



Stories From Physics, Leo Tolstoy

## Stories From Physics

Translated by Nathan Haskell Dole 1888

### Chapter I

#### THE MAGNET

IN days of old there was a shepherd whose name was Magnis. One of Magnis's sheep went astray. He went to the mountains to search for it. He reached a spot where there were only bare rocks. As he walked over these rocks he began to be conscious that his boots were adhering to them. He felt of them with his hand; the rocks were dry, and did not stick to his hands. He started to walk on again; still his boots stuck fast.

He sat down, took off one of his boots, and holding it in his hands, began to touch the rocks with it.

When he touched them with the leather or the sole, it did not adhere; but when he touched them with the nails, then it adhered.

Magnis had a crook with an iron point. He touched the stones with the wood, it did not adhere; but when he touched it with the iron, it clung so powerfully that he had to pull it away by main force.

When Magnis examined the stone, he' saw that it was like iron, and he carried some of the pieces of rock home with him. From that time they understood this stone, and called it lodestone, or magnet.

Magnets are found in the ground, together with iron ore. The best iron is found when the ore contains lodestone.

If a piece of iron is put on the magnet, then the iron also begins to attract other pieces of iron. And if a steel needle is laid on a magnet and kept there for some time, then the needle itself becomes a magnet, and is able to attract iron to itself.

If two magnets are laid side by side, two of the ends or poles will repel each other; the other two will attract each other. If a magnetic needle be broken in two, then again each half will attract at one pole and repel

at the other. And if it be broken again, the same thing will happen; and no matter how many times it is broken, it will be always the same like poles repelling one another, unlike poles attracting one another; just as if the magnet pushed with one end and pulled with the other.

And, however often you break it, one pole will always push and the other draw.

It is exactly like a pine cone : no matter where it is broken off, one end is always convex, the other hollow. And if they are put end to end, the convex fits into the hollow; but the convex will not fit the convex, nor the cup the cup.

If a needle is magnetized by being left some time in contact with a magnet, and is balanced on a point in such a way that it will move freely on the point, then no matter in which direction the magnetic needle is turned, as soon as it is set free, it will come to rest with one pole pointing to the south, the other pointing to the north.

Before the magnet was discovered men did not dare to sail very far out on the sea. Whenever they sailed out of sight of land, then they could judge only by the sun and the stars where they were going. But if it was stormy, and the sun and stars were hid, then they had no way of telling where their course lay; and the vessel would drift before the wind, and be dashed on the rocks and go to pieces.

Until the discovery of the magnet they did not sail on the ocean far from land; but after it was discovered, then they made use of the magnetic needle balanced on the point so as to turn freely. By means of this needle they could tell in which direction they were sailing. With the magnetic needle they began to make long voyages far from land, and afterward they discovered many new countries.

There is always on board ship a magnetic needle, called the compass, and they have a measuring-line with knots, at the stern of the ship. And the cord is so constructed that it uncoils and tells how fast the vessel is sailing.

Thus it is that, when they sail a ship, they always know where they are at any given time, and whether they are far from land, and in what direction they are going.

## Chapter II

### HUMIDITY

WHY does the spider sometimes make a closely spun web and sit in the very center of its nest, and why does it sometimes come out of its nest and spin a new web ?

The spider makes its web according as the weather is at the time, and as it is going to be. By examining its web one can predict what the weather will be; if the spider hides itself away deep down in its nest and does not come out, it means rain. If it emerges from its nest and spins new threads, it means that it will be fine.

How can the spider tell in advance what the weather will be ?

Its sensibilities are so delicate that as soon as the atmosphere begins to have greater humidity, even though this humidity is not perceptible to us, and to us the weather is still clear, the spider perceives that rain is coming. Just as a man feels the dampness when he is undressed, but does not feel it when he is dressed, so the rain is perceptible to the spider when for us it is only preparing to rain.

Why is it that in winter doors swell and refuse to shut, but in summer they dry up and shrink ?

Because in autumn and winter the wood absorbs moisture like a sponge, and swells; but in summer the water evaporates and the wood shrinks.

Why does a soft wood like poplar swell more than oak, for example ?

Because in the hard wood, in the oak, there are less empty spaces, and less room for the water to sink in; while in the soft wood, in the poplar, there are more empty spaces and more room for the water. In decaying wood there is still more room and therefore decayed wood swells more than any other kind and sinks sooner.

Beehives are made of the softest wood or of rotten wood; the best hives are made of rotten willow. Why ? Because the air penetrates the rotten stump, and bees like the air in this kind of a hive.

Why do boards warp ?

Because they dry unevenly. If you put a damp board into an oven, the water exudes from one side, and the board gets dry on that side and makes the other side yield to it. It is impossible to shrink the damp side because there is water in it and the whole board bends.

In order to keep floors from warping, they cut out pieces of dry wood and plunge them into boiling water. When the water has been wholly boiled away the pieces are glued together and will not warp, and this kind of inlaid floor is called parquet.

### Chapter III

#### DIFFERENT DEGREES OF COHERENCE

WHY is it that the bolsters under a wagon are made of oak while the naves of the wheels are turned out of birch ?

It is necessary to have the bolsters and naves strong, but oak is not more expensive than birch. It is because oak splits lengthwise, while birch\* is not easily split, but is made of tough filaments.

Accordingly, though oak has a closer texture than birch, it is so constituted that it splits, while birch is not easily split.

Why are the rims of the wheels and the bounds bent from oak or elm, but never out of birch or linden ?

Because oak and elm, when soaked and softened, become elastic and do not break, while birch and linden splinter on all sides.

All this is due to the fact that the coherence of Parti-cles in oak and birch wood differs in degree.

### Chapter IV

#### CRYSTALS

IF salt is stirred up in water the Particles of the salt are diffused through it and become invisible, but if more and more salt is added then at last the salt ceases to dissolve, and, however much you stir it, the salt remains like a white powder at the bottom. The water had dissolved the salt to the point of saturation and could take no more. But if the water be heated it will dissolve more; and the salt which refused to melt in the cold water will dissolve away. But if still more salt be added, then not even boiling water will dissolve it. Now, if you still continue to boil the water, the water itself will evaporate in the form of steam, and the salt will be left.

So it is of everything which water dissolves : the water has a limit beyond which it cease\* to dissolve sub-stances. Everything is more readily dissolved by hot water than by cold water; but, nevertheless, when the hot water is saturated, it ceases to dissolve any more. The substance remains unchanged but the water may pass off as steam.

If powdered saltpeter is dissolved in water and then more saltpeter is added, and if the whole is heated and allowed to cool without being stirred, then the super-fluous saltpeter will not settle on the bottom in the form of a powder, but will form in clustering hexagonal prisms on the bottom and on the sides. If powdered saltpeter is dissolved in water and then put in a warm place, then the water will evaporate and the residuum of saltpeter will be precipitated in the form of hexagonal crystals.

If common salt is dissolved in water and the water is heated and allowed to evaporate, then the residuum of salt is precipitated also, not in the form of a powder, but in cubes. If saltpeter and salt are dissolved together, the residuum of the two substances do not combine, but each is precipitated in its own form : the salt-peter in prisms, the salt in cubes.

If lime or any other salt or any other substance is dissolved in water and the water is evaporated, each substance is precipitated in its own peculiar way : one in triangular prisms, another in octagonal, another in brick-like forms, another in stars each in its own way. These figures are

different in all solid substances. Sometimes they are large and are found like stones in the ground; sometimes they are so small that they are invisible to the naked eye; but still each substance has its own form.

If, when water is saturated with saltpeter and the figures begin to form, the edges of the figure are broken with a needle, then again in the same place there will be deposited new atoms of the saltpeter, and the broken edge will be repaired just exactly in its own proper form in hexagonal prisms. It is the same with salt and with everything else. All the infinitesimal atoms move and take their places where they are needed.

When water becomes ice, the same phenomenon takes place. A snowflake comes flying down; no figure can be seen in it. But as soon as it lights on anything moist and cold, on a pane of glass, or on fur, its form may be discerned. You can see a little star or a little plate. On the window-panes the vapor does not freeze at haphazard, but as soon as it begins to freeze it instantly branches out into star shapes.

What is ice ? It is cold solid water. When water turns from a liquid to a solid it forms figures and liberates heat. The same thing takes place with salt-peter when it changes from a liquid to a solid form : heat is liberated. The same with salt, the same with cast-iron, when it cools down from its melted to its solid form.

When anything turns from a liquid to a solid, it liberates heat and begins to form crystals. But when it changes from a solid to a liquid then it absorbs heat; its coldness disappears and its crystals melt.

Take melted iron and let it cool; take hot dough and let it cool; take slaked lime and let it cool heat is produced. Take ice and melt it cold is produced. Take saltpeter, salt, or anything else which is soluble, and put it into water cold is produced. So that when you want to make ice-cream, you melt salt and water.

Chapter V

BAD AIR

ONE festive day, at the village of Nikolskoye, the people had gone to mass. On the estate 1 were left the cattle-woman, the village elder, 2 and the hostler.

The cattle-woman went to the well after water. The well was in the yard itself. She was drawing up the bucket, but failed to hold it. The bucket slipped from her, struck against the side of the well, and broke the rope.

The cattle-woman returned to her cottage, and said to the elder :

“ Aleksandr, come, little father, to the well; I have dropped the bucket”

Aleksandr replied :

“ You dropped it, and you must get it out.”

The cattle-woman replied that she was going to climb down into the well, only she wanted him to hold her.

The elder said :

“Very well, then; let us go; you have been fasting lately, so I can hold you; but if you had had dinner, it would be impossible.”

The elder fastened a stake to the rope, and the woman sat astride of it, clinging to the rope, and she began to descend into the well, and the elder unwound the rope by means of the windlass. The well was about fourteen feet 1 deep, and there was a third of a fathom of water in it.

The elder kept turning back the windlass slowly, and shouting to the woman :

“ Is that enough ? “

And the cattle-woman kept crying :

“Just a little more.”

Suddenly the elder felt the rope slacken; he shouted to the woman, but she gave no answer. The elder looked down into the well, and saw that the woman was lying with her head in the water and her feet in the air.

The elder began to shout and call the people, but there was no one to come. Only the hostler came running.



The elder bade him hold the windlass, and he himself pulled up the rope, got astride of the stake, and de-scended into the well.

As soon as the hostler let the elder down to the water's edge, the same thing happened. He let go of the rope, and fell head-first down on the cattle-woman.

The hostler began to cry for help; then he ran to the church for the people. Mass was over, and the people were returning from church. All the peasant men and women hastened to the well. They all stood around the curb, and each offered advice, but no one knew what to do.

A young carpenter forced his way through the throng, up to the well, seized the rope, sat on the stake, and told them to let him down. But Ivan took the precaution to fasten the rope to his waist. Two men let him down, and all the rest looked into the well to see what would happen to Ivan.

As soon as he reached the level of the water, he let go of the rope with his hands, and would have fallen in head-first, but for the fact of the girdle holding him.

All cried :

“Pull him back!”

And they lifted Ivan to the top.

He hung on the rope like a dead weight. His head hung down and thumped against the edge of the well.

His face was bluish purple. They seized him, un-fastened the rope, and laid him on the ground. They thought that he was dead; but he suddenly drew a deep sigh, began to clear his throat, and came to.

Then still others proposed to go down; but an old peasant said that it was impossible to go down into the well, for there was bad air in it, and this bad air was death to men.

Then the men ran to get gaffs, and they attempted to hook up the elder and the woman. The elder's wife and mother were shrieking near the well; the others were trying to calm them.

Then the peasants brought the gaffs to the well, and began to grapple for the two victims. Twice they lifted the elder, by means of his clothes,

halfway up the well, to the well-curb; but he was heavy, his clothes tore, and he fell back. At last they hooked him with two gaffs and brought him to the surface. Then they brought up the cattle-woman in the same way.

Both were stone dead, and could not be brought to life.

Then, when an investigation of the well was made, they found that the bottom of the well was full of bad air.

This sort of air is so heavy, that no man can live in it nor any living thing exist in it.

They let a cat down into the well, and as soon as it reached the place where the bad air was, it immediately died.

Not only can no living thing live in it, but a candle cannot burn in it.

They let down a candle, and as soon as it reached the same place, it was immediately extinguished.

There are places under the earth where this bad air accumulates; and if you should go into them, you would immediately perish. Hence in mines they have lamps, and before a man goes into such a place they let a lamp down first.

If the lamp goes out, then it is impossible for a man to enter. So they send down a supply of fresh air until the lamp will burn. Near the city of Naples there is such a grotto. In it the bad air always stands to a height of an arshin I above the ground, and above that the air is pure. A man can walk through this grotto and receive no harm; but as soon as a dog enters, he chokes to death.

Whence comes this bad air ?

It is made out of the same good air which we breathe. If many people are collected in one room, and all the doors and windows are shut so that no fresh air can get in, then the atmosphere becomes the same as in the well, and the people perish.

A hundred years ago the Hindus shut one hundred and forty-six Englishmen into a dungeon, and locked them up in an underground hole, where the air could not get to them.

The imprisoned Englishmen, after they had been there a few hours, began to choke, and at the end of the night one hundred and twenty-three of them were dead, and the rest were taken out barely alive, and ill.

At first the air had been pure in the dungeon; but when the prisoners had breathed up all the good air, and it was impossible to get any fresh supply, it became bad, like that in the well, and they died.

How is it that bad air is made out of good air, when many people are together ?

Because when people breathe, the good air is taken into the lungs, and breathed out as bad air.

## Chapter VI

### HOW AIR BALLOONS ARE MADE

IF you take an inflated bladder and immerse it in water and then let go of it, the bladder rises to the top and begins to float. In exactly the same way if you boil water in a kettle, you will see on the bottom, over the fire, how the water becomes volatile, becomes a gas; and when a little of this aqueous gas collects it immediately rises to the top in the form of bubbles. First, one bubble flies up, then another, and when the water is thoroughly heated, then the bubbles rise unceasingly; then the water boils.

Just exactly as the bubbles filled with steam fly up to the top because they are lighter than water so up through the atmosphere will rise a balloon inflated with hydrogen gas or with heated air, because heated air is lighter than cold air, and hydrogen is the lightest of all gases.

Air balloons are made of hydrogen or of heated air. This is the way they are made of hydrogen. A large bag is made and attached by ropes to stakes, and then it is filled with hydrogen gas. As soon as the ropes are cut, the balloon rises and floats until it escapes from the atmosphere that is heavier than hydrogen. But when it reaches a rarer Part of the

atmosphere, the balloon stops rising and then it floats along like a bubble on the top of the water.

Balloons are made of heated air in this manner: a large empty bag is made with a wide mouth below like a pitcher upside down, and in the mouth is placed a bunch of cotton which is soaked with ether and then set on fire. The air in the balloon is heated by the fire and becomes lighter than the cold air outside, and the balloon rises like a bubble in water, and it floats up in the air until it reaches atmosphere so rare as to be lighter than the heated air.

Almost a century ago some Frenchmen the Mont-golfier brothers 1 invented the hot air balloon. They made a bag of cloth and paper and filled it with hot air; it floated. Then they made another still larger, attached a ram, a cock, and a duck to it and sent it up. The balloon ascended and returned successfully. Then they attached a small boat to it, and a man took his place in the boat. The balloon went up so high that it was lost to sight; it floated off and then came down without injury. Then they invented the method of inflating balloons with hydrogen, and they kept going higher and more rapidly.

In order to make a balloon ascension a basket is attached to the bag, and two, three, and even as many as eight men accommodate themselves in it, taking with them food and drink.

In order to regulate the movements of the balloon up and down at will, a valve is constructed in the balloon, and the aeronaut 2 can open it or shut it at his own pleasure. If the balloon rises too high, and the aeronaut wishes to descend, he opens the valve, the gas escapes, the balloon contracts, and begins to sink. Moreover, he always carries bags of sand. If a bag is thrown out, the balloon becomes lighter, and it rises. If the aero-naut wishes to come down, and sees that it is not a fit place for landing, on account of a river or a forest, then he empties out some sand, and the balloon becomes lighter and rises again.

## Chapter VII

### GALVANISM

ONCE there was a learned Italian named Galvani. He had an electrical machine and he was showing his pupils what electricity was. He rubbed glass vigorously with oiled silk, and then he approached to the glass a copper knob with a glass handle, and instantly a spark leaped from the glass to the copper knob. He told them that a similar spark would be elicited by sealing-wax and am-ber. He showed how feathers and pieces of paper are sometimes attracted by electricity, sometimes repelled, and why this is. He performed many different experi-ments with electricity and showed them to his pupils.

Once it happened that his wife was taken ill. He summoned the doctor and asked him how to cure her. The doctor ordered him to have made for her a frog soup. Galvani sent out to get some edible frogs. They were caught, killed, and laid on the table.

The cook did not come to get the frogs, and Galvani went on to show his pupils his experiment with the electrical machine, and produced sparks.

Suddenly he noticed that the dead frogs lying on the table moved their legs. He began to study them and discovered that each time he elicited a spark from the electrical machine the frogs kicked.

Galvani procured some more frogs and began a series of experiments. Each time it proved that whenever he produced a spark the dead frogs acted as if they were alive. And so it occurred to Galvani that living frogs might move their legs from this cause, that electricity might pass through them.

But Galvani knew that electricity is in the atmos-phere; that while it is more noticeable in sealing-wax, amber, and glass, still it is in the air, and that thunder and lightning are produced by atmospheric electricity.

So he began to make experiments whether dead frogs would move their legs 'under the influence of atmospheric electricity. For this purpose he took some frogs, skinned them, cut off their heads and fore paws, and attached them by copper hooks to the roof, under an iron gutter. He thought that if a thunder-shower came up and the

atmosphere was full of electricity, then the electricity would be brought to the frogs through the copper wire, and they would begin to kick.

But though several thunder-showers came up, the frogs did not move. Galvani proceeded to take them down, and while he was doing so, he touched the leg of one of the frogs to the gutter and the leg kicked ! Galvani then took the frogs and began to make the following experiment : he attached iron wire to the copper hook and then touched the frog's leg with the wire the leg kicked.

Here Galvani came to the conclusion that all animals are alive only because they have electricity in them, and that electricity leaps from the brain into the flesh and thus animals move.

No one had at that time gone very thoroughly into the study of this matter, and as nothing was known about it, every one put faith in Galvani's explanation.

But about this time another scientist, Volta, began to experiment for himself, and proved conclusively that Galvani was mistaken. He tried touching the frogs, not as Galvani had done with a copper hook and an iron wire, but first with a copper hook and a copper wire and then with an iron hook and an iron wire and the frogs did not stir. They moved only when Volta touched them with an iron wire attached to copper.

So Volta came to the conclusion that the electricity was not in the dead frog, but in the iron and copper. He continued to make his tests, and this was the result : As soon as he placed iron and copper together, electricity was produced, and the electricity caused the dead frogs to kick. Then Volta began to try how to make electricity in a different way from what had been done before. He tried putting together various metals like the iron and copper, and he reached the conclusion that only from the contact of such metals as silver, platinum, zinc, tin, iron, he could produce electric sparks.

After Volta, new methods were invented for getting a stronger current of electricity by putting the metals into various liquids, water, and acids. By the use of these liquids electricity acquired so much more energy that it was no longer necessary to rub, as had been done be-

fore; all that was required was to place in a single dish pieces of different metals and pour on them the liquid, and electricity would be created and sparks would be elicited.

As soon as this kind of electricity was discovered, methods were invented for putting it to use; they could cover objects with gold and silver by means of electricity, and by means of electricity they could transmit signals from one distant place to another.

To do this, pieces of different metals are placed in glass jars, and liquids are poured over them. The electricity is produced in these jars, and this electricity is conveyed by means of a wire to any desired place, and from that place is led into the earth. The electricity in the earth runs back again to the jars and is conducted into them by means of another wire. Thus this electricity keeps going in a circuit, as in a ring by the wire to the earth and back by the earth and again by the wire and again by the earth. Electricity can go in either direction, according as you may wish : it may go first by the wire and return by the earth, or go first by the earth and return by the wire.

Over the wire, in the place where the signals are given, is placed a magnetic needle, and this needle points in one direction if the electric current comes by the wire and returns by the earth, and in the other if the electric current comes by the earth and returns by the wire. By this needle signals are given, and by means of these signals telegraphic messages are sent from one place to another.

## Chapter VIII

### SOLAR HEAT

ON a clear, frosty day in winter, if you happen to be in a field or in the forest, and look around you and listen, you see the snow everywhere, the rivers are frozen across, the dry grass sticks out from the snow, the trees stand bare; there is not a sound.

Then look in the summer : the rivers are running and murmuring; in every little pond the frogs are calling and croaking; the birds are flying about and singing and whistling; flies and gnats are humming and buzzing; the trees and the grass are growing and waving. Freeze a kettle of water, it grows as hard as stone. Place the frozen kettle on the fire; the ice begins to crack, to melt, to move. The water begins to tremble and to send up bubbles; then when it begins to boil, it tosses and is agitated. The same phenomenon happens all over the world by the action of heat. When there is no heat, everything is dead. When there is heat, everything lives and moves. Little heat little motion; more heat more motion; much heat much motion; great heat great motion.

Whence comes the heat to the world ?

It comes from the sun.

In winter the sun runs low, its rays do not warm the earth, and nothing stirs. The little sun begins to go higher above our heads; it begins to send its light down directly on the earth everything grows warm, and life and motion increase.

The snow begins to melt, the ice on the rivers begins to break up, the brooks come leaping down from the hills, the vapor from the waters rises into the sky and becomes clouds, and the showers fall.

What does all this ?

The sun.

Seeds are sown, the germs sprout, the roots catch hold of the soil, from the old roots new runners strike out; the trees and grasses begin to grow.

What does all this ?

The sun.

The moles and bears come out of their lairs, flies and bees grow lively, gnats abound, fishes come out from their eggs into the warmth.

What does all that ?

The sun.

In one place the air grows warm, begins to rise, and into its place flows a colder air there is a wind.

What does that ?



The sun.

The clouds come up, they roll up and they separate, then there is lightning.

What makes those flashes ?

The sun.

Herbs, grain, fruits, trees grow. Animals feed on them, human beings make their sustenance of them, and store them up for fodder and fuel against the winter; men build houses, railways, and cities.

What furnishes the material ?

The sun.

A man builds himself a house. What does he make it out of? Of lumber.

The lumber is sawed out of trees, the sun made the trees grow.

You heat a stove with fuel.

What produced the fuel ?

The sun.

A man eats bread and potatoes.

What produced them ?

The sun.

A man eats meat. What fed the animals, the birds ? Grass, but the sun produced the grass. A man builds a stone house with brick and mortar. The brick and mortar were burnt with fuel. The sun produced the fuel.

Everything needed by man, everything that comes directly into use, is due to the sun, and much of the sun's heat goes into everything. Grain is necessary to all men because the sun makes it grow and there is much solar heat stored away in it. Grain warms who-ever eats it.

Fuel and lumber are useful because there is much heat in them.

Whoever buys fuel for winter's use, buys solar heat. And in winter you can burn your fuel when-ever you please and liberate the solar heat into your room.

And when there is heat there is also motion. What-ever motion there is, it all comes from heat either di-rectly from the sun's heat or from heat stored away by the sun in coal, in firewood, in grain, and in grass. Horses and cattle draw loads, men work; what moves them ? Heat. But whence comes the heat ? From food. But the food was produced by the sun.

Water-mills and windmills are set in motion and grind. What moves them ? Wind and water. But what drives the wind ? Heat. And what drives the water? Heat, to be sure. It raises the water in the form of vapor into the sky, and if it were not for heat the water would not fall.

A machine does work. Steam moves it. What makes the steam ? Fuel; and in the fuel is the sun's heat.

Out of heat comes motion, and out of motion comes heat. And both the heat and the motion are due to the sun.

The End