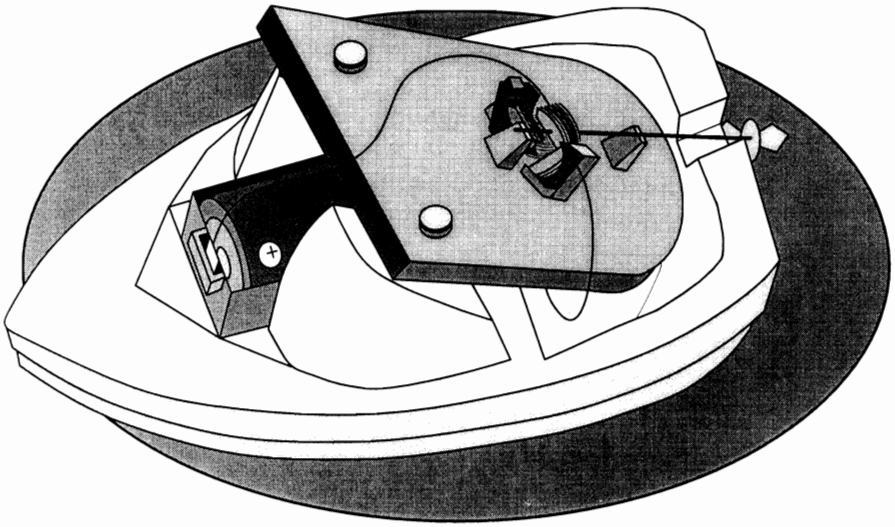
MIGHTY MOTOR

Build a real electric motor.
Power your own motorboat.

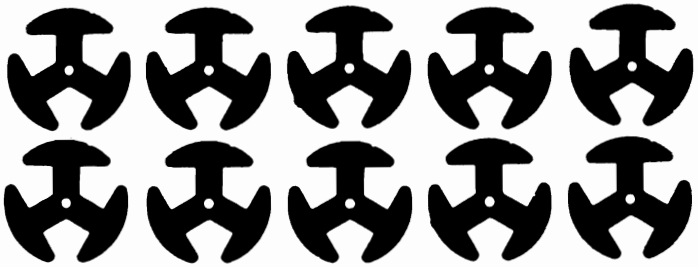


WARNING:

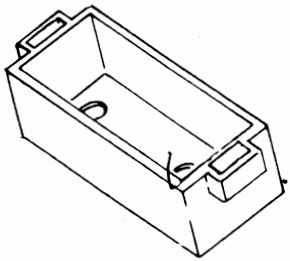
BE CAREFUL WHEN USING PARTS WITH SHARP POINTS OR EDGES.
KEEP AWAY FROM CHILDREN UNDER THREE YEARS OF AGE.
USE ONLY BATTERIES.
THE USE OF ANY OTHER ELECTRICAL SOURCE IS DANGEROUS.
DO NOT USE RECHARGEABLE (NICKEL-CADMIUM) BATTERIES.
ADULTS ARE ADVISED TO READ MANUAL AND SUPERVISE WHEN NECESSARY.

TREE OF KNOWLEDGE

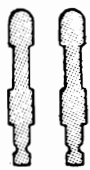
What's in your kit



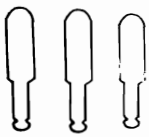
10 armature plates



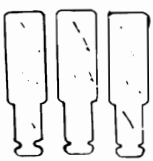
battery holder



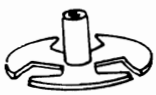
2 brushes (bronze)



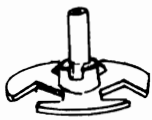
3 armature contacts (brass)



3 battery contacts

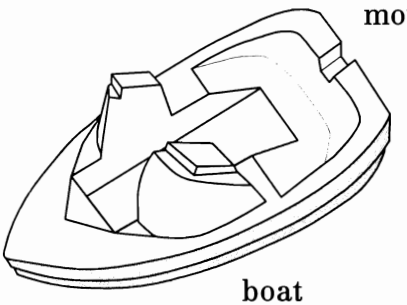


rear spacer



front spacer

motor shaft



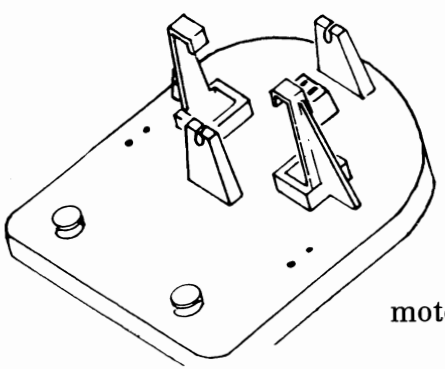
boat

propeller

compass needle

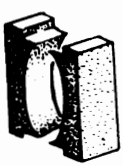
spacer ring

spacer cap

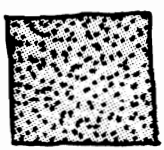


motor base

wire



2 magnets



sandpaper

You also need:
a pencil
a D-cell battery
a pair of scissors

BEFORE YOU BEGIN

Your Mighty Motor Kit is complete except for one important item: a D-cell battery. You will need one before you get started.

PREPARE PLASTIC PARTS

1. Cut plastic parts off the runner.

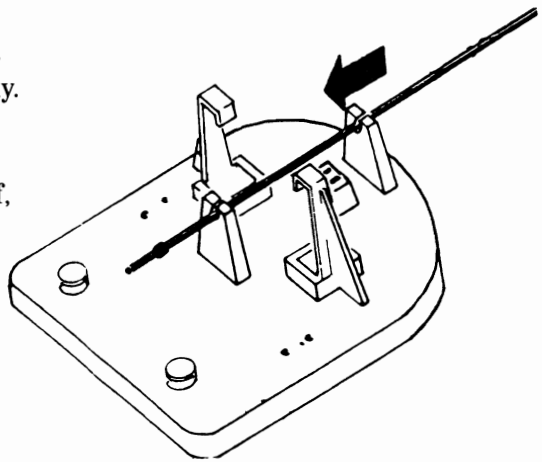
Carefully cut or break off the following 6 plastic parts that are attached to the runner: the motor base, battery holder, rear spacer, front spacer, spacer ring and spacer cap. Now you can throw the runner away.

2. Trim parts.

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

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 OK. If it feels stiff, the insides of the holes may need to be smoothed out.

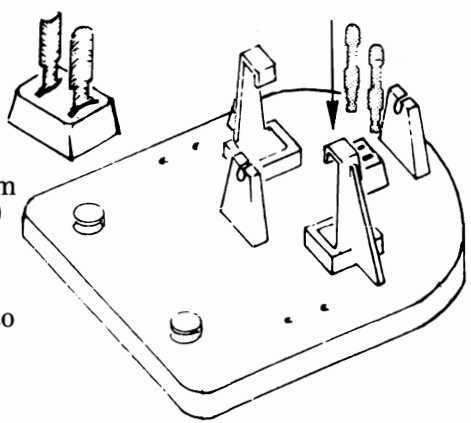
One end of the motor shaft has a double dent hammered into it. The shaft is a bit wider at this point. Use this dented end of the shaft like a ramrod to smooth the inside of the holes. Move it rapidly in and out of each hole.

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 smoothed 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.

Take the two copper-colored metal pieces that electricians call "brushes." They bring the electricity to the motor.



Note that close to the curved end of the motor base is a nearly square pillar with 2 slots in it. The brushes go into these slots. 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.

Fit the brushes, facing in the correct direction, into their slots. The ends should come out the other side of the base, underneath it.
Be careful not to bend the brushes.

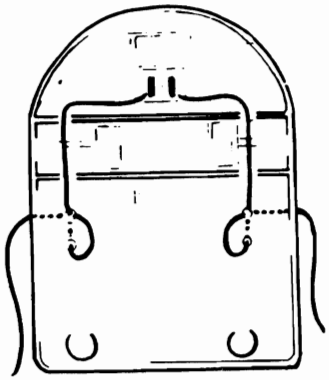
2. Prepare the 2 battery wires.
Cut off 2 pieces of wire from the coil of wire that comes in your kit. Each piece should be 9 inches long.

3. Sandpaper 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. This will scrape off some of the orange coating on the wire. Repeat several times, twisting the wire each time, until about 1 inch at the end of the wire is bare, shiny copper all around and there is no trace of the orange coating.

Sandpaper all 4 ends of the two wires. Be sure no orange coating is left for a distance of 1 inch from the tips of the 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. Take the other wire and wrap a bare end around the end of the other brush.

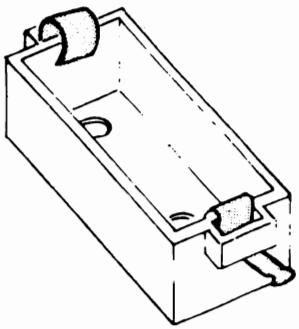
5. Bring the battery wires to the top of the base.
Take one of the battery wires underneath the base, lead it out toward the side of the base and pass it through the slots in the ribs, as the diagram shows. Put it through one of the little holes, then back through the neighboring hole, then through the first hole again. The wire ends up on top of the base. Do this with both wires.



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

PREPARE BATTERY HOLDER

1. Prepare 2 battery contacts.
Take 2 of the battery contacts and bend the wide ends around a pencil. They should look like the drawing. The third battery contact is *not* bent.



2. Put battery contacts into battery holder.
Drop the two battery contacts into the slots at the end of the holder. The curved ends go inside the holder. Then the notched ends up and out, as the drawing shows.

3. Attach battery wires
Take the third battery contact - the *unbent* one. Wrap the bare end of one of the battery wires around the notched end of the 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. This leaves the second battery contact with 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.

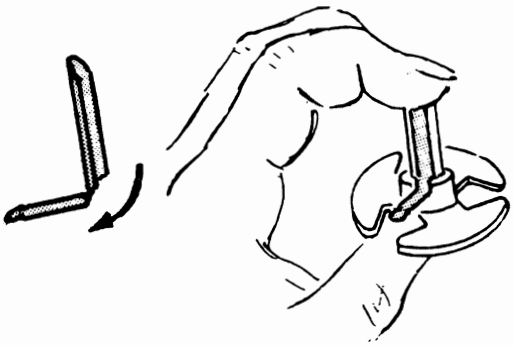
1. Slip the rear spacer onto the motor shaft.
Take the rear spacer and slip it, *the end tube side first*, onto the end of the motor shaft without the dents. Slide the spacer all the way up the shaft, up to the dents. Then slip the tip of the tube over the dents, so the dents hold the spacer in place.

Be sure you have the rear spacer. It has a shorter end tube than the front spacer.

2. Stack the armature plates.
Take the 10 armature plates and stack them, one on top of another. Notice that each plate has a tiny notch at the edge of one of its 3 T-shaped arms. These notches should line up.

When the plates are evenly stacked, with all notches in line, you can hold them in place by carefully picking them up and inserting a pencil into the space between two of the arms of the plates. Slide the plates all the way onto the pencil, and they will not drop off.

3. Bend the 3 armature contacts.
Take the 3 brass armature contacts and bend each of them into an L-shape, as in the drawing. The notched ends must bend away from the hollow (concave) side of the contacts. Check the drawing carefully.



4. Fit the contacts onto the front spacer and hold them in place with the spacer ring.
This step is one you have to be careful with, since you're working with small parts. Hold the front spacer between your thumb and forefinger, the way the drawing shows.

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.

Now carefully give the spacer (and contact) a 1/3 turn. Fit the second contact against the tube. Fit the last contact the way you did the other two.

Finally, slide the spacer ring 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.

Take the front spacer and slide it onto the motor shaft so that it fits *flat* against the armature plates. Take the spacer cap and slide it 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:

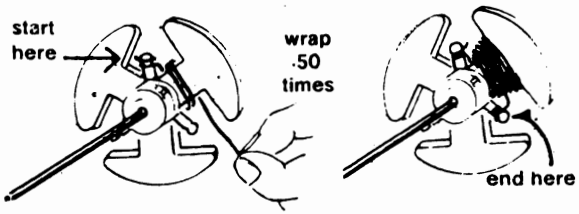
1. Attach wire to an armature contact.

Sandpaper the end of the wire on your wire coil. Clean it free of orange coating for a distance of 1 inch from the end. Wrap the bare end of the wire around one of the armature contacts. Wrap it around 2 or 3 times.

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, the way the diagram shows. Continue wrapping the wire around the stem of the "T." Wrap 50 times. Wrap firmly. The closer together your windings are, the better. Be sure your wire doesn't snag on anything.



After 50 turns, cut off the wire, leaving an end 1 inch long. Put the rest of the coil aside. Since your wire is now holding everything together, you can get rid of the pencil.

3. Attach the end of the wire to the second armature contact.

Sand the end of your armature wire a distance of 1 inch, as you did before. Then wrap the bare end around the other contact that is next to the arm you just wound. Your 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.
Sandpaper 1 inch of the end of the coil wire. Wrap it around the contact you just ended on. Then wind the second arm - back through the slot, down, around, and up, in exactly the same way you did the first. Wind 50 times, and cut off the wire, leaving 1 inch extra. Sandpaper this end and wrap it around the last contact.

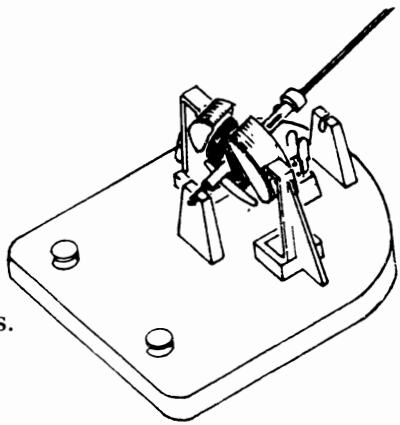
5. Wind the third arm of the armature.

Follow the same steps. Sandpaper the coil wire end. Wrap it around the contact you just ended on. Wind the last arm of the armature. Wind in the same direction as you did before. Cut the wire, leaving 1 inch. Sandpaper the end. Wrap it around the contact you originally started with.

PUT YOUR MOTOR TOGETHER

1. Put the armature into the motor base.

Follow these steps to put the armature into the motor base. You must be careful not to bend or damage the brushes. Do not bend the motor shaft either.

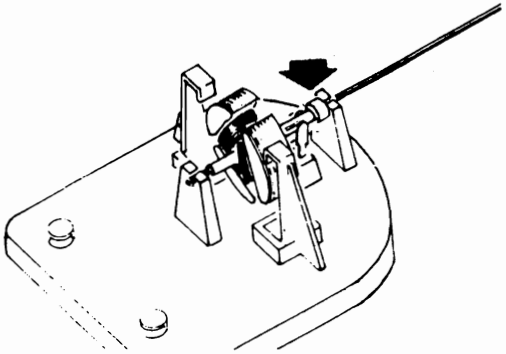


Put the short end of the motor shaft all the way into the rear motor shaft support, as shown in the drawing. Insert it at an angle, as shown, to keep from damaging the brushes. Lower the long end of the motor shaft until it rests on the front motor shaft support.

You may have to separate 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.

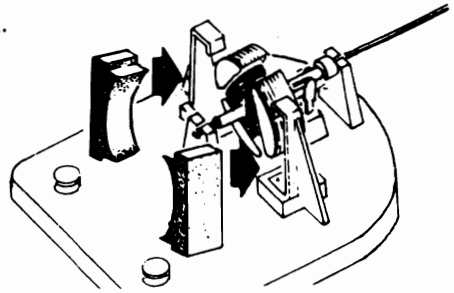
Check to make sure the brushes are resting on either side of the armature contacts. The spacer cap should be between the brushes and the shaft support.

Now 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.
Take one of the magnets and slide it 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. Then slide the battery holder towards the armature. The base should hold in place. Put a D-cell into the battery holder.

4. Start the motor.
Take the switch (the flat metal piece attached to the loose battery wire). Hold it 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. This should do the trick.

When you want the motor to keep on running, push the switch down between the battery and the battery contact. This will hold the switch in place, and the motor will run. Pull the switch out when you want to stop the motor.

TROUBLE SHOOTING
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 a good one. Old batteries are often dead batteries.

f) Check the spacer cap all around. Make sure no bits of plastic are interfering with the spin.

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

USING THE MOTOR IN THE MOTORBOAT
When your motor is running at its best, you can use it to drive the boat that comes with the kit. Here's what to do:

Remove the battery holder carefully, making sure not to damage the wire connections (to the battery).

Place the battery and holder so that the battery fits between the 2 supports at the front of the boat.

Fit the motor base above the battery and the supports, so that the round part of the base goes to the back of the boat.

Make sure that the shaft does not touch the boat.

Start the motor going and lower the boat carefully into the water.
You can use it in a pond, a stream, a bathtub, or in the ocean on a calm day.

Warning: Your boat may go backwards the first time you try it. If so, just take 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.

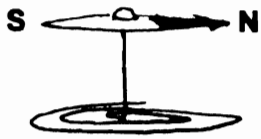
THINGS TO DO WITH YOUR MOTOR
Here are some different things you can do with your motor. If you do them all, you'll have a pretty good idea of how and why your motor works.

1. Turn the battery around.
Start your motor and notice in which direction it spins. Then take the battery out of the battery holder, turn it around, and put it back in. Start the motor again. In 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 electricity flowed first in one direction, then in another. Electricity 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. Now stop the motor and take out the magnets. Exchange them and put them back in the magnet holders, so that the left-hand magnet is now on the right side and vice-versa. Start the motor.
In 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. Your compass needle is used in this part of the instructions.



Take a few inches of wire. Coil the 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.

Now 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
Now if you bring these two *magnetically unlike* 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: ***unlikes attract.***

Now bring the curved face of one magnet and the flat back of the other, one at 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 are shaped differently.) The magnets repel each other.

This shows the second half of the basic law of magnetism: ***likes repel.***

The whole law is: ***Unlikes attract. Likes repel.*** North attracts South, and vice-versa. North repels North. South repels South.

5. The armature is an electromagnet.
Now 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 begins to flow, the needle spins and points to the nearest arm of the armature. The armature is a maget as long as electricity is flowing through it. If you disconnect the switch, it stops being a magnet. This kind of magnet is called an ***electromagnet.***

Whenever electricity flows through a wie that is wrapped around metal, the metal becomes an electromagnet.

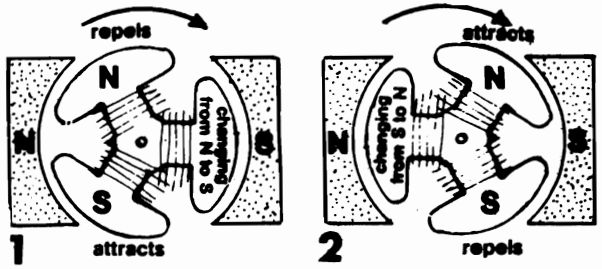
Now reverse the battery. The compass needle spins and the other end points to the armature. Reversing the battery changes the direction that current flows through the armature, and also changes the poles of the armature arms.

6. The arms of the armature change poles as they move.
Adjust the compass needle stand so that the needle is on the exact level as the motor shaft, neither higher or 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 ***unlike*** 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.



Unlikes attract. So the arms are first attracted to the magnets and the motor turns. As the arm goes past the magnet, it changes poles. It becomes ***like*** the magnet. ***Likes repel.*** And now the armature spins away.

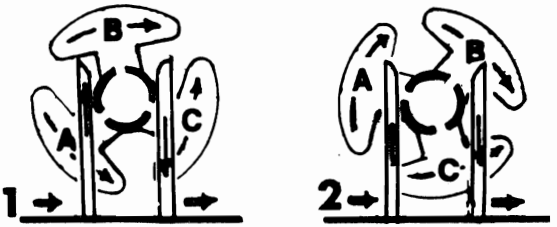
The diagram shows what happens in two positions.

8. Current changes direction inside the armature
Previously in Activity 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.

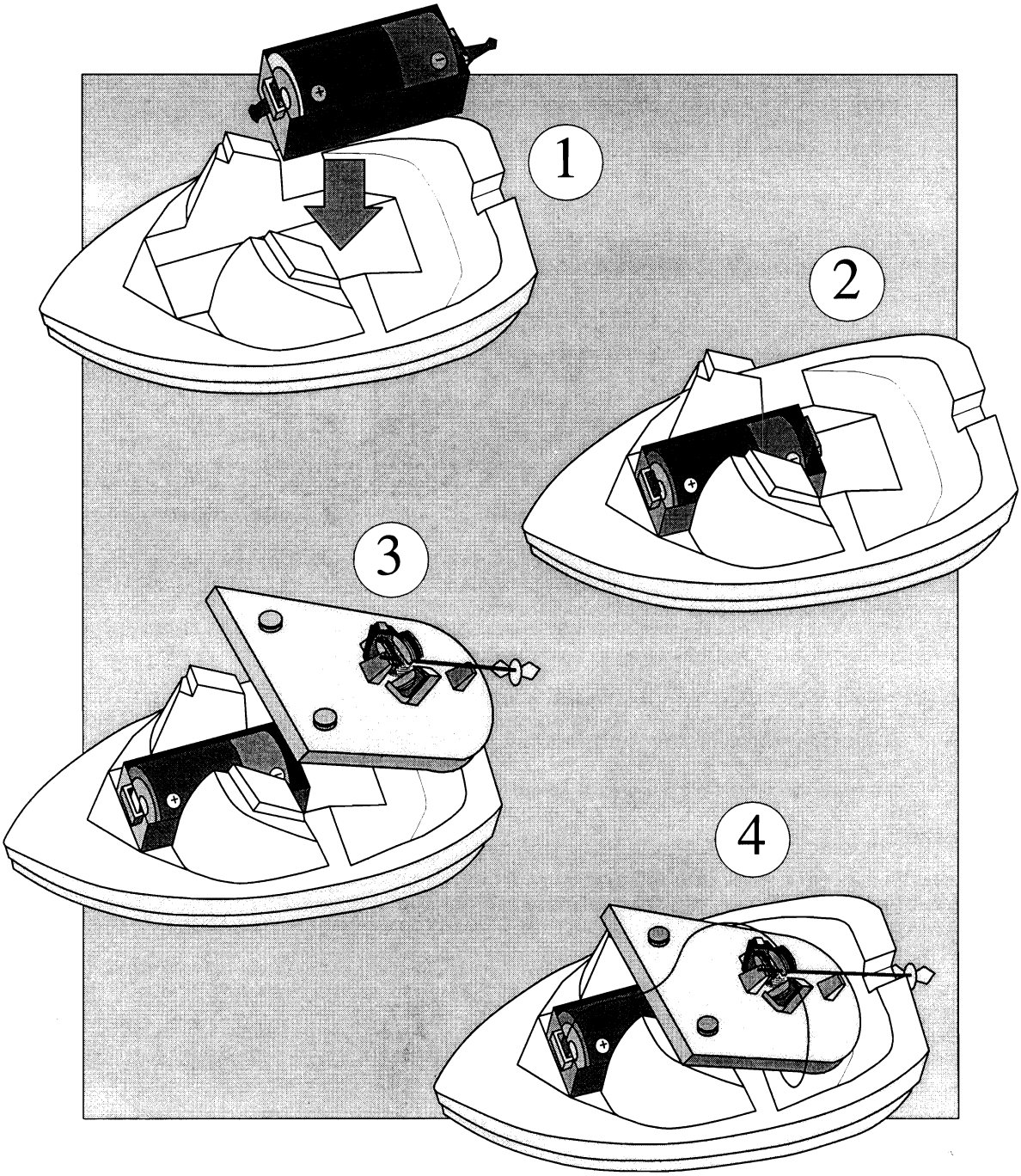
It is a change of current direction that keeps the arms of the armature switching poles back and forth, and that makes the motor spin. Here's how the current changes direction:

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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