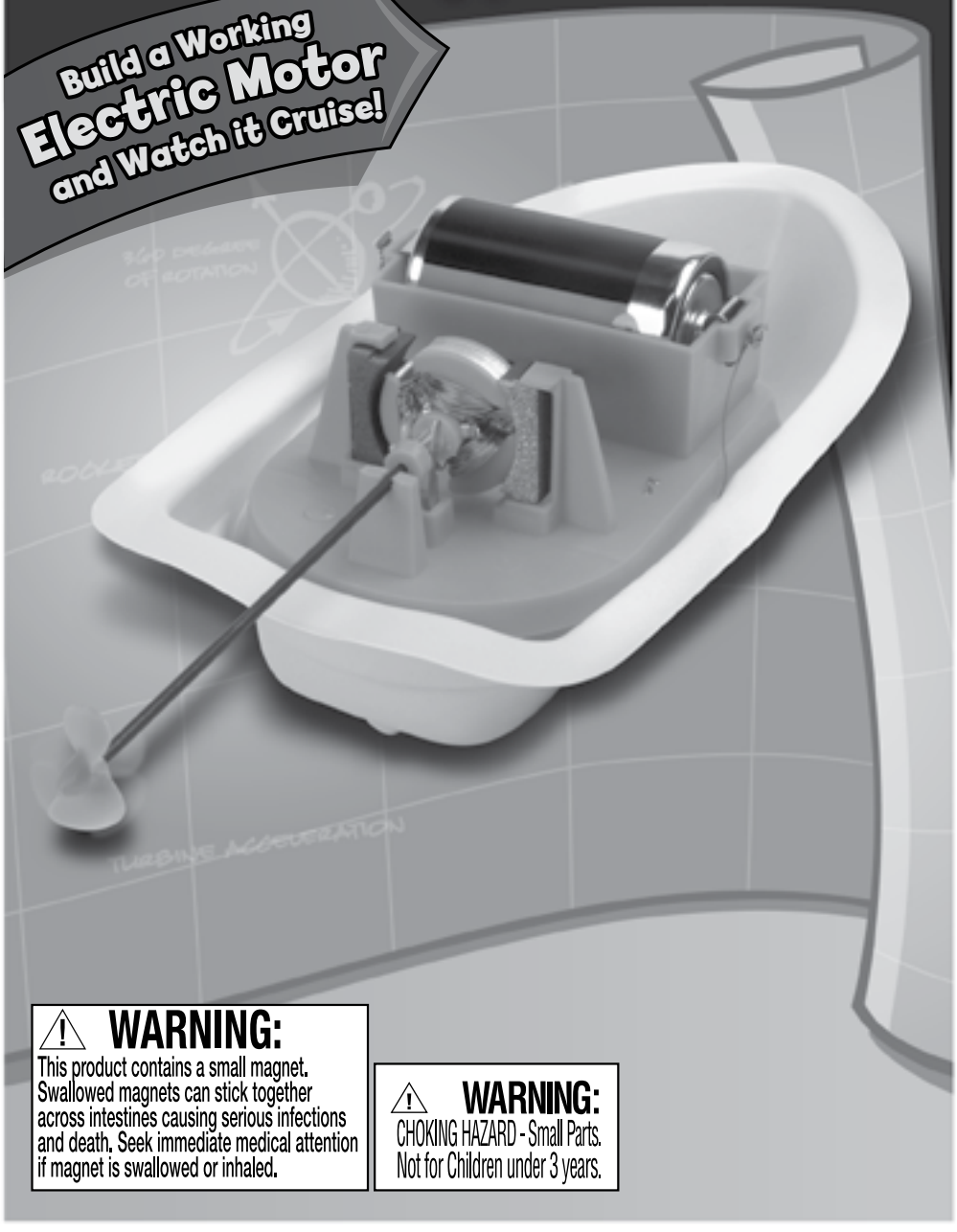
SCIENTIFIC EXPLORER™

ELECTRIC MOTOR™

8+

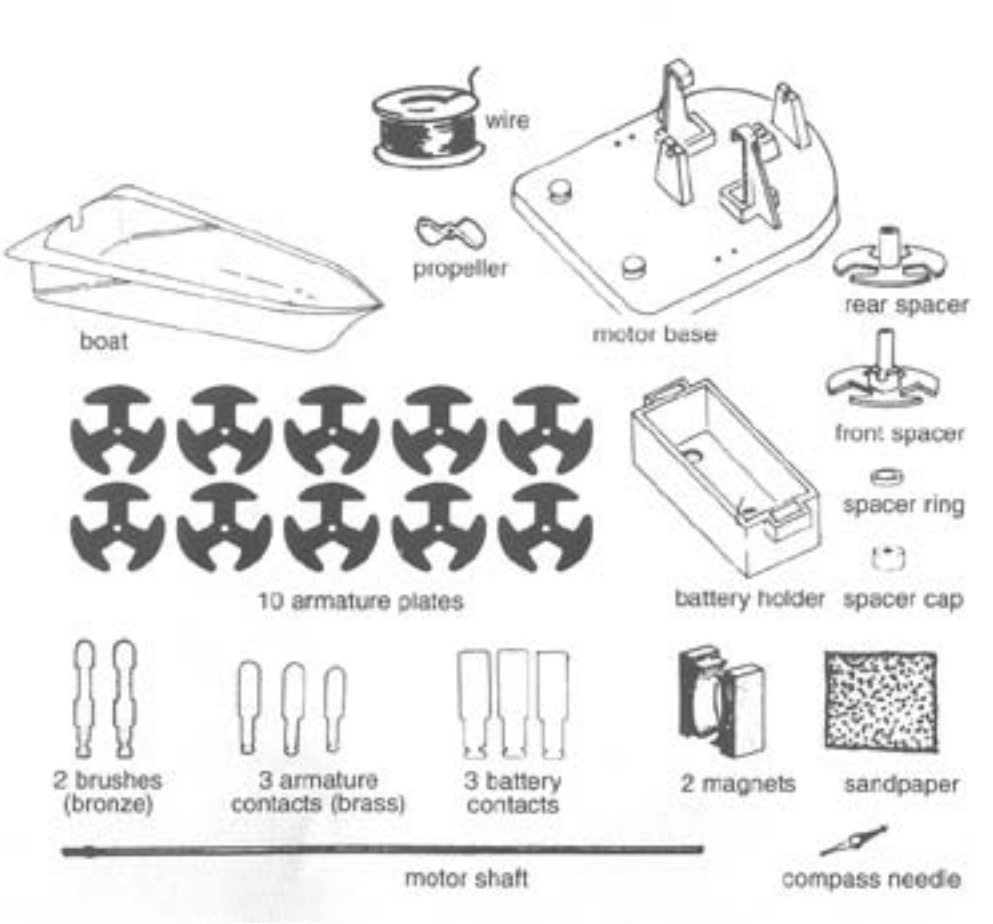
Build a Working Electric Motor and Watch it Cruise!



⚠ WARNING:
This product contains a small magnet. Swallowed magnets can stick together across intestines causing serious infections and death. Seek immediate medical attention if magnet is swallowed or inhaled.

⚠ WARNING:
CHOKING HAZARD - Small Parts.
Not for Children under 3 years.

WHAT'S IN YOUR KIT



You also need:

- a pencil
- a D-cell battery
- a pair of scissors or wire cutters
- ruler

PREPARE PLASTIC PARTS

1. Cut Plastic Parts Off the Runner

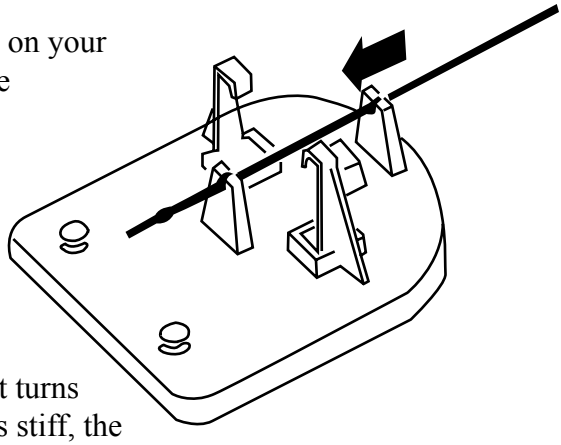
Cut off or break off the following 6 plastic parts from the runner to which they are attached: motor base, battery holder, rear spacer, front spacer, spacer ring, and spacer cap. Then throw the runner away.

2. Trim Parts

Cut off or sand off any little bits of plastic that stick out from the edges of the pieces you just removed from the runner. The two spacers in particular must have smooth edges all the way around.

3. Smooth Out the Insides of the Holes in the Motor Shaft Supports

The two motor shaft supports on your base have holes at the top (see diagram). These holes are designed to hold the motor shaft in place while allowing it to turn freely.

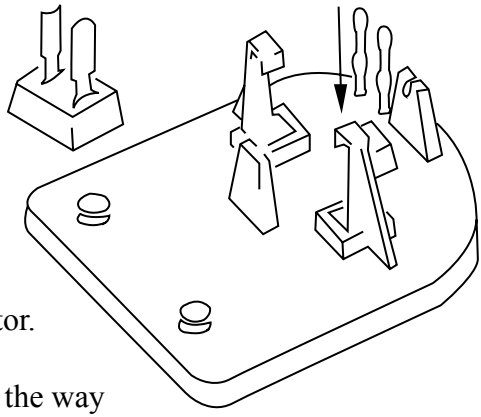


Slide the motor shaft into the holes, as the diagram shows. Twirl it with your fingers. If it turns easily, the fit is O.K. If it feels stiff, the insides of the holes may need to be smoothed out.

One end of the motor shaft has a double dent hammered into it. The shaft is a little bit wider at this point. Use this dented end of the shaft like a file to smooth the inside of the holes. Move it rapidly in and out of each hole. Use gentle pressure, while turning the shaft so all sides of the hole are smoothed out. Hold the motor shaft near the dented end as you do this, to prevent bending the shaft.

When the holes are smooth and the shaft is able to spin easily, remove the shaft and put it aside.

PREPARE THE MOTOR BASE



1. Put the 2 Brushes into the Base
Near the curved end of the motor base is a nearly square pillar with 2 slots in it. Insert the two copper-colored metal pieces that electricians call “brushes”.
They bring the electricity to the motor.

Study the diagram carefully. Notice the way that the curved (convex) sides of the brushes face each other, and the hollow (concave) sides face outward.

The ends should come out the other side of the base, underneath it. Be careful not to bend the brushes.

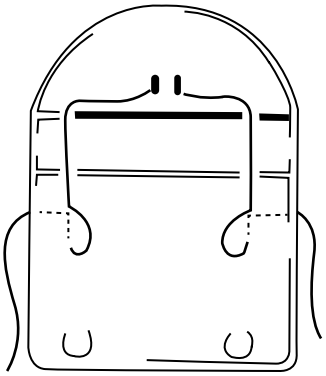
2. Prepare 2 Battery Wires
Cut off 2 9-inch pieces of wire from the coil of wire.

3. Sand the Wire Ends
Fold the sandpaper with the rough side inside. Place the end of one piece of wire in the fold of the sandpaper. Squeeze the sandpaper gently and pull the wire out, scraping some of the orange coating off the wire. Repeat several times, twisting the wire each time, until about 1 inch of the end of the wire is bare, shiny copper all around. Sand both ends of the two wires.

4. Wrap Ends of Battery Wires Around Brushes
Turn the motor base upside down. Wrap the bare end of one wire two or three times around the end of one of the brushes. Wrap a bare end of the other wire around the end of the other brush.

5. Thread the Battery Wires to the Top of the Base

Lay one wire in the square slots in the ribs at one side of the base. (See diagram.) Thread it down through the first small hole, up through the other small hole, and back down through the first hole again. The wire is now on top of the base.

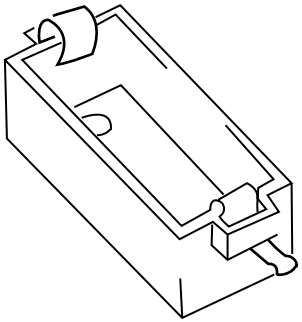


Be careful not to pull on the brushes when you are not working with the battery wires.

PREPARE BATTERY HOLDER

1. Prepare 2 Battery Contacts

Bend the wide end of a battery contact around a pencil. Repeat with second battery contact. (See diagram.)



2. Put Battery Contacts into Battery Holder

Drop the battery contacts into the slots at each end of the holder. The curved ends go inside the holder. Bend the notched end up and out, as in the drawing.

3. Attach Battery Wires

Wrap the bare end of one of the battery wires around the notched end of the unbent battery contact. This will be an on-off switch.

Wrap the bare end of the other wire around the notched end of one of the contacts in the battery holder. The second battery contact has no wire attached to it.

PREPARE ARMATURE FOR WINDING

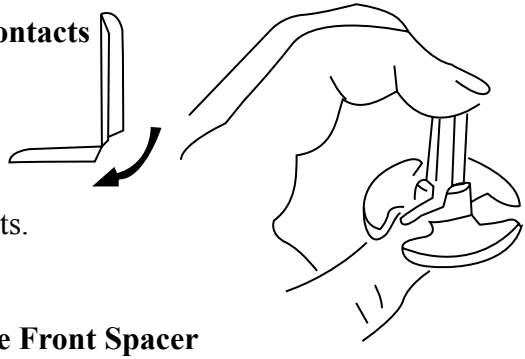
The main part of the motor, wound with wire that actually does the spinning, is known as the armature.

1. Slip the Plastic Rear Spacer (see key) ***tube side first*** on the smooth end of the motor shaft. Slide it up to the dents.
Slide the tip of the tube over the dents, so the dents hold the spacer in place.

2. Stack the Armature Plates
Stack the 10 armature plates on top of each other. Notice that each plate has a tiny notch at the edge of one of its 3 T-shaped arms. These notches should line up.

Hold the plates together by carefully inserting a pencil into the space between two arms.

3. Bend the 3 Armature Contacts
Bend the 3 brass armature contacts into an L-shape. The notched ends must bend away from the hollow (concave) side of the contacts. Refer to the drawing.



4. Fit the Contacts onto the Front Spacer and Hold them in Place with the Spacer Ring
Work carefully with these small parts.

Hold the front spacer (see key) between your thumb and forefinger, as in the drawing.

Fit one of the brass armature contacts in place. The curved side fits against the end of the tube of the spacer. The bent end sits in one of the small notches between the arms at the base of the spacer tube. Your forefinger should hold the contact in place.

Repeat with the remaining 2 contacts in the open notches.

Finally, slide the spacer ring (see key) onto the tube and over the three contacts to hold them in place. Slide the ring as far down as it will go.

5. Put Armature Parts Together
Slide the armature plates onto the motor shaft and up against the rear spacer. Keep the pencil in place.

Slide the front spacer onto the motor shaft so that it fits flat against the armature plates.

Slide the spacer cap onto the motor shaft so that it fits over the end of the spacer and the contacts and holds them in place.

Keep the pencil holding everything neatly together.

WIND THE ARMATURE
The next step in making your motor is to wind wire around each of the arms of the armature. Follow these steps:

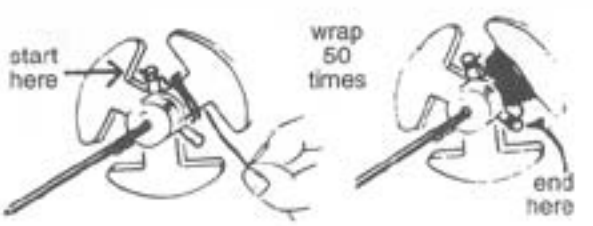
1. Attach Wire to an Armature Contact
Sand 1inch of the end of the wire on your wire coil.
Wrap the bare end of the wire 2 or 3 times around one of the armature contacts.

2. Wind the Wire Around an Arm of the Armature 50 times
The contact you wrapped the wire around is in front of a space between 2 armature arms.

Bring the wire back through that space. Wrap it ***down*** and ***around***, back through the next space, and up past the contact again, as in the diagram. Continue wrapping wire around the stem of the "T." Wrap 50 times, firmly. The closer together your windings are, the better.

Cut off the wire, leaving an end 1-inch long.

Remove the pencil.



3. Attach the End of the Wire to the Second Armature Contact
Sand the final 1 inch of the armature wire. Wrap the next contact. The winding of one arm of the armature is now complete.

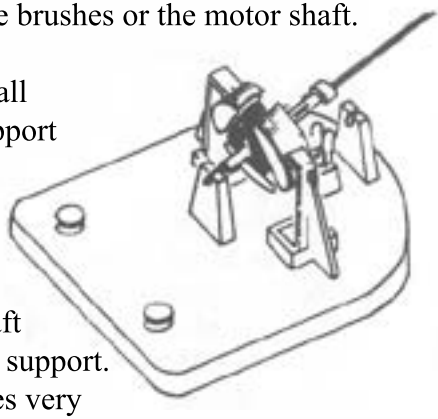
4. Wind the Second Arm of the Armature
Wind the second arm exactly the same way you did the first arm.

Sand 1 inch of the end of the coil wire. Wrap it around the contact on which you just ended. Then wind the second arm back through the slot, down, around, and up, in exactly the same way you did the first time. Wind 50 times, and cut off the wire, leaving 1 inch extra. Sand this end and wrap it around the last contact.

5. Wind the Third Arm of the Armature
Follow the same steps. Sand the coil wire end. Wrap it around the contact on which you just ended. Wind the last arm of the armature. Wind in the same direction as you did before. Cut the wire, leaving 1 inch. Sand the end. Wrap it around the orginal contact.

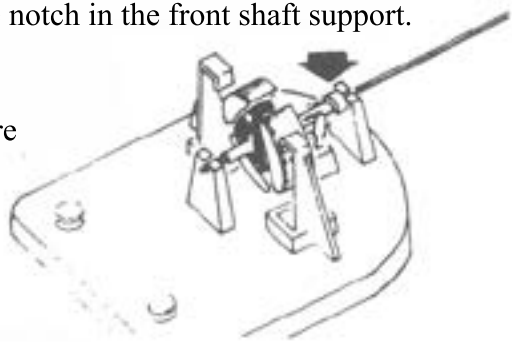
PUT YOUR MOTOR TOGETHER
1. Put the Armature into the Motor Base

Be careful not to bend or damage the brushes or the motor shaft.



Put the short end of the motor shaft all the way into the rear motor shaft support as in the drawing. Insert it at an angle, as shown, to keep from damaging the brushes.

Lower the long end of the motor shaft until it rests on the front motor shaft support. You may have to seperate the brushes very slightly to do this. Use a pencil to pry the tops ***gently*** apart. The long end of the shaft can then rest on the notch in the front shaft support.



Check to make sure the brushes are resting on either side of the armature contacts. The spacer cap should be between the brushes and the shaft support.

Press down firmly on the spacer cap. The armature and shaft will snap into place. You should be able to spin the armature between your thumb and forefinger.

2. Put Magnets into Magnet Holders

Slide one of the magnets all the way into one of the magnet holders as shown. There is a little "shelf" at the front of the magnet holder, near the brushes. Make sure the magnet sits all the way in with its front edge resting on the shelf. You may have to lift up slightly on the magnet to fit it onto the shelf.

Spin the armature to make sure it moves freely and does not touch the magnets at any point.

3. Put the Battery Holder in Place and Insert a Battery
Fit the holes in the bottom of the battery holder over the round projections in the base. Slide the battery holder towards the armature, to hold it in place. Put a D-cell into the battery holder.

4. Start the Motor
Hold the switch, (the flat metal piece attached to the loose battery wire) against the battery contact that does not have a wire running from it. This completes the electrical circuit. Your motor should start to spin rapidly. If it doesn't, give the motor shaft a spin with your other hand.

To keep the motor running, push the switch down between the battery and the battery contact. Pull the switch out when you want to stop the motor.

TROUBLESHOOTING
If your motor does not spin rapidly, check for each of the following. Usually the trouble is easily found and corrected.

a. Check the battery contacts. They should both be firmly pressed against the battery ends. If there is any space at all between the battery and the contacts, the motor won't work.
b. Check the brushes. They should both be pressing against the armature contacts. If they are not, remove the magnets and take out the armature by grasping the shaft next to the front support and lifting ***straight up***. Pinch the brushes together. Replace everything and try again.
c. Check the placement of the magnets. Make sure they do not interfere with the movement of the armature.
d. Does the armature rotate smoothly when you spin it by hand? The magnet's pull will slow it down a little, but it should not feel stiff. If it feels stiff, check to make sure you have not accidentally bent the motor shaft.
e. Make sure your battery is good.
f. Check the spacer caps all around. Make sure no bits of plastic are interfering with the spin.

g. Make sure each arm of the armature was wound in the same direction.

USING THE MOTOR IN THE MOTOR BOAT

When your motor is running at its best, you can use it to drive the boat:

1. Push the propeller firmly onto the end of the motor shaft.
2. Take the battery holder off the base. Put it flat in the battery holder space inside the boat.
3. Rest the motor base on the little shelves in the rear of the boat, with the propeller shaft slanting downward.

That's it. Your motor boat is ready to go. You can use it in a pond, a stream, a bathtub, or the ocean on a calm day. Just start the motor going and lower the boat carefully into the water. ***If your boat tips, balance it by putting paper clips on one side.***

Warning: If your boat goes backwards the first time you try it, remove the battery from the battery holder, turn it around, and put it back in. This will cause your motor to spin the other way and drive the boat in the proper direction.

THINGS TO DO WITH YOUR MOTOR

Try some different things with your motor. If you do them all, you'll have a pretty good idea of how and why your motor works.

1. Turn the Battery Around

Start the motor and notice the direction it spins. Take the battery out of the battery holder, turn it around, and put it back in. Start the motor again. Which direction does it spin now?

The direction a motor spins depends on the direction the electricity is flowing through it. You proved this by turning the battery around so that the electricty flowed first in one direction, then in another. Electricty comes out of the flat end of a battery and returns through the end with the button. So turning the battery around changes the direction of the current flow.

2. Exchange Magnets

Start the motor and notice the direction it turns. Stop the motor and take out the magnets. Exchange them and put them back into the magnet holders, so the left-hand magnet is now the right side and vice-versa.

Start the motor. Which direction does it spin now?

3. The Compass Needle and the Magnets

Since a motor works with magnets, you should learn something about magnetism to understand how a motor works. Use your compass needle. Make a stand by coiling a few inches of wire around one finger, leaving one end sticking up. Rest the needle on the end of the wire that sticks up.

Balance the compass needle on the stand, away from any metal or magnets. It should spin freely. The painted, arrow-shaped end should swing and point north (N). This is the N pole of the compass needle. The other end points south (S). This is the S pole of the needle.

Take the 2 magnets out of their holders. One at a time, bring the ***curved*** face of each magnet ***slowly*** towards the compass. Stop when the magnet is about 2 inches away from the needle.

You'll find that one magnet attracts the N pole of the needle. The other attracts the S pole.

The magnet that attracts N also repels S. Bring it near the S pole of the needle, and watch the needle spin away. The other magnet-the one that attracted S- repels N. Try it.

This experiment shows that the two magnets are different. Their curved faces are magnetized differently.

4. The Basic Law of Magnetism

If you bring these two magnetically opposite magnets together, what happens? Bring the two curved faces together.

You should find that they attract each other. This gives you the first part of the basic law of magnetism: ***opposites attract.***
Bring the curved face of one magnet and the flat back of the other, one at a time, near the compass needle. You'll find that ***magnetically*** they are ***alike***. They both repel or both attract the compass needle.
Bring the curved face of one magnet next to the flat/face of the other (remember, these faces are ***magnetically alike***, even though they're shaped differently.) The magnets repel each other.
This shows the second half of the basic law of magnetism: ***likes repel.***
The whole law is :***Opposites attract. Likes repel.*** North attracts South, and vice-versa. North repels North. South repels South.

5. The Armature is an Electromagnet
Set up the motor without the magnets. Put the compass stand on the rounded end of the motor base. Touch your switch to the battery contact. The second the electricity starts to flow, the needle spins and points to the nearest arm of the armature. The armature is a magnet as long as electricty is flowing through it. If you disconnect the switch, it stops being a magnet. This kind of magnet is called an ***electromagnet.***

Whenever electricty flows through a wire that is wrapped around metal, the metal becomes an electromagnet.

Reverse the battery. The compass needle spins and the other end points to the armature. Reversing the battery changes the direction that the current flows through the armature, and also changes the poles of the armature arms.

6. The Arms of the Armature Change Poles as They Move
Adjust the compass needle stand so that the needle is on the same exact level as the motor shaft, neither higher nor lower. Magnets are still removed.

Switch the motor current on. Once again the compass needle points to the nearest arm of the armature.

Now ***slowly*** turn the armature. Notice that the needle suddenly spins halfway around. As each arm passes the needle, the needle points first one way, then the other.
Each arm is changing from a north pole to a south pole, and vice-versa.

Look carefully where the brushes are touching the armature contacts. Notice that the changes take place whenever one of the brushes stops touching one contact and starts touching the one next to it. This happens first on one side, then on the other.

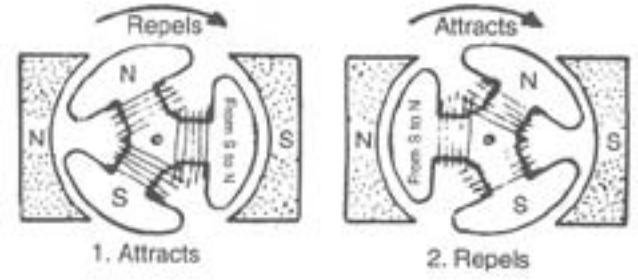
7. The Motor Magnets First Attract, then Repel, the Armature
The motor is designed with a N-face magnet on one side and a S-face magnet on the other.

When an arm of the armature approaches a magnet, it is electrically magnetized so that it will be ***opposite*** the magnet it is approaching. The arm approaching the N magnet will be an S. The other arm, approaching the S magnet, will be an N.

Opposites attract. So the arms are first attracted to the magnets and the motor turns.

As the arm goes past a magnet, it changes poles. It becomes ***like*** the magnet. ***Likes repel.*** And now the armature spins away.

The diagrams show what happens in two positions:



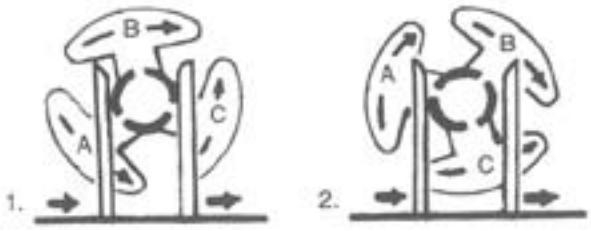
1. Attracts 2. Repels

8. Current Changes Direction Inside the Armature

In experiment 5, you saw that changing the direction of current flow through the arm of an armature also changes it from one pole to the other.

It is a change of current direction that keeps the arms of the armature switching poles back and forth, and that makes the motor spin.

Here's how the current changes direction:



When the current comes into the armature from the brushes, it splits and takes two different paths. Some current goes around the top and some goes around the bottom. The diagram shows the direction of current flow in the arms of the armature in two different positions:

Look at the direction of current flow in Arm A in Position 1. Now look at it in Position 2. Notice that the direction of current has changed in this arm. It stays the same in Arms B and C. But turn the armature a little more, and B will change.

If you look at where the brushes touch the armature contacts, as you slowly turn the armature by hand, you will see how the changing position of the contacts affects the direction of the current flows through each armature arm.

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