9H Hands-on

Science series

Electricity

196455

★Batteries sold separately.

Principles of Electric Current

Study Guide

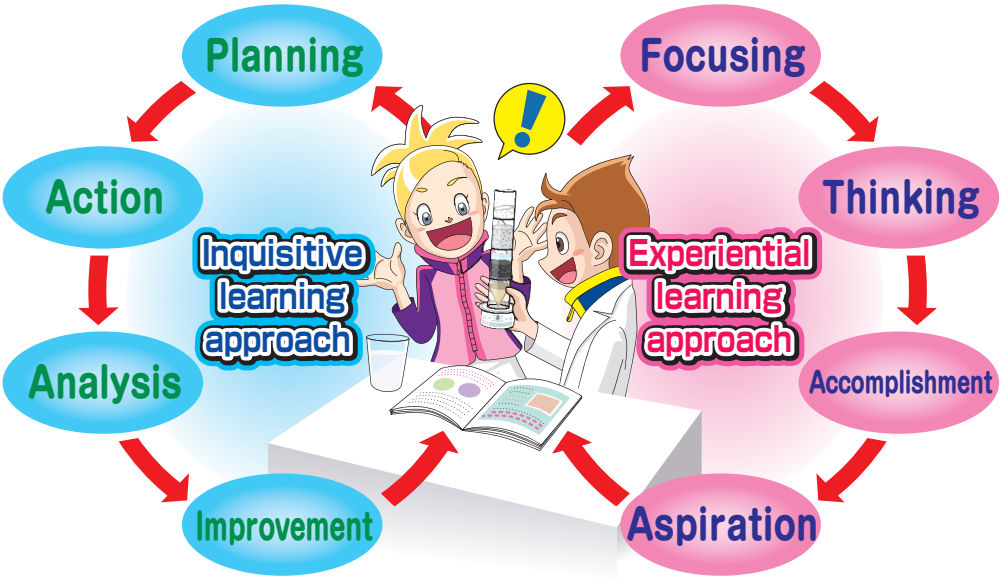
AGE 8+

⚠ **WARNING:**

CHOKING HAZARD - Small parts. Not for children under 3 yrs.

ArTeC

Two cycles for turning a child into a science lover



Inquisitive learning approach nurtures the abilities of...

① Planning ··· Look ahead by yourself
② Action ··· Put the plan into practice
③ Analysis ··· Self-examine the result of the action
④ Improvement ··· Improve the results based on the analysis

Experiential learning approach nurtures the abilities of...

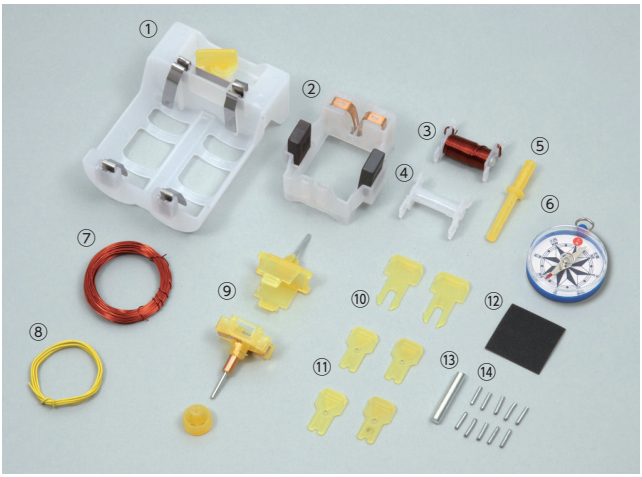
① Focusing ··· Direct attention to what is fun
② Thinking ··· Focus and think hard while experiencing
③ Accomplishment ··· Sense of accomplishment by figuring out something after thinking
④ Aspiration ··· Gain a strong desire for achievement after the accomplishment

The inquisitive learning and experiential learning approaches of Artec's Science Series will turn children into great lovers of science!

Check the contents.

◆ Contents ◆

① Battery holder × 1
② Motor case × 1
③ 200-turn coil × 1
④ Bobbin × 1
⑤ Plastic core × 1
⑥ Compass × 1
⑦ Enameled wire × 1
⑧ Coated wire × 1
⑨ Armature × 1
⑩ Shaft retainer × 1
⑪ Connecting plug × 4
⑫ Sandpaper × 1
⑬ Iron core × 1
⑭ Iron bar × 10

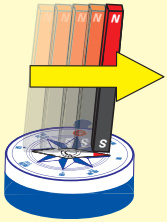


What you need from home:

○ Battery (1.5V D/R20)
○ Scissors
○ Tape

What if the N-pole needle does not point north?

If the S-pole of the bar magnet attracts the S-pole needle of the compass, slide the bar magnet along the needle until it reaches the N-pole. Hold the needle in place, being careful not to let it turn. When the N-pole needle and the S-pole of the bar magnet attract each other, the compass is OK.



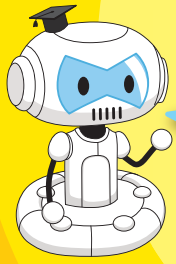
Warning

- CHOKING HAZARD - Small parts. Not for children under 3 yrs. Keep out of reach of small children to prevent accidental swallowing.
- Not suitable for children under 8 yrs. This product contains small magnets. Swallowed magnets can stick together across intestines causing serious infections and death. Seek immediate medical attention if magnets are swallowed.
- Not suitable for children under 8 yrs. Hot surface.

Make sure to read these carefully before use.
(Parents/guardians, read these instructions carefully.)

- Instructions for parents are included and must be observed. ● 2 x 1.5 V x D/LR20 (not included)
- Non-rechargeable batteries are not to be recharged. ● Rechargeable batteries are to be removed from the toy before being charged. ● Rechargeable batteries are only to be charged under adult supervision.
- Different types of batteries or new and used batteries are not to be mixed. ● Exhausted batteries are to be removed from the toy. ● Take care to avoid the following situations, which may cause the battery leakage, overheating, explosion, or overheating of other accessible parts such as wires, motors, etc., make sure to follow the instruction and not to allow below happened:
- Short-circuiting of batteries Incorrectly attaching the connecting plugs.
- Continuing operating while the motor is stalled.
- Installing batteries with the polarity reversed. ● Wires are not to be inserted into socket-outlets.
- When not using the product for a long period of time, remove the batteries and store the product.
- Please pay attention that during normal operation, the temperature rising on metal contact pieces, copper pieces coil and the batteries surface will exceed the limit and very hot, make sure do not touch the abouve mentioned surface.
- The packaging must be retained since it contains important information.
- Store this product away from high temperatures, humidity, and direct sunlight.

What is an Electromagnet?



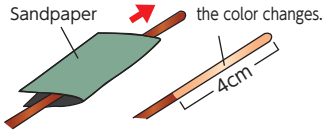
A magnet will always remain a magnet. But in the case of an electromagnet, it only becomes a magnet when current flows through it. Let's make it!

Assembly Assemble the electromagnet (100-turn coil).

What you need from the kit: ① Battery holder ④ Bobbin ⑤ Plastic core ⑦ Enameled wire ⑪ Connecting plug ⑫ Sandpaper

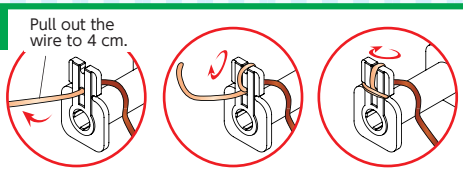
What you need from home: ● Battery (1.5V D/R20) × 1 ● Tape

1



Buff both sides of the enameled wire with sandpaper to strip off about 4 cm of the surface. If you do not strip off the surface of the wire neatly, it may not allow the electric current to flow.

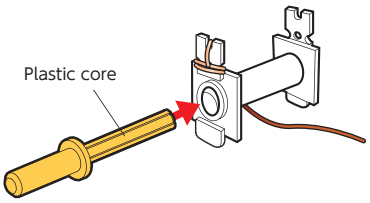
2



1. Insert the wire into the hole of the bobbin from the inside.
2. Wind the wire around the vertical chase.
3. Then wind the wire around the horizontal chase.

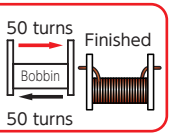
Wind one end of the enameled wire around the bobbin stopper.

3

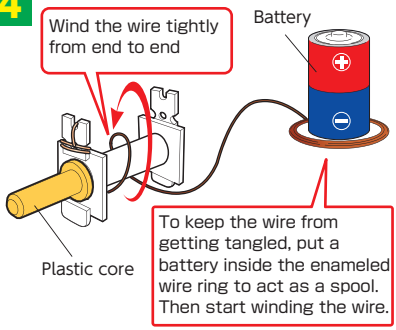


Insert the plastic core into the bobbin to make winding the enameled wire easier.

If you wind the wire tightly from one end to the other, you can wind approximately 50 turns. Then wind approximately 50 turns coming back the other way, to make a total of 100 turns.

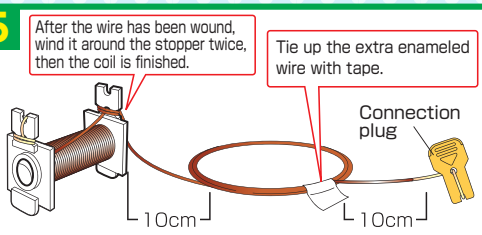


4

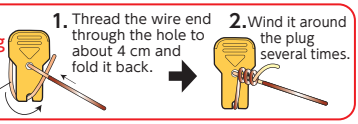


Wind the enameled wire tightly around the bobbin for 100 turns.

5



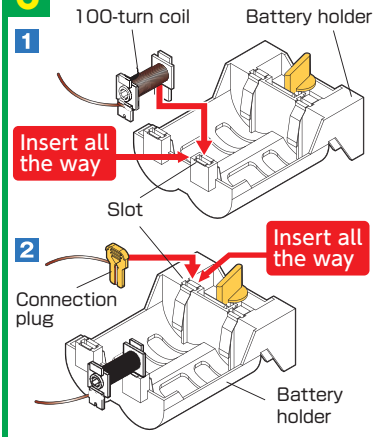
How to attach the connecting plugs to the enameled wires



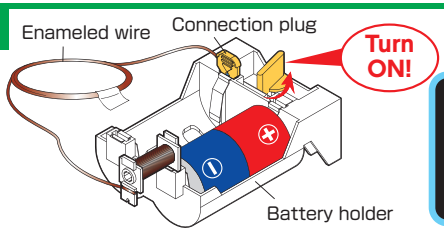
Attach a connecting plug to the free end of the enameled wire. Tie up the extra enameled wire with tape.

Warning Don't cut away any excess enameled wire; the resistance will be reduced and consequently caused a short circuit.

6



7



Turning the switch ON allows current to flow.

Warning Do not keep the switch ON. Otherwise, the electromagnet will become very hot. Take the battery out after the experiment is finished.

Experiment Let's do three experiments with the electromagnet!

What you need from the kit:
⑤ Plastic core ⑬ Iron core ⑭ Iron bar
○ The assembled electromagnet

Choose the correct answer before doing the experiments.

1 What happens when you move the iron bar towards the hole of the energized 100-turn coil?

- (A) The iron bar is repulsed
- (B) The iron bar gets pulled toward the hole of coil
- (C) Nothing happens

Your answer:

2 What happens when you move the iron bar towards the energized 100-turn coil (with plastic core)?

- (A) The iron bar is repulsed
- (B) The iron bar is attracted to the plastic core
- (C) Nothing happens

Your answer:

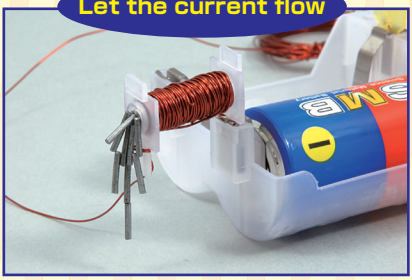
3 What happens when you move the iron bar towards the energized 100-turn coil (with iron core)?

- (A) The iron bar is repulsed
- (B) The iron bar is attracted to the iron core
- (C) Nothing happens

Your answer:

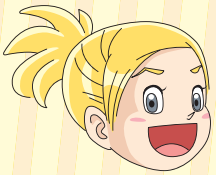
Results

When the coil is carrying an electric current, it attracts iron like a magnet. When the coil is not carrying an electric current, nothing happens.



The iron bars are attracted to the coil

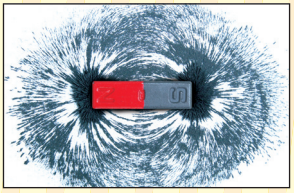
The iron bars are not attracted to the coil

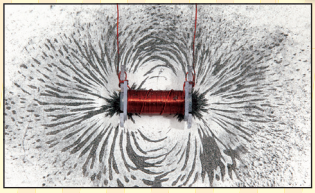


The iron core becomes a strong magnet because it allows electrical current to flow.

Let's check the pictures below! You can see there is magnetic force present because it makes the iron filings create a circle around the magnet. This is visible proof that the magnet attracts the iron filings. The force that attracts the iron to the magnet is called magnetic force.

Just like a bar magnet, an electric magnet has magnetic force.





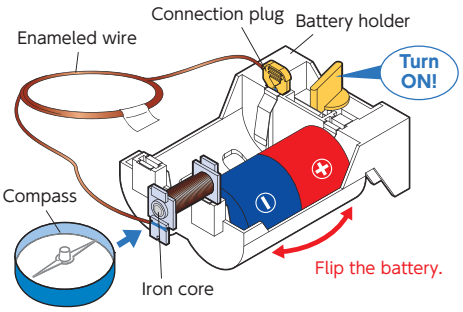
We learned the electromagnet attracts iron when it carries an electrical current. Does the electromagnet have an S-pole and an N-pole like a magnet?

Experiment Let's check the electromagnet's poles!

What you need from the kit: ⑥ Compass ○ The assembled electromagnet

1 Insert the iron core into the 100-turn coil. Move the compass toward the iron core which is carrying an electric current, then check whether the electromagnet has an S-pole and N-pole or not.

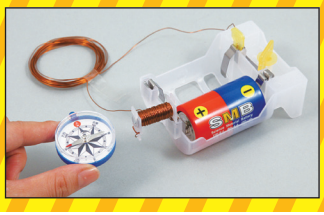
2 After experiment **1**, flip the battery so the poles are reversed, then move the compass toward the iron core, as in **1**.



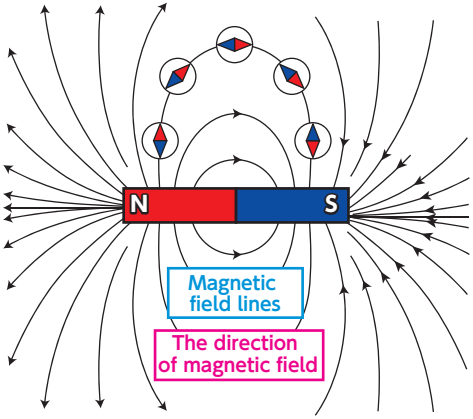
Results

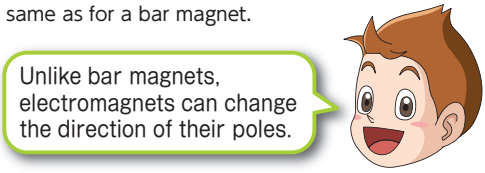
1 When you put the compass beside the electromagnet as shown below, the arrow of the compass points to a definite point.

2 If you flip the battery (change the direction of current), the compass's poles will switch position.

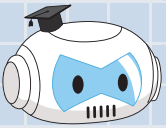


The diagram on the right shows the direction of the magnet's force. The direction which is shown on the compass as a red mark on the arrow is called the direction of magnetic field. The lines which are shown on the compass as red marks on the arrow are called magnetic field lines. This is the reason why the arrow of the compass indicates a definite point.
The magnetic field of an electromagnet is the same as for a bar magnet.

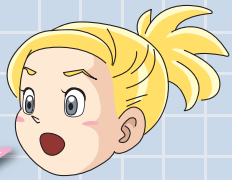




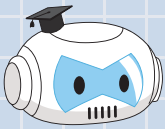
Make the electromagnet stronger!



Unlike bar magnets, electromagnets can change the strength of their magnetic force.



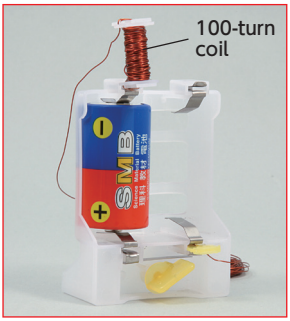
How can the strength be changed?



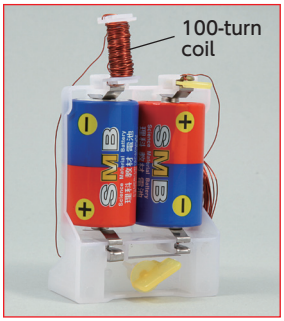
There are two ways to change it, as shown below in **1** and **2**.

1

In the case of changing the number of the batteries, which setup has the stronger magnetic field?



① One battery

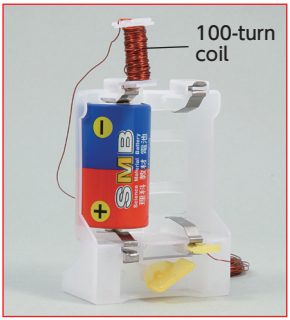


② Two batteries

Your answer

2

In the case of changing the number of turns on the coil, which one has the stronger magnetic field?



① 100 turns

② 200 turns

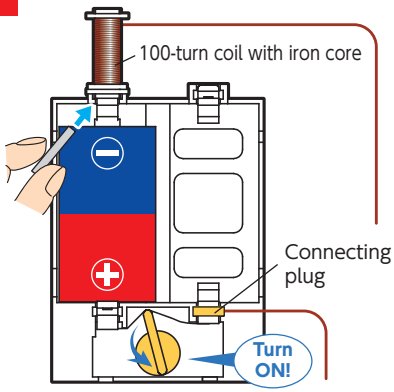
Your answer

Experiment Check the strength of an electromagnet!

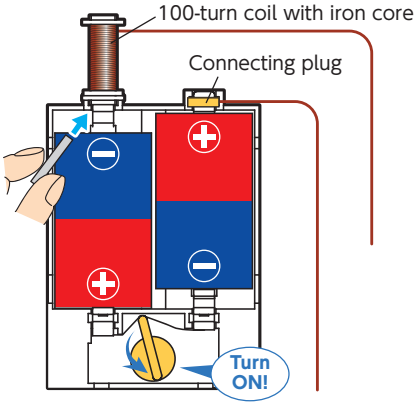
What you need from the kit: ⑫ Sandpaper ⑬ Iron core ○ The assembled electromagnet

Compare the arrangement of one battery and two batteries (connected in series). Count the number of iron bars on the iron core, and write it down in the table on next page.

1 Check by changing the number of batteries

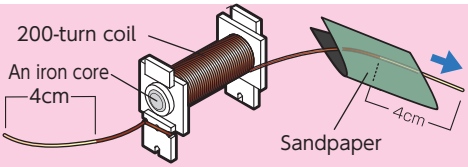


One battery

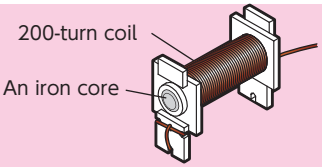


Two batteries

2 Check by changing the number of turns on the coil.

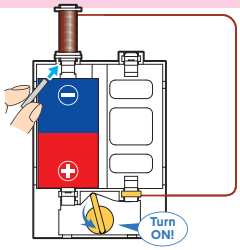


Buff both sides of the enameled wire on the 200-turn coil with sandpaper until you strip off about 4 cm of the surface.



Wind one end of the enameled wires around the bobbin stopper.

Connect the 100- and 200-turn coils as shown on the right. In the table on page 9, record the number of iron bars that stick to each iron core .



Warning Do not keep the switch turned ON. The electromagnet will become very hot. Take the battery out after the experiment is finished.

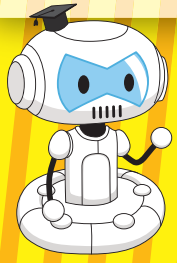
Results

Write down the number of iron bars on the iron core in the table below for each case of one and two batteries.

Experiment	Number of batteries	Number of iron bars on the iron core
1	One battery	Bars
2	Two batteries	Bars

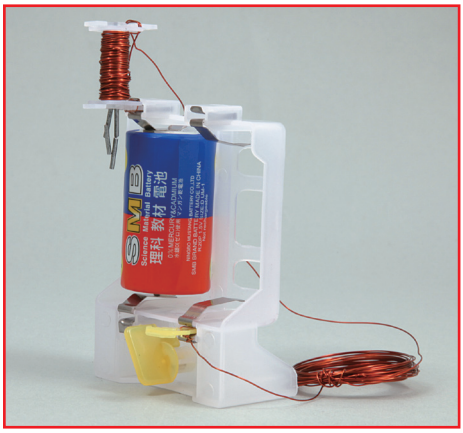
Write down the number of iron bars on the iron core in the table below for each case of one and two batteries.

Experiment	Number of turns on the coil	Number of iron bars on the iron core
1	100 turns	Bars
2	200 turns	Bars

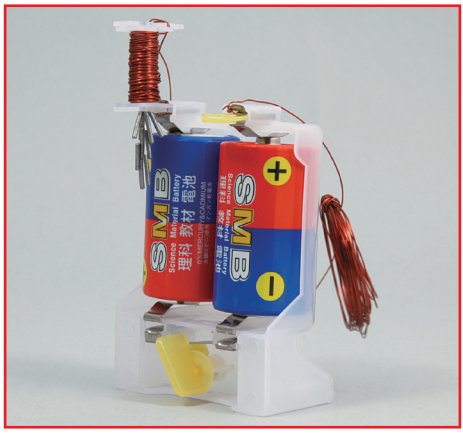


What happened to the number of iron bars on the iron core?
In which setup are the most iron bars attracted?

The strength of the electromagnet when you change the number of batteries



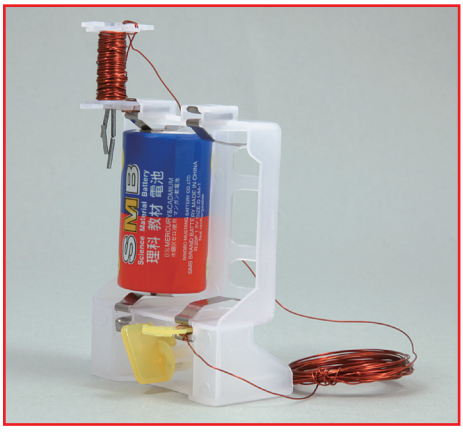
■ **One battery**(100-turn coil)



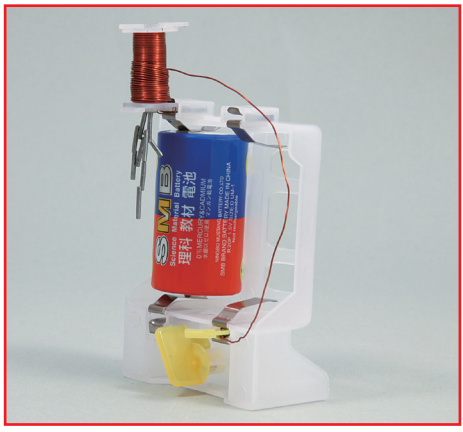
■ **Two batteries**(100-turn coil)

Weak Strength of the electromagnet **Strong**

Do The strength of the electromagnet in relation to the number of coil turns

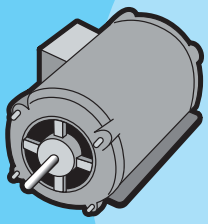


■ **100-turn coil** (one battery)



■ **200-turn coil** (one battery)

Weak Strength of the electromagnet **Strong**



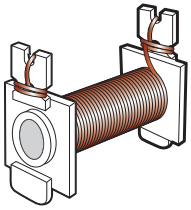
We can see that there are lots of electric appliances that use electromagnets. Almost all of them are built with a motor in the appliance which uses the force of an electromagnet. To learn about the motor which is used in an appliance, let's make a motor!

Assembly Let's make your motor!

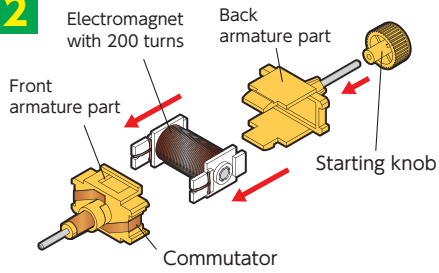
What you need from the kit: ② Motor case ③ 200-turn coil ⑦ Enameled wire ⑧ Coated wire ⑨ Armature ⑩ Shaft retainer ⑪ Connecting plug ⑫ Sandpaper

1

Referring to page 3, wind each side of the enameled wire onto each bobbin stopper of the 200-turn electromagnet.

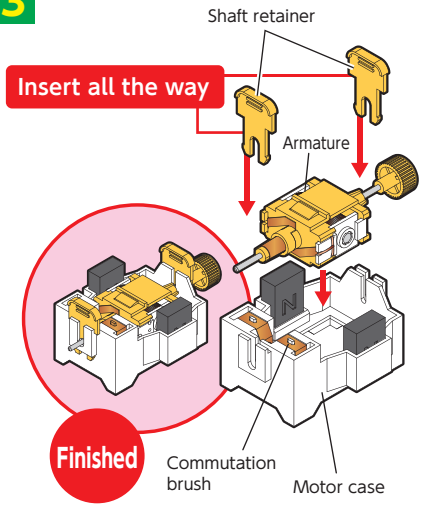


2



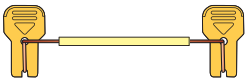
Hold the 200-turn electromagnet between the front and back armature parts, then put the starting knob on it.

3



Set the armature firmly into the motor case.

4



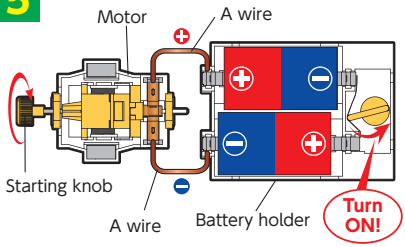
Cut the plastic wire at 30 cm and remove the plastic cover for a length of 4 cm from each end. Then attach the wires to the plugs as shown.

How to attach the connecting plugs to the coated wire

1. Thread the end of the wire through the hole about 4 cm and fold it back.
2. Wind it around the plug several times.
3. Finished

★ Wind tightly so the wire will not stick out.

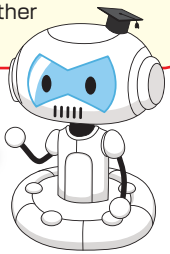
5



Put the batteries in it, then turn the switch on. Turn the starting knob and check that the motor starts to rotate.

When the motor does not start to rotate

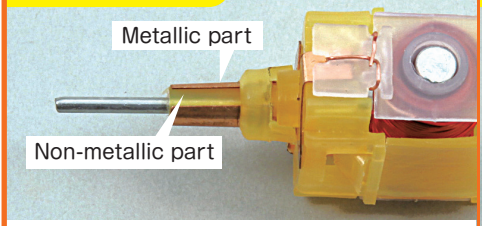
- Check the connections of the wires → See page 11 and recheck how to make a motor.
- Check the battery level → If it is low, change to a new battery.
- Is there an iron core in the coil? → Check that the coil has an iron core in it.
- Check that the enamel of the enameled wire is stripped off
  → Buff the enameled wire with sandpaper again.
- Turn the starting knob easily with your fingers→ See page 11 and check section 3 .
- Make sure the enameled wire which is wound around the stopper of the coil is touching the commutator of the armature → See page 11 and check section 3 .
- Make sure the commutator and commutation brush are touching each other
  → See page 11 and check section 4 .



Before studying how to rotate the motor, learn the part names.

Motor part names and functions

Commutator

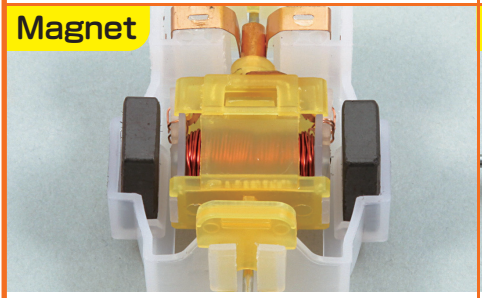


The commutator has a metallic part and a non-metallic part. Every half rotation of the electromagnet changes the direction of the current flow.

Commutation brush

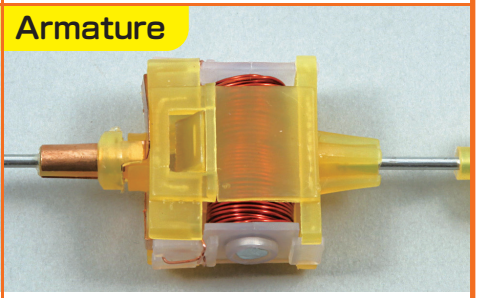
When the commutation brush touches the commutator, current flows to the armature.

Magnet



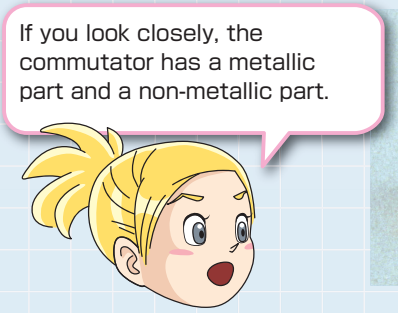
Repulsing or getting attracted by the magnetic force of the electromagnet, the magnet makes the armature rotate.

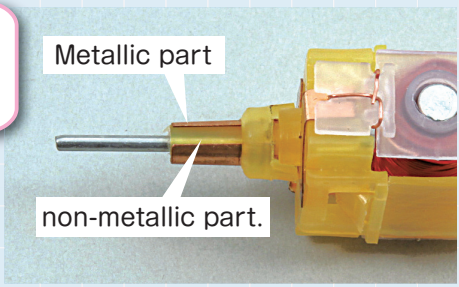
Armature



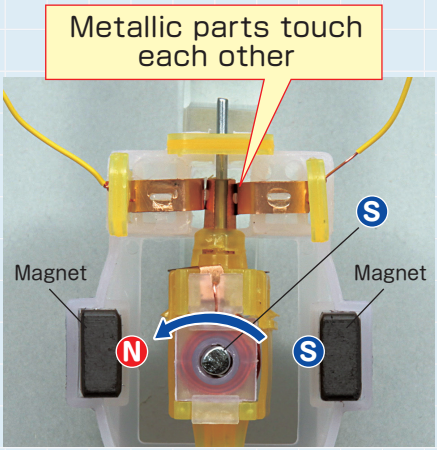
The armature is made by winding coils around an iron core. If electric current flows, it becomes electromagnetic.

Mechanism of the motor

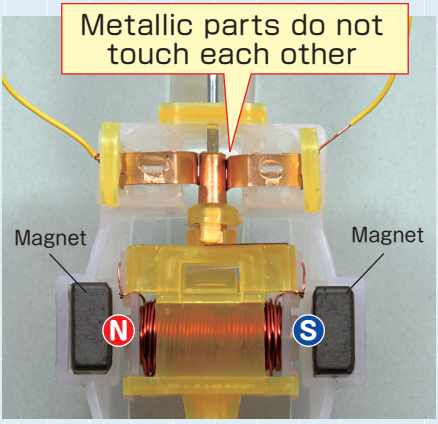




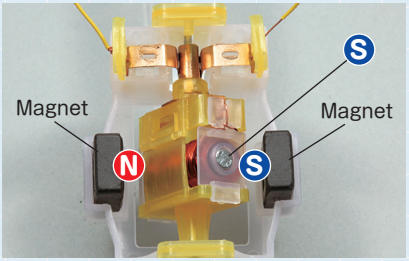
1 When the commutation brush touches the metallic part of the commutator, the electric current flows on the armature. When the electric current flows, the armature becomes an electromagnet. The N-pole and S-pole of the electromagnet are attracted by the S-pole and N-pole of the magnets that are placed on either side of the armature, so it starts to rotate.



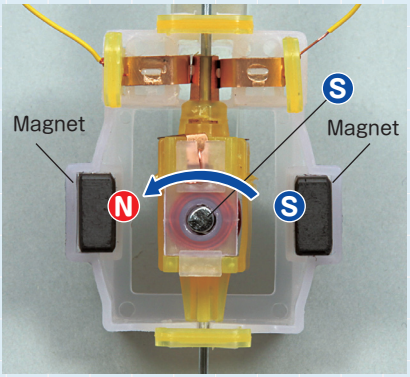
2 After rotating the armature by attracting the N-pole and S-pole to each other, the commutation brush and metallic part of the commutator separate. Because of this separation, the electric current cannot flow on the armature. This causes the armature to lose the force of the electromagnet.

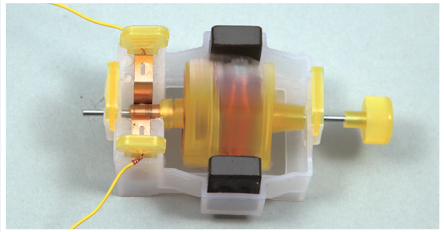


3 Because of the loss of the magnetic force of the electromagnet, the armature and the magnet are not attracted to each other. However the armature keeps rotating using the extra rotational force that it gained.

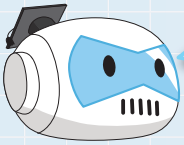


4 The armature rotates using the extra rotational force, and the commutation brush touches the metallic part of commutator again. At this time, the electric current flows opposite to the direction it flowed in setup **1**. Then the electromagnet's N-pole and S-poles are switched. By repulsing the same poles (N-pole and N-pole, and S-pole and S-pole) the armature gains force and keeps rotating.



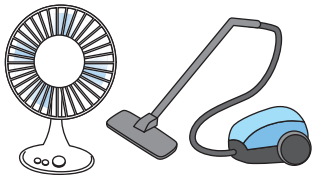


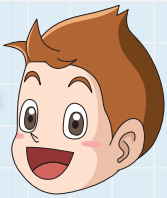
By repeating steps 1 to 4, the motor keeps rotating.



Using the rotation of a motor, you can operate electrical appliances or rotate the wheels of an electric car.

There are motors in vacuum cleaners and fans, aren't there?



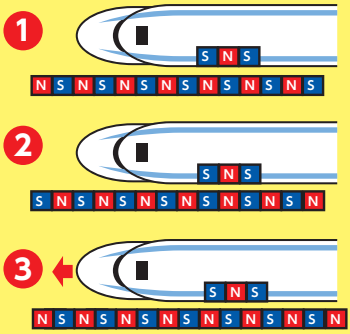


Electricity and magnetism at work for the future of our world.

Recently, vehicles have been developed that run on electricity and use magnetism. There are coils in locomotives and some train bodies have magnets. By sending an electric current to them, we can switch the N-pole and S-pole of the electromagnet. Then a train can move by the forces of attraction and repulsion.

JR-Maglev (a Maglev train in Japan). Photo by Yosemite.

Pictures of a linear motor car engine.



When it stops, the poles are set to attract between the body and rail.

Then switch the rail's pole to repulse the body.

The body starts to move. After the body moves to the place where it is attracted between the body and rail, then it switches the rail's pole to repulsion. Through these steps, the linear motor car is able to run.

Also, by changing the interval time of the switching between the N-pole and S-pole, it is possible to adjust the speed of the car. Compared to a conventional train, a linear motor car can move while floating. Because there is nothing touching the ground, there is less vibration. For this reason, it has attracted positive attention as a means of transport that is both fast and comfortable.

Advantages of a linear motor car

- Rapid and quiet
- By using electric power, the problem of fuel and spare parts can be reduced.
- Because it uses electric power this is a zero-emission vehicle.

Electromagnets are used in many useful products in our lives, so they have become indispensable to us. Let's check and find out how electromagnets are used around you in your own life.

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