece of metal for a time, thus, and then place it upon the wax, you observe it runs away; it melts the wax underneath it, and slides down in this way. This body [a similar short rod of metal] which has not been rubbed, will never melt the wax, and there it rests. The sliding of the other piece of metal is due to the heat produced by the friction. And in various other ways heat is produced by friction. For instance, if you take a saw, and pass that saw through wood, if you are careless and do not put grease upon the saw, then there is so much friction that the amount of heat developed in the saw becomes very great indeed. The saw becomes quite hot. And that is the theory and that is the reason why carpenters grease their saws when they use them. They do not want to make heat, for when this friction is overcome you actually *create* heat. Now, the carpenter is not anxious to make heat; he wants to get through the wood, and he wants to get through it with the least possible trouble; and, in consequence, he lessens the heat by putting grease upon the saw; he makes it as smooth as possible.

In this way, then, that is, by means of friction, we can actually generate, produce, create, this thing we call heat—this motion; and that is a very important point. It was thought for a long time impossible that heat could be generated. It was supposed that there was a certain quantity of heat in the universe, and that this was perfectly constant, no change occurring in it; but you see we have simply to produce this motion of the particles, and then that motion we call heat is set up. I have here an experiment that will still further illustrate this. When I was a boy—and I suppose I was like the average of boys—I was very fond of savages, and people of that kind. Now, I should like immensely to be able to transform myself into a New Zealand savage for the next five minutes. If I could do so I should be able to make a very beautiful experiment which it is not now in my power to do, for I am not so clever as those savages. My friend, Sir John Lubbock, who is a very great man on savages, has given me these two sticks. These are the genuine articles, brought from Australia. This stick is made of a particular kind of wood, pithy, and rather soft: and you see there are holes in one of the pieces of wood. This second stick is made of a harder material. Now, one of these native savages takes one stick and places the end of it in one of the holes of the other stick. He then clasps it, thus, and by the friction he uses he causes a little dust, first of all at the end. He works on until that dust takes fire; and then he manages by blowing, and by operating with far more skill than I can bring to bear upon the experiment, to actually produce flame. These are the very articles used by these New Zealand savages when they wish to produce fire by friction.

Well, I can illustrate still further this mode of producing heat. I have here, you see, a hollow tube, A, and I will place

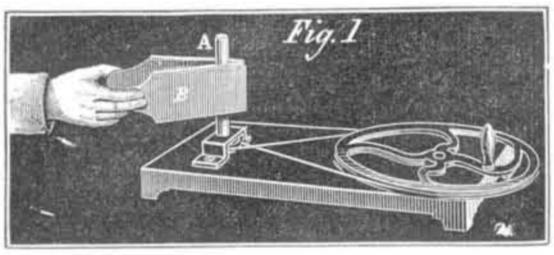
Fig. 1

in this tube a quantity of a certain liquid which boils a little more readily than water. I might take water, but I will make use of ether for the purpose of making the experiment more rapidly. Now I will try whether I can not boil that liquid by friction. You see after putting the ether into the tube I cork it up thus, and then fix the tube on this instrument which is called a whirling table, and by means of which I can cause the tube of liquid to spin round with great rapidity. The tube is now fixed firmly upon the whirling table, and we will there spin it rapidly round and round. I could boil that ether by simply clasping the tube in my naked hand. I have done so over and over again. The friction of my hand against this tube has been sufficient to boil this ether, but I have found it very hot and very unpleasant; and in order to protect my hand I will take a piece of flannel, B, and grasp the tube tightly with the flannel round it. Now, I want you to observe that if the experiment succeeds—(and experiments are always liable to fail)—the friction of the flannel against the tube which goes round and round will cause the ether to boil, and when that happens the steam of the ether underneath the cork will project the cork into the air. I want you now to observe the cork while I clasp the tube in the flannel. [In the course of a few seconds the cork flew from the mouth of the tube.] There it is, you see. Look at that!—boiled in half a minute—boiled by the friction of that piece of flannel against the tube. Well, now, I have here another tube, and I have here a quantity of metal. Look at it,—hard metal. There it is. Now, I break that metal into bits thus; and I purposely avoided putting it into this tube until now so that you might actually see the metal going in, and see that there is no delusion or mistake about the matter. Now, I will place some of this broken metal in this tube. We can put a little more in afterwards. I have put in as much as will go in now. I expect to be able to melt that metal by friction. I will cork the tube up tightly as in the former case, and when the metal is melted I will pour it out on this plate. [The rotation was commenced.] I am beginning to feel the heat now, and I have no doubt that very soon we shall have the metal in the tube molten. [Examines the contents of the tube.] Yes. I will put in more so as to get a greater quantity melted. I will pour it out presently, but you must first exercise your patience until we get it all melted. I put in as much as the cavity would hold in the first instance. Now, we will work the whirling table once more, and I will clasp it as before. [After a further interval]—Now the tube is so hot that I have no doubt the metal inside is melted. Yes, it is melted. Let us put in a last bit, and thus we shall get back the whole of that cake after it has been liquefied by the friction. I cork up the tube in order to keep the molten metal from splashing about. [The tube was caused to revolve again for a short time, and then detached from the whirling table. The metal was poured out, and found to be completely fused.]

Well, there are various other ways by which this motion that we call heat can be generated. It can be generated by percussion—by hitting with anything hard. For instance, I have here a piece of lead—a lead bullet; if I place this bullet upon an anvil, and strike it in this way, when I take it up afterward it is too hot to hold, and burns me. I have actually created that heat. I have called that heat into existence. By hitting this bullet I have thrown its particles into this peculiar vibratory motion to which we give the name of heat.

Now, how do we know the precise amount of heat produced by a stroke of this kind? I had intended to make an experiment before you in connection with this point; but you will understand the experiment without my taking up your time to perform it in your presence. Here is a piece of lead, and there I have upon the floor a thick plate of iron. I intended to send one of my assistants to the top of the house, and I intended him to drop this piece of lead down, and let it fall upon this plate of iron. Now, it so happens that the hight of this room is such that this piece of lead, having a certain amount of temperature on leaving the hand, would have that warmth augmented by one degree of temperature. I must here make use of the term "degree," although I cannot explain it till the second lecture; but you will remember that by the falling of this piece of lead from the ceiling, upon this plate of metal, we should raise the temperature of the lead one degree Fah. In like manner, if I sent up this liquid metal, which is called mercury, and had it poured out from the ceiling, and let it come down upon this plate, the mercury in falling from the top of the house to the bottom would have its temperature raised one degree. But if I took water it would be totally different. In this case I should have to go, not to a hight of 30 feet, but to a hight of 770 feet and a little more, in order that the water should have its temperature raised one degree. You will understand this difference between water and mercury and between water and lead, by-and-by. I now wish you to understand that we can tell the exact amount of heat which a shot falling from a certain hight can generate or produce; and we should find an increase of heat produced in all such cases if we had instruments of sufficient delicacy. No doubt many of you will see when you grow up that fine waterfall in Switzerland where the river Aar jumps or tumbles down a perpendicular precipice. I suppose it jumps from a vertical hight of 400 feet. Well, if you could place a thermometer at the top of that fall, and another at the bottom, the water at the bottom, if the thermometer were delicate enough, would be found warmer than the water at the top; and knowing the hight from which the cataract plunges, we can tell the exact amount of heat generated by its fall downward, through this power of percussion in developing heat.

When I was a boy instead of using percussion caps, which are now so common for firing guns, they used to employ an instrument of this kind in guns—[exhibiting an old-fashioned gun lock]. Here is a piece of steel, and this other substance is a piece of ordinary flint which you see moves forward in this way. Now, I can cock that gun lock, and then by pressing on the trigger I release the hold, and the flint falls against the steel, and you notice the sparks produced. This is a very old lock, and a very bad one; but still you see there are sparks produced when I liberate the flint, and it strikes against this steel. If we put a little powder in the pan beneath the flint we imitate what used to be the method of firing guns in former days. [The lock was then primed.] Now, you see when I let the flint strike the steel the gunpowder is exploded by the sparks produced. In the same way tobacco smokers and others used to get a light by igniting tinder by means of the sparks produced from a flint when struck on a piece of steel.

Now, what is the meaning of this experiment? What is the theory of that gun lock? It is this. You have seen that when I struck the lead I raised its temperature. A very great man who used to lecture in this room many years ago—Sir Humphry Davy—caused a lock of this kind to go off where there was no air, and when he examined the lock afterward he found that the flint had struck away little bits of the steel from the part of the lock against which it struck; and when he examined those little bits of steel he found that they had been fused; so that really the percussion of this flint against the steel surface is so strong that it raises those particles of steel which it breaks off almost to a white heat. When steel or iron is thus raised to a high temperature it is affected by a certain substance which is round about in the air. You must remember the name of that substance, it is so very important. It is called oxygen; and when iron or steel is raised to a sufficient temperature, this oxygen instantly attacks it—plunges against it. As before, I must ask you to exercise your imagination with regard to this oxygen. You must figure in your minds this oxygen as very small particles diffused throughout the air. Then, I say, when the iron or steel is raised to a high temperature the oxygen diffused through the air plunges against it, and hits it so hard that there is a kind of percussion. The oxygen hits the iron or the steel so hard as to produce this thing that we call heat, and produce it in such a degree as actually to render the body white hot. Now, I want to show you that this is the case. I have here the means of producing a flame of considerable size; and down stairs we have a pair of bellows. A man has just quitted the room to work those bellows. A current of air will pass through this tube, and we shall obtain here a flame of considerable power. Now, what I want you to understand is this—that if by means of this flame I heat particles of iron or steel, you will find that those particles of iron or steel will shoot out like stars because of the plunging upon them of the oxygen of the air. Here I have a vessel containing these iron filings, and as I throw them on the flame you see the sparks produced are very brilliant indeed. The iron is burned in this way. I have thrown in sufficient of it to illustrate what I have been saying. First of all these particles of iron were heated exactly as in the case of the gun lock; and when they were heated the oxygen of the atmosphere plunged against them, and plunged against them so violently as to produce these star-like forms which you have seen. Some call this force attraction or chemical affinity; but what I want you to see is this—that these particles of iron when heated to this temperature are showered down upon by the oxygen of the air. This wonderful substance of the air, called oxygen, forms but a small portion of the atmosphere—about one fifth of it by weight. Hence, if we had the whole atmosphere composed of oxygen those effects of combustion would be very much greater indeed than they are at present. I have here some pure oxygen obtained by proper methods, and I will just ask you to observe how much more powerfully this atmosphere of pure oxygen acts upon a body than does the oxygen in the ordinary air, where it is diluted, as I have said, to a considerable extent. I have here a piece of wood which I set fire to. I blow the flame out then, leaving the end red. You see the air has no power to make it ignite again. If I bring it into the oxygen see what occurs. [The incandescent end of the stick was introduced into a jar of oxygen gas, and immediately burst into a brilliant flame]. The oxygen when it is not diluted has this wonderful effect. And so I might take paper or other combustible bodies instead of the wood. In fact I might use iron. I will produce here a flame from a mixture of oxygen and another gas called hydrogen, and I will cause the oxygen to burn, not a piece of paper or wood, but actually a piece of steel. I hold a piece of steel here in my hand. It is the spring of a watch. A man has now gone down to start the apparatus. I shall very soon have a jet of gas passing through here. I will ignite that jet of gas, and then you will see the flame of the hydrogen—not a brilliant flame by any means. [A jet of hydrogen was then ignited]. I will presently mix with the hydrogen flame which you see a quantity of this oxygen, but I want first to raise this steel to a very high temperature, and then to allow the oxygen gas to act upon it. I will now throw into this jet of hydrogen a quantity of this wonderful oxygen. You will see that the flame becomes very much smaller; and now it is enormously hot. Observe what it can do with that piece of steel. Observe how it can burn it away. This substance called oxygen is playing upon that spring. If I take away the hydrogen you see no flame whatever, but we have only the pure cold oxygen; but when once the temperature of the steel has been raised sufficiently, the force with which the oxygen particles, or atoms as I called them, plunge down upon the steel is sufficient to produce this wonderful effect. [The watch spring continued to burn in the jet of oxygen].

Well now, we have the generation of heat exemplified in this way. I showed you first of all that it could be generated by friction to such an extent that you were able to melt metal with it. I then showed you that it was generated by ordinary mechanical percussion, as in the striking of two pieces of lead by the hammer. And now I ask your power of imagination to help me here in the case of the oxygen uniting with the iron or the steel, which is, to all intents and purposes, a case of percussion. It is, however, a case of the percussion of atoms, instead of the percussion of a hammer descending upon a weight. Now, I think that if you have followed me I have not uttered a word that you cannot perfectly understand. You can picture before your mind these little oxygen atoms showering down with this tremendous force upon the surface of the iron; and the object I have in lecturing to you, boys and girls, is that you may see with the eyes of your mind those things which are too small to be seen with the eyes of your body, and that is the power I referred to in the first instance—the power of imagination.

I have here a variety of jars of this oxygen gas. I do not want to spend too much time in operating with them, but one experiment I must make because it is of such importance and such historic interest in science. The great Sir Isaac Newton, regarding whom a great deal of nonsense and a great deal of wrong has been uttered lately in the newspapers and elsewhere, operated with a diamond in the course of his experiments on optics; and he concluded from his experiments on the diamond that that beautiful gem, the hardest of all substances, was an unctuous, peculiar substance like wax or grease. Long before the experiment was ever made, this Newton by that very power which exists in every boy and girl here present, and which I called upon in the beginning of the lecture, saw that this beautiful gem was a combustible substance; and now I want to show you that Newton was true in his prediction. I have here a small diamond—(for diamonds are very precious, as you know, and it would be a wasteful expenditure, of course, to use a large one); and I will first of all heat it by means of this very hot flame that we possess here. I have there some oxygen gas, and after heating the diamond I will plunge it into the oxygen gas, and I think you will find it will there glow like a little star. Perhaps the hydrogen cannot heat it strongly enough, but we will try it. [The heated diamond was lowered into a jar of oxygen]. Yes, there is the diamond burning before you. And now, how are you to figure that diamond? How are you to imagine the state of things going on there? At the present time it is surrounded by oxygen; and the oxygen atoms, as I have called them, are showering down upon the diamond, and showering down upon it with such percussive force as to render it that bright and brilliant star. Now, I think every boy and girl here present can picture before his and her mind what is going on. Imagine these atoms of oxygen showering down upon the diamond, and the force with which they do so raises the diamond to that temperature.

In all these cases heat is actually generated. There is called into existence heat which did not exist before. It is, as I have said, a kind of motion which can be generated in the way which I have indicated.

Having now obtained a general notion as to the methods in which heat is generated, we may pass on for a moment or two to investigate what it can do—how bodies are affected by it

I have arranged an experiment here, in the front of the table, which will enable you to see what heat can do; and here again I would call upon that wonderful power of imagination. Imagine the particles of a body getting gradually warmer, vibrating with greater and greater intensity. What is the natural consequence? That these particles should force themselves assunder, that the body should become bigger by being heated, that the volume of the body should be augmented by the augmentation of its temperature. Here I have a platinum wire stretched from this stand to this. You observe that at the end I have attached a straw with a piece of paper fastened on it. Here you observe a little wheel, and from that wheel you observe a weight descending. Round the axis of the wheel a platinum wire is coiled. Now the platinum wire is pulling in one direction, and the weight is pulling in the other direction, but if you relax the platinum wire the weight will instantly predominate and the index will rise up. Observe that index rises if I relax the wire by simply pressing this rod to which one end of it is fixed; and when I take my hand away the wire remains no longer relaxed, and the index falls back again. (A great portion of what we call "experimental science" consists of devices of this kind. This was devised by my assistant, Mr. Cottrell). But how shall I heat that wire? By a power which is far away from here, which I hope to be able to talk to you about at some future time. Coming up from the yard beneath there is a power which heats the wire; it is called an electric current. When the current comes the platinum wire will be heated and elongated, and the elongation of the wire will manifest itself on the index. You see this piece of paper smoking with the heat of the wire. If I stop the current, the source of heat is detached, and the wire cools. When the wire cools it contracts, and when it contracts the index falls in this peculiar way.

I have another experiment here to show how heat operates in causing bodies to expand. I have here two bars—one of iron and the other of brass; and at the present time you see here in front of the table a little piece of apparatus the meaning of which you will understand immediately. I will show you that this wire which you see here in front is a little coil of platinum wire But before I show you this wire I should just like to show you what a power we possess for heating the platinum wire, when we augment our current. This current comes from a battery down stairs, which I trust to have the pleasure of explaining to you, not this year, but perhaps in some future year. Now the assistant will give me a powerful current, and I think you will see that this wire will be raised to redness throughout its entire length. [The electric current was then passed through the wire.] The platinum wire is now red hot, and the index goes up in this prompt way. You will see the glow of the red-hot wire now the light is lowered. Now, if I shorten the length of wire less and less resistance is thrown in the way of the current, and a greater amount of electricity passes through, and you have the wire raised to this much greater temperature. There is one thing to be observed here. You must not allow yourselves to suppose that this apparent thickening of the wire on being heated is due to a real thickening. The red-hot wire looks as thick as a quill. This appearance, which I have no doubt is visible to you, is not due to a real thickening. It is an effect produced by a bright light on the eye. A bright body is always seen larger than it ought to be, and this particular wire now before you is seen thicker by those in more distant parts of the theater than it is by those near at hand. This proves that it is a deception of the eye—a kind of illusion called "irradiation." It is not a real thickening. [The platinum wire was still farther shortened and then parted assunder]. There, the wire is now fused by this electric current.

Now, I will call back your attention to this spiral, C, which you see here. Here on one of these supports, A B, is a piece of brass, p, and here is another, p'; and stretching across from support to support are two bars, one of brass and one of iron. At present they are not long enough to span the distance from one support to the other; but I will heat them, and then they will expand, and you will find that when they expand sufficiently to bridge this chasm from one support to another an electric current will pass, and then that spiral, C, will be like a voice telling us that the bars have expanded from one support to the other. We will now light the jets of gas underneath these bars, which at present are too short to span the distance between the supports. [After an interval]—Observe now that what I predicted a moment ago has occurred. The spiral is now ignited. If I remove this brass bar the spiral sinks. What I want to show you by this experiment is that the brass expands more than the iron. It was the expansion of the brass which bridged the chasm across.

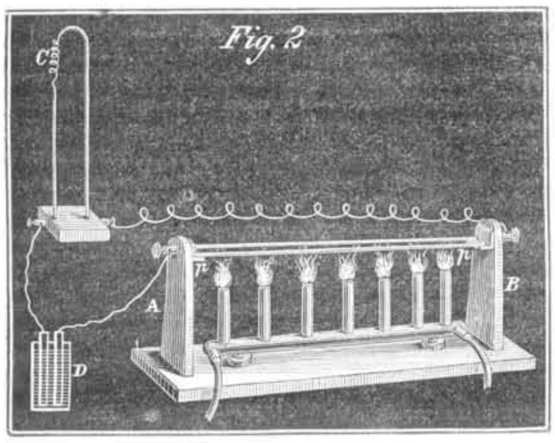
Fig. 2

I have told you that a great portion of experimental science is taken up by devices of this kind to render these small expansions evident. I think there is before you on the floor in front of the table a piece of apparatus more delicate than any that has ever yet been made. It is an apparatus intended to show, among other things, the expansion of volume by heat. You will understand this apparatus immediately by reference to this small sketch that I have drawn upon the blackboard. I have taken simply the essential parts of the apparatus, and you will understand them, I am sure, perfectly well.

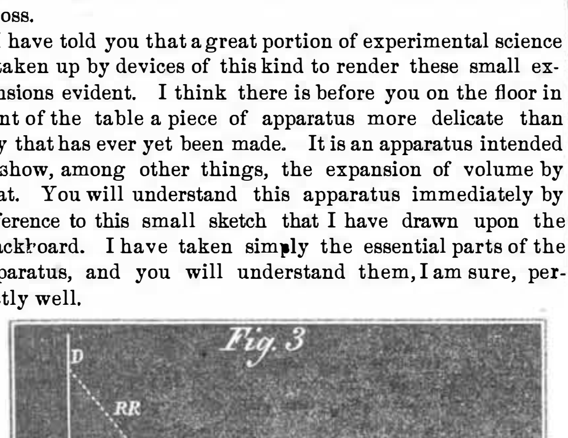
Fig. 3

The bottom part, B, of the sketch represents the upper end of that upright bar of metal which you see between those two brass pillars in the apparatus in the middle of the room. On the top of this bar rests a little brass stem, S; and the top of that stem is pointed and presses upon a very hard flat stone—a plate of agate, A. Now, conceive the top of this bar to be lifted, and to push this stem up against the plate of agate. What will occur? You see the arm, C, above the piece of agate. That arm moves upon a pivot which you see marked by a dot; a very little pushing of this arm causes it to move through a greater space than the body which pushes it. Now, attached to this arm is a piece of the hair spring of a watch, and that is carried round an axis, X, attached to which axis is a piece of looking glass—that is, a mirror, M. Upon that mirror a beam of light, R, is cast. The figure at the left of the sketch I suppose to be the front part of a lamp from which the light will issue. The beam of light will fall upon that mirror, and will be reflected upward, R R, and will mark itself as a spot of light upon the screen, D. Now, if you conceive the end of the bar to be lifted, and to push the arm upward, it will cause the axis of the mirror to turn round, and cause the mirror to take another position; and when the mirror takes another position, this beam of reflected light will travel with the mirror, and will travel with twice the velocity of the mirror. Thus, in this experiment, instead of having a straw for an index, I use a beam of light. You will understand the apparatus when I make the experiment. I think, as I have said, it is the most delicate instrument of the kind that has ever yet been made. Now I will try and get the apparatus in proper order for showing the experiment. I throw a beam of light upon the mirror, and there you see it reflected and quivering on the wall. I will bring it down so as to get it on the screen. You see it is exceedingly sensitive. That constitutes our index. And now I will ask you to observe what I am going to do. I will not touch that heavy bar of lead; I will not heat it with a flame; I will simply breathe against it; and I believe that this apparatus is so exceedingly delicate that the mere breathing against this mass of lead (and it is very large) will cause the lead to expand upward, and will bring down that spot of light from the top of the screen to the bottom. [The lecturer then breathed on the bar of lead, and the image of the beam of light gradually traveled down the screen]. The mere warmth of the breath is sufficient to produce this effect. Now I will pour upon the bar a little liquid that will chill it—make it cold; and I think you will find that as the bar cools it will contract, and that the beam of light will go back to the top of the screen. [The spot of light was successfully brought back to the upper part of the screen in the manner described.]

Correspondence.

The Editors are not responsible for the opinions expressed by their correspondents.

Mathematical Formulæ.

MESSRS. EDITORS:—I send you this communication under the impression that its publication will be an acceptable service to engineers and others, who may have occasion to make the calculations referred to. The formulæ are deduced from well-known principles of geometry by the application of algebra, and are, I believe, new and original.

When I speak of the center of the engine, the reader will understand me to mean a point in a vertical line passing through the main center of the working beam. Now, it is certain that the center of the cylinder should not be placed at a distance from the center of the engine, equal to the length of half the beam; or, in other words, under the "end center" when the beam is in a horizontal position; but should be placed under the middle point of a line representing the versed sine of half the arc, described by the "end center."

The formulæ given below will enable any one conversant with figures at all, to calculate not only the true distance from the center of the cylinder without reference to the "vibration" or versed sine, but also to calculate when the distance, as above, and stroke are given, what length of beam is required.

Let b=half the beam. d=distance from center of engine to center of cylinder. s=half the stroke.

Formula No. 1.—

$$d=\frac{b}{2}+\sqrt{\frac{b^2-s^2}{4}}$$

Formula No. 2.

$$b=\frac{s^2}{4d}+d.$$

Suppose I wish to set up an engine the beam of which is 20·8 feet, and the stroke 8 feet, what distance from the center of the engine shall the center of the cylinder be placed to work correctly? By formula No. 1. b=10·4 and b÷2=5·2, b^2=10·4^2=108·16; and 108·16—s^2 or 16=92·16. 92·16÷4=23·04, the square root of which is 4·8; hence, 5·2 plus 4·8=10 feet, equal the distance required.

Suppose an engineer takes charge of a steamer, and by measurement finds the distance from center of engine to center of cylinder is 9 feet, and the stroke 9 feet, and he wishes to find the length of a beam, which shall work correctly.

By formula 2. s=4·5 and s^2=20·25. 20·25÷4d, or 36=0·5625; and 0·5625 plus d; or 9=9·5625, the true length of half the beam.

The formulæ above, if translated into words, would be as follows: No. 1. The distance is equal to half of one half the beam, added to the square root of the quotient of one fourth the difference between the square of half the beam and the square of half the stroke.

No. 2. Half the beam is equal to the quotient of the square of half the stroke, divided by four times the given distance, added to the distance.

N. B. WEBSTER, C. E.

Kenansville, N. C.

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Slack Water Navigation.

MESSRS. EDITORS:—In your journal, No. 3, of the current volume, is an article on Slack Water Navigation, which very judiciously sets forth the many advantages to accrue from such a system properly managed. More than twenty-five years ago the State of Kentucky expended nearly $2,000,000 in a system of slack water improvements on the Kentucky and Green rivers.

The experiment, taking into account the increased value of lands, and corresponding increase of revenue from taxation, has proved the investment eminently wise, although proper frugality has not been observed in expenditures.

A private company is now preparing to lock and dam the Kentucky river for two hundred and fifty miles above the present limit of navigation. This will give constant, cheap, and safe transportation to an inexhaustible supply of coal, iron, and lumber. The experience of Kentucky fully indorses slack water improvements as useful and economical.

JOHN MASON BROWN.

Frankfort, Ky., January, 1868.

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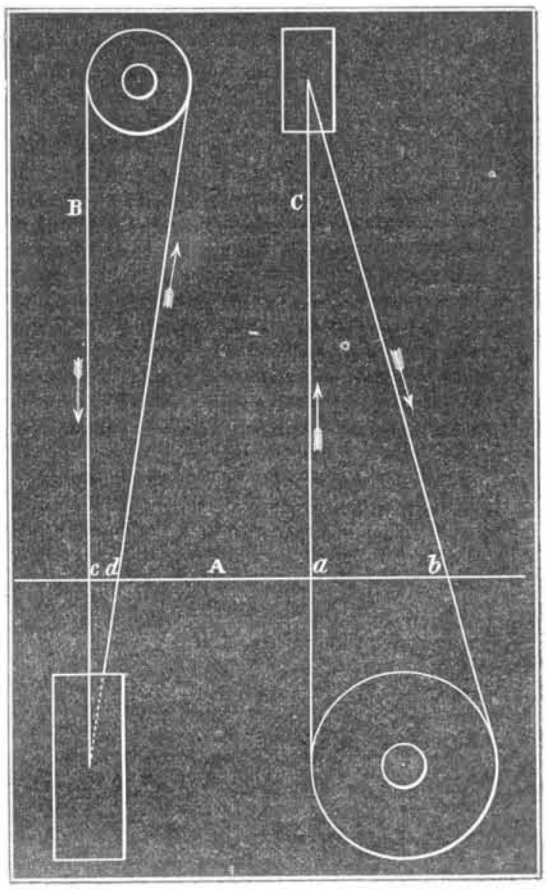
Belt Holes--Quarter Turned Belts.

MESSRS. EDITORS:—One of your correspondents asks how to lay out holes through a floor for a quarter-twist belt. The only proper method is by diagrams. Sweep a clean place on a smooth floor and set out with chalk line and "tram" two views of the pulleys and the floor, getting the distances as accurately as possible, or lay them down on paper to a suitable scale. Notice that a belt to work at quarter twist must run *on* to both pulleys in a line parallel with the plane of rotation, as B, in the diagram, running on the lower pulley, or C, running in an opposite direction on the upper one. Therefore, drop the perpendiculars, B and C, as shown, and draw the diagonals, giving the distances, a b and c d, on the floor line, A. Now drop a plumb line from each side of the upper pulley at the center of the face to the floor, and from one point so found, c, in the diagram, lay off the distance, a b, in a line parallel with the upper shaft, and from the other point, a, in the diagram, the distance, c d, parallel with the lower shaft; the points so found will be the centers of the belt holes. The twist to be given to the holes, if such a refinement is necessary, may be made a matter of judgment.



Rochester, N. Y. F. H. C.

[We have engraved and published the accompanying diagram for the purpose of illustrating a subject which seems to be somewhat puzzling to mechanics. On page 169 of Vol. XVII. we published some directions for laying out belt holes through floors, which we thought to be sufficiently explicit and plain to be easily understood without the aid of diagrams. But from a number of communications on this subject, since received, it is evident that the subject is not yet fully understood, and we publish our correspondent's diagram and description with a hope that they will make the matter plain. It is of very great importance to all mechanics, especially to millwrights, and we trust that this, with the article to which we have referred, will furnish the desired information.—EDS.

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Patentability of Medical and Surgical Improvements.

MESSRS. EDITORS:—Knowing how great an interest you take in all matters pertaining to the welfare of the inventing class, and how ably you have heretofore defended their cause, I take the liberty to bring to your notice an abuse, which is now being carried on rather extensively, and which, if allowed to continue, will seriously endanger the prospects of many of our ablest inventors. I am sorry to say that the offenders of the patent law, to which I have reference, belong to a very respectable class of society, and this makes their offence still more aggravating.

Among the medical profession, it has always been a point of honor, that all discoveries made by doctors for facilitating the cure of diseases, should be surrendered to the whole profession. It is evident that to this arrangement the rapid development and present comparative state of perfection of medical science is mainly due, as we would, if each doctor had kept his discoveries to himself, be still on the same leve with the physicians of ancient times. But this principle o mutual information and instruction seems to be misunderstood by a great number of the physicians of this country, as they appear to claim, under cover of the above principle, all the *mechanical* inventions made by their colleagues. I have