great attractive power for iron on being connected with a galvanic battery, and as instantly divested of it when the connection is severed. It may thus be made to impart motion to an iron rod, and through it to various kinds of machinery. So strong at one time was the impression that the enormous attractive power of the electro-magnet could be advantageously used as a mechanical agent, that the United States government appropriated $20,000, and Russia $120,000, for experiments on the subject; and various machines were contrived in which it was used as a motive power. In none, however, thus far invented, has it been found to approach steam in efficiency or economy.

A boat 28 feet long with a dozen persons on board has been propelled against the current at the rate of three miles an hour by electro-magnetic action. A locomotive engine has also been driven from ten to twelve miles an hour. But this is the utmost that has been effected, and in both cases the cost of keeping the galvanic battery in operation was much greater than that of producing an equivalent quantity of steam. The difficulty appears to be twofold. First, the attractive power of the magnet rapidly diminishes as the distance from it increases. Secondly, electric currents opposite in direction to the primary one are excited in the moving machinery; which, increasing in power with its velocity, nullify much of the effect of the magnet. Until these difficulties are removed, electro-magnetism can not be advantageously used as a mechanical agent.

915. THE ELECTRO-MAGNETIC TELEGRAPH.—Although unavailable as a motive power, electro-magnetism has been turned to practical account in the Telegraph, one of the crowning triumphs of human ingenuity. For this great invention as at present perfected, which enables us, almost with the rapidity of thought, to communicate with distant points, over miles of intervening land or sea, the world is chiefly indebted to an American—Samuel F. B. Morse.

916. *Morse's Telegraph.*—The principles on which Morse's Telegraph operates are as follows:—

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bar? Describe the process. 914. On what principle may an electro-magnet be made to impart motion to an iron rod? For what were appropriations made by the United States government and Russia? What has been effected with machinery moved by electro-magnetism? How does the expense compare with that of steam? What difficulties interfere with the usefulness of electro-magnetism as a motive power? 915. In what has electro-magnetism been turned to practical account? To whom is

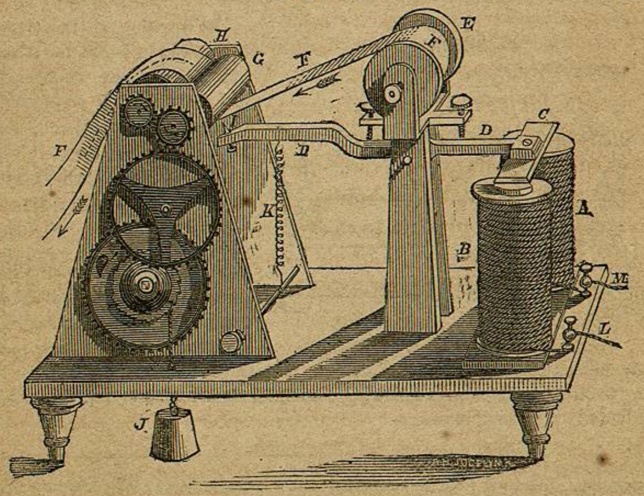
1. An electro-magnet may be alternately endowed with and deprived of the property of attracting iron by connecting and disconnecting it with a galvanic battery.

2. The battery may be miles away from the magnet. If wires connect the two, the electric current will still be carried to the helix and produce the same effects.

3. A person stationed near the battery may complete and break the circuit at pleasure. As he does so, one end of a lever placed near the poles of the distant magnet will be attracted or released. When it is attracted, the other end of the lever, which is furnished with a point, is made to indent a strip of paper passed in front of it by machinery, with dots or dashes, according to the time that the operator by the battery keeps the circuit complete. If, now, different combinations of dots and dashes are agreed upon to represent certain letters, it is evident that a message can be communicated from the one point to the other.

Fig. 326 represents Morse's recording apparatus.

Fig. 326.



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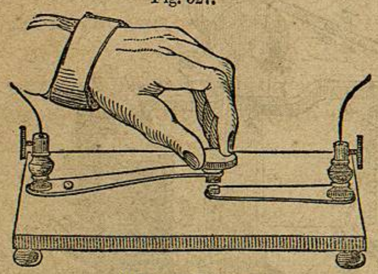
the world chiefly indebted for the Telegraph? 916. State the principles on which Morse's Telegraph operates. Describe Morse's recording apparatus, and its mode of

A B is the electro-magnet, connected with the distant battery by the wires L, M, which are raised on poles and insulated by glass supports. C is an armature of soft iron attached to one end of the lever D D, so as to rest about one-eighth of an inch above the poles of the magnet. The other end of the lever carries a point or style, I, which is raised as C is depressed. A strip of paper, F, F, rolled on the spool E, is made to pass in front of the style, between the two cylinders G, H, by means of wheel-work set in motion by the weight J when the current passes. K is a spring, to pull down the end of the lever bearing the style when the other end is released by the magnet. A striking apparatus was formerly connected with the machinery in such a way as to give warning to the attendant with the first motion of the lever; but it is now generally dispensed with, as the clicking sound produced by the lever is found to be sufficient for the purpose.

Instead of carrying both wires over poles from the electro-magnet to the battery, the earth is now generally made to form one-half the circuit. This is effected by carrying down the wire from the magnet, and connecting it with a metallic plate buried in the ground; a similar plate must be buried where the battery is stationed, and a wire from the latter connected with it. If this is done, but one wire need pass over the poles to complete the circuit.

917. The apparatus used by the operator where the battery is stationed, to complete and break the circuit, is called the Signal Key. It is represented in Fig. 327.

Fig. 327.



THE SIGNAL KEY.

By pressing on the knob, the screws in which the wires are fastened are connected, and the circuit is completed. On removing the hand, the knob springs up, the circuit is broken, and the current ceases. If the knob is kept pressed down, the paper at the other end is indented with a continuous line; but by tapping on it so as to form different combinations of dots and dashes, which stand for letters, and are understood at both ends of the line, a message is transmitted. According to Morse's system, the following combinations are used to represent the different letters and figures:—

operation. What was formerly connected with the machinery? Why is it now dispensed with? Instead of carrying both wires over poles from the electro-magnet to the battery, what is now the more usual arrangement? How is the earth made to form half of the circuit? 917. What is the Signal Key? Describe it, and its mode

LETTERS.			FIGURES.
a - —	*j* — - — -	*s* - - -	1 - — — -
b — - - -	*k* — - —	*t* —	2 - - — - -
c - - -	*l* ——	*u* - - —	3 - - - — -
d — - -	*m* — —	*v* - - - —	4 - - - - —
e -	*n* — -	*w* - — —	5 — — —
f - — -	*o* - -	*x* - — - -	6 - - - - - -
g — — -	*p* - - - - -	*y* - - - -	7 — — - -
h - - - -	*q* - - — -	*z* - - - -	8 — - - - -
i - -	*r* - - -	*&* - - - -	9 — - - —
			0 ——

To prevent confusion, a small space is left after each letter, a longer one between words, and a still longer one at the end of a sentence. The operators in telegraph offices become so familiar with this alphabet that they understand a message from the mere clicks of the lever, without looking at the paper on which it is recorded.

918. An electric current is transmitted by a wire to a great distance, but not with undiminished power. When, therefore, the stations are very far apart, the electro-magnet is charged too feebly to make the style indent the paper. In this case, the wire from the original battery is made to act on a very delicate armature, so as to complete the circuit of a second battery placed near the machine. This Relay Battery, as it is called, acts on the recording apparatus as described above, or transmits a fresh and vigorous current to another relay battery. In this way lines of any length may be formed.

As relay batteries do not interrupt the circuit, any number of them may be placed at intervals along a line. Each may work a recording apparatus of its own, and a given communication may thus be registered simultaneously at a multitude of different stations.

Relay batteries may be dispensed with by increasing the number of plates employed and distributing them in groups along the line. It has been computed that if a telegraph wire could be carried round the earth, 1200 of Grove's pint cups, distributed in equi-distant groups of fifties, would supply the galvanic power for the whole distance.

of operation. How are the different letters represented? 918. What difficulty is there when the current is transmitted to a great distance? How is this remedied? How does the Relay Battery act? How may a given message be registered simultaneously at different stations? What may be substituted for relay batteries? How many cups would supply the galvanic power for a telegraph round the earth?

919. *House's and Bain's Telegraph.*—Morse's apparatus, having been first introduced and being very simple and not likely to get out of order, is more used than any other, both in this country and in Europe. There are other ingenious systems, however, which are employed to some extent. Among these are House's Printing Telegraph and Bain's Electro-chemical Telegraph.

House's apparatus is one of the most wonderful achievements of inventive art. Making use of the electro-magnet in connection with ingenious and somewhat intricate machinery, it enables the operator, by playing on twenty-eight keys like those of a piano (representing the twenty-six letters and two punctuation points), to print ordinary letters on a strip of paper at the other end of the line at the rate of about two hundred a minute. The great advantages of House's system are that there is little or no liability to mistake in transmitting a message, and that the latter, being produced in Roman capitals, need not be transcribed, but may be sent just as it comes from the machine to the person for whom it is intended.

In Bain's Electro-chemical Telegraph no magnet is used. The point of the wire, which is stationary, constitutes the pen, and rests lightly on a metallic plate, which is made to revolve by machinery. On this plate is placed paper which has been previously moistened with some chemical preparation decomposable by voltaic electricity. When the connection is made by the distant operator, the current passes from the wire to the plate through the paper, and in passing decomposes the chemical compound with which the paper is impregnated. The result is a deep blue spot on the paper, which renders the dot or dash visible, just as the indentation does according to Morse's system. As even a feeble voltaic current has the power of decomposition, there is not the same necessity for relay batteries on Bain's line as on either of the others.

920. *Submarine Telegraphs.*—Submarine Telegraphs are telegraphs connecting points separated by water, in which the wire is submerged. The first successful telegraph of this kind was laid in 1851 across the English Channel, and connected Dover with the French coast. This was followed by several others; and in 1858, after several unsuccessful attempts, a telegraph cable nearly 2,000 miles in length was laid across the Atlantic Ocean, between Valentia Bay, Ireland, and Trinity Bay on the coast of Newfoundland. It consisted of a group of seven copper wires insulated and protected by a casing of gutta-percha, the whole surrounded by strands of iron wire, and sunk to the bottom of the ocean, at a depth nowhere exceeding $2\frac{1}{2}$ miles.

Public interest was strongly excited in this great enterprise; but it has thus far been doomed to disappointment. After transmitting several messages, the Atlantic Telegraph, for some unexplained reason, ceased to work, though signals have from time to time been received. There is little doubt, however, that the work is feasible, and that we shall soon have regular telegraphic communication between the opposite sides of the Atlantic.

919. What other telegraph systems besides Morse's are in use? What is said of House's apparatus? What are its great advantages? What is the principle involved in Bain's Electro-chemical Telegraph? What advantage is there connected with this system? 920. What are Submarine Telegraphs? Where and when was the first submarine telegraph laid? In 1858 what great enterprise was carried through? Describe the Atlantic cable. What is said of the working of the Atlantic telegraph? 921. What fact relating to frictional electricity was known more than a hundred years ago? What experiment was performed by Franklin in 1748? Who made the first attempt to transmit a message by electricity? Describe the plan of Le Sage. 922. By what was the discovery of voltaic electricity followed? What suggestions were called

921. *History of the Telegraph.*—The fact that frictional electricity could be conveyed by wires to a great distance was known more than a hundred years ago. Franklin, in 1748, set fire to alcohol by means of a wire from an electrical machine carried across the Schuylkill River. The first attempt to transmit a communication by electricity, however, was made in 1774 by Le Sage [*luh sahzh*], a Frenchman, at Geneva.

Le Sage used twenty-four wires insulated in glass tubes buried in the earth, each of which represented a letter of the French alphabet. The wires were connected with an electrical machine in the order necessary to spell out the words, and electroscopes attached to them at the other end indicated this order by their successive divergence to an attendant stationed there.

922. Volta's discovery in 1800 furnished a far more efficient agent for telegraphic communication than frictional electricity, and was followed in a few years by a plan for an electro-chemical telegraph, requiring thirty-five wires, to represent the different letters and figures, and to act by the decomposition of water.

The great discovery of electro-magnetism in 1819 called forth many new suggestions,—among others, the use of the deflections of the needle as signals; but none of the plans proposed were practicable on a large scale. A more permanent galvanic power was needed; and this was not supplied till 1836, when Daniell brought out his constant battery. The appearance of this battery and the improved electro-magnets prepared by Prof. Henry, was followed in 1837 by the invention of apparatus for transmitting and recording communications, by Samuel F. B. Morse, who had been experimenting on the subject for five years. Application was at once made to the Congress of the United States for aid to construct a line of sufficient length to test the invention; and after discouraging delays, in 1843, the sum of $30,000 was appropriated by that body, with which a line was established between Baltimore and Washington, a distance of forty miles. The enterprise was crowned with complete success; and the first news transmitted was the proceedings of the democratic convention of 1844, then sitting in Baltimore, by which James K. Polk was nominated for the presidency.

So manifold were the advantages of telegraphic communication, that immediately on the announcement of Morse's success companies were formed, and wires were soon seen threading the country in all directions. The various lines now in operation in the United States and British Provinces make a total of about 45,000 miles, on nine-tenths of which Morse's apparatus is used, House's and Bain's being chiefly employed on the remainder. With Morse's instruments about 9,000 letters may be transmitted in an hour. The construction of the line costs not far from $150 a mile.

The same year in which Morse perfected his invention (1837), plans for telegraphic communication based on the deflections of the needle were announced by Wheatstone in England, and Steinheil [*stine'-hile*], a German philosopher, to whom the discovery that the earth could be made to complete the circuit seems to be due. They are therefore sometimes mentioned as entitled to share with Morse the honor of his great invention. Their systems, however, were but modifications of what had been proposed some years before; though practicable, they could not compete in rapidity of operation with Morse's, and consequently never came into general use.

923. ELECTRO-MAGNETIC CLOCKS.—American ingenuity

forth by the discovery of electro-magnetism? By whom and when was the first perfect apparatus for transmitting and recording communications invented? What two improvements prepared the way for Morse's invention? How was Morse enabled to test his invention? What was the result? What was the first news transmitted? How many miles of telegraph are now in operation? On how much of this is Morse's apparatus used? What is the cost of constructing a telegraphic line? Who are sometimes mentioned as sharing with Morse the honor of inventing the telegraph?

has applied electro-magnetism to the determining of minute intervals of time and the regulation of clocks. The time of astronomical observations may thus be fixed with perfect precision to the tenth of a second.

The pendulum of a clock, for instance, is, by some mechanical contrivance, made by its vibrations to close and break a galvanic circuit. With Morse's apparatus, each vibration is indicated by a dot on a strip of paper passed in front of the style. If now an observer have a signal-key connected with the same circuit, by depressing it the instant a star passes one of the wires of his telescope, he permanently records its transit on the same paper by a dot intermediate between two vibration-dots, the exact time of which is known.

924. By the same agency a number of clocks may be made to keep uniform time.

This is effected by connecting any number of distant clocks, by means of wires, with one standard time-piece, which is itself connected with a galvanic battery,—so that the circuit may be closed and broken by all the pendulums simultaneously. Wheels connect the pendulums with the hands of the clocks, which are thus made to move with perfect uniformity. Some railroad companies use an arrangement of this kind to make the clocks at their different stations keep time together.

925. ELECTRO-MAGNETIC FIRE-ALARM.—The principle of the telegraph has been used for raising a simultaneous alarm of fire at a number of different stations connected with one principal station by wires. By completing and breaking the galvanic circuit, an attendant who is constantly on watch at the principal station, and receives his information by telegraphic signals from the district in which the fire is detected, strikes alarm-bells at the various distant stations a certain number of times, according to the number of the district in question. Such an arrangement has been used in Boston with great success.

926. THE HELIX, A MAGNET.—The helix, when traversed by a current of electricity, not only has high magnetizing powers, as we have seen, but is also itself a magnet. If

What is said of their claims? 923. To what has American ingenuity applied electro-magnetism? Show how an astronomical observation may be telegraphically recorded. 924. How may a number of clocks be made to keep uniform time by means of electro-magnetism? 925. For what has the principle of the telegraph been used? Show how an alarm of fire may be simultaneously raised at different stations. 926. What is the effect of an electric current traversing a helix on the helix itself?

suspended so as to allow it freedom of motion, it points north and south, and dips like the magnetic needle. So, like poles of two helices repel each other; unlike poles attract each other.

Even when not bent in the form of helices, two wires traversed by electric currents, if brought near each other in parallel lines and free to move, exhibit mutual attraction or repulsion. When their currents move in the same direction, they attract each other; when in contrary directions, they repel each other.

Magneto-electricity.

927. Not only is magnetism developed by electric currents, but electric currents are produced by magnetism. That branch of science which treats of electric currents so produced is called Magneto-electricity.

The phenomena of magneto-electricity, like those of electro-magnetism, go far towards proving the intimate connection between electricity and magnetism, if not their actual identity.

928. *Experiments.*—Connect the ends of wire from a helix with a galvanometer. Then quickly thrust into the helix one of the poles of a bar magnet. The needle of the galvanometer is at once deflected, showing the passage of an electric current over the wire. If the opposite pole is introduced into the helix, a current passes in the contrary direction.

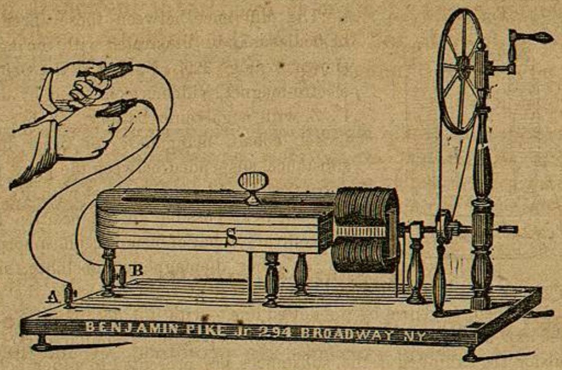
Within a helix place a soft iron bar of such length that each end may project a little. Over its ends bring the poles of a horse-shoe magnet, so suspended as to have freedom of revolution. On turning the magnet rapidly, the poles of the bar are reversed twice for each revolution, and an electric current is produced on the wire, as is shown by a galvanometer attached to it. This principle has been applied in different magneto-electric machines, with which water may be decomposed, platinum wire heated to redness, sparks produced, shocks given, and other experiments performed.

929. The Magneto-electric Machine.—Fig. 328 represents one form of the Magneto-electric Machine.

S is a compound horse-shoe magnet supported on three pillars. In front of its poles, and as near as it can be brought without touching, is a bar of soft iron bent at right angles, and surrounded with several coils of insulated copper wire. The ends of this wire are pressed by springs against a con-

Prove that it renders the helix magnetic. What phenomena are exhibited by two straight wires traversed by electric currents, when brought near each other? 927. What is Magneto-electricity? What is said of its phenomena? 928. What is the first experiment illustrative of magneto-electricity? The second experiment? In what is the principle here described applied? 929. Describe the Magneto-electric

Fig. 328.



MAGNETO-ELECTRIC MACHINE.

ducting metallic plate, connected by wires passing under the stand with the screw-cups A, B. The soft iron armature just described is mounted on an axis which is made to revolve by a wheel turned by a handle. The handle being rapidly turned, each half-revolution of the armature brings its extremities near opposite poles of the magnet, thus reversing its polarity, and producing a strong electric current on the wire. If small copper cylinders attached to the wires are grasped one in each hand, as shown in the figure, a series of severe shocks are received, and the muscles are so contracted that it is almost impossible to open the hands and let go the conductors.

Machines of this kind, adapted to medical use, have been found efficacious in cases of rheumatism, dyspepsia, sprains, nervous diseases, &c., the current being made to pass through the diseased part.

Diamagnetism.

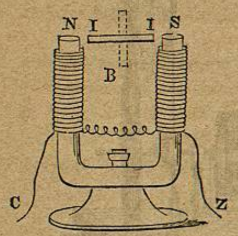
930. Experiments with powerful electro-magnets show that almost all substances are susceptible of magnetic influence. Some are attracted by the magnet; others, repelled; while a few are not acted on at all, though when more powerful magnets shall be made they may perhaps be found to fall under one of the two previous classes.

Hence arises a three-fold division of bodies. 1. Magnetic bodies, or such as are attracted by an electro-magnet.

Machine represented in Fig. 328, and its mode of operation. What is the effect of such a machine on the human system? What use has been made of machines of this kind? 930. What has been shown by experiments with powerful electro-magnets? Name the three classes into which bodies are divided with reference to the influence

2. Diamagnetic, or such as are repelled. 3. Indifferent, or such as are not acted on at all.

Fig. 329.



The difference between these three classes of bodies may be illustrated with the apparatus shown in Fig. 329. N, S, are the poles of an electro-magnet, which is connected by the wires C, Z, with a galvanic battery. A bar of iron, nickel, cobalt, manganese, or other magnetic substance, suspended between the poles so as to move freely, will come to rest with its ends as near them as possible, in the position I I. On the contrary, a bar of bismuth, phosphorus, zinc, tin, or other diamagnetic substance, similarly suspended, will be repelled and come to rest at right angles to the position just described, as shown by the dotted line,—with its sides opposite the poles of the axis and its ends as far from them as possible. Similar attraction and repulsion are exhibited if the substances are presented to either pole separately. An indifferent substance will remain in any position in which it is placed, being neither attracted like the iron nor repelled like the bismuth.

Similar experiments may be made on liquids and gases by enclosing them in tubes. It is thus found that oxygen is magnetic; water, alcohol, ether, and the oils, diamagnetic.

CHAPTER XVIII.

ASTRONOMY.

931. Astronomy is the science that treats of the heavenly bodies,—their motions, size, distance, &c.

By the heavenly bodies are meant the sun, the moon, stars, planets, and comets.

932. Astronomy, as it is the most sublime, is also the oldest of sciences. The shepherds of the patriarchal age, tending their flocks by day and night beneath the canopy of heaven, naturally directed their gaze to the brilliant

exerted on them by electro-magnets. Define each. Illustrate the difference between these three classes with the apparatus represented in Fig. 329. How may similar experiments be made on liquids and gases? What gas is found to be magnetic? What liquids are diamagnetic?

931. What is Astronomy? What are meant by the heavenly bodies? 932. Who

orbs with which it is studded, observed their motions, and thus became the first astronomers. Chaldean observations are said to extend back to within a hundred years of the flood. The Chinese, also, paid great attention to this science in remote antiquity. We are told that more than 2,000 years before the birth of Christ, an emperor of China put to death his two chief astronomers for not predicting an eclipse of the sun.

Destitute of the admirable instruments which modern science has produced and used with signal success, the ancient astronomers of course erred in many of their conclusions. We can only wonder that they obtained as much knowledge as they did respecting the heavenly bodies.

933. To unfold the principles of astronomy at length would require a volume, and to understand them thoroughly, a knowledge of the higher mathematics is essential. We can here present only such leading facts as will serve to give a general view of the science.

934. Fundamental Facts.—The great facts established by the researches of astronomers are as follows:—

1. Space is filled with worlds.

Looking up into the heavens on a clear night, we see them all around us. The telescope reveals millions. There are no doubt millions more too remote to be seen at all, and others which from being non-luminous escape our vision. Powerful instruments reach to points from which light, travelling as it does with the enormous velocity of 192,000 miles in a second, would be 60,000 years in reaching us, and throughout the whole of this vast field worlds are everywhere scattered. We can but infer that the regions to which man's eye has never penetrated are similarly studded; and that, if an observer could be transported to the remotest star visible with his telescope, he would see spread before him in the same direction a firmament no less rich and splendid than that which he beheld from the earth.

2. These worlds are divided into systems, the members of which are bound together by mutual attraction. Each system has a central sun, round which the other members, called Planets, revolve. While this revolution is going on, the suns themselves with their respective planets move about a common fixed central point.

3. The stars that we see twinkling in the sky are suns.

were the first astronomers? How far back are Chaldean observations said to extend? What story shows the attention paid to astronomy by the Chinese in remote antiquity? What is said of the ancient astronomers? What is the first great fact established by astronomers? What facts are stated respecting the number of worlds? What inference is drawn respecting the regions of space unpenetrated by the eye of man? How are these worlds divided? What are the stars that we see twinkling