www.pl.euhou.net
Logo designed by Armella Leung,
www.armella.fr.to

Maria Dobkowska
Zespół Szkół Integracyjnych nr 62
im. Raoula Wallenberga
Warsaw, Poland

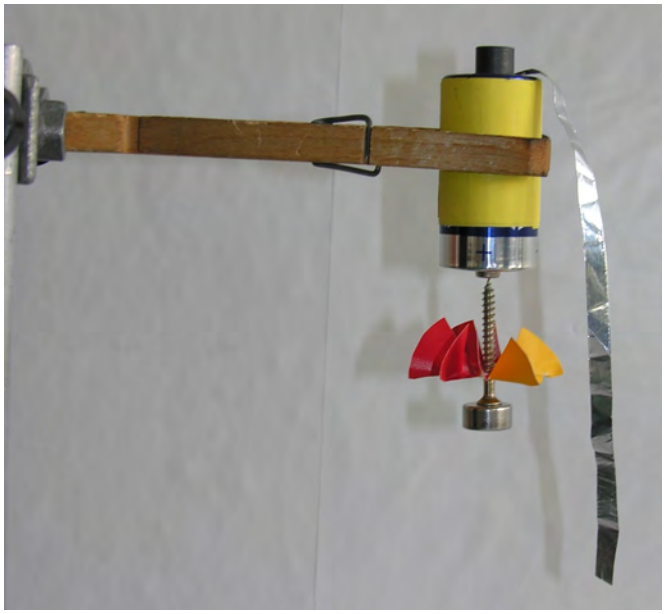
Arvind Gupta
ArvindGuptaToys, India
http://www.arvindguptatoys.com/

Ariel Majcher
The Andrzej Soltan Institute for Nuclear Studies,
Otwock-Świerk, Poland

Krzysztof P. Wojewoda
Zespół Szkół Ogólnokształcących nr 4
Bydgoszcz, Poland

Simple models of an electric motor

Easy-to-make models of an electric motor have been shown at the international festivals Physics on Stage and Science on Stage, visited by teachers and popularizers of physics and other natural sciences. We wish to describe here two slightly modified models of an electric motor, which can make physics lessons far more interesting. Both models can be easily made by each pupil of the middle school (gymnasium), whereas in high school the models can encourage pupils to further analysis of acting forces.



1. Necessary materials

For building a motor you will need the following materials:

- ➔ battery (any of the following: R6, R14 or R20),
- ➔ scissors,
- ➔ round neodymium magnet; currently neodymium magnets are easily accessible and cheap; we recommend buying between ten and twenty magnets to your physics laboratory (E-Bay!), because they can be useful for many interesting demonstrations and experiments.

In case of a **motor** with a **rotating magnet** you will also need:

- ➔ aluminium foil (typical, meant for being used in a household or e.g. in baking),
- ➔ flat ferrite magnet for holding the foil,
- ➔ screw or nail; the nail should be steel and not brass,
- ➔ colourful paper.

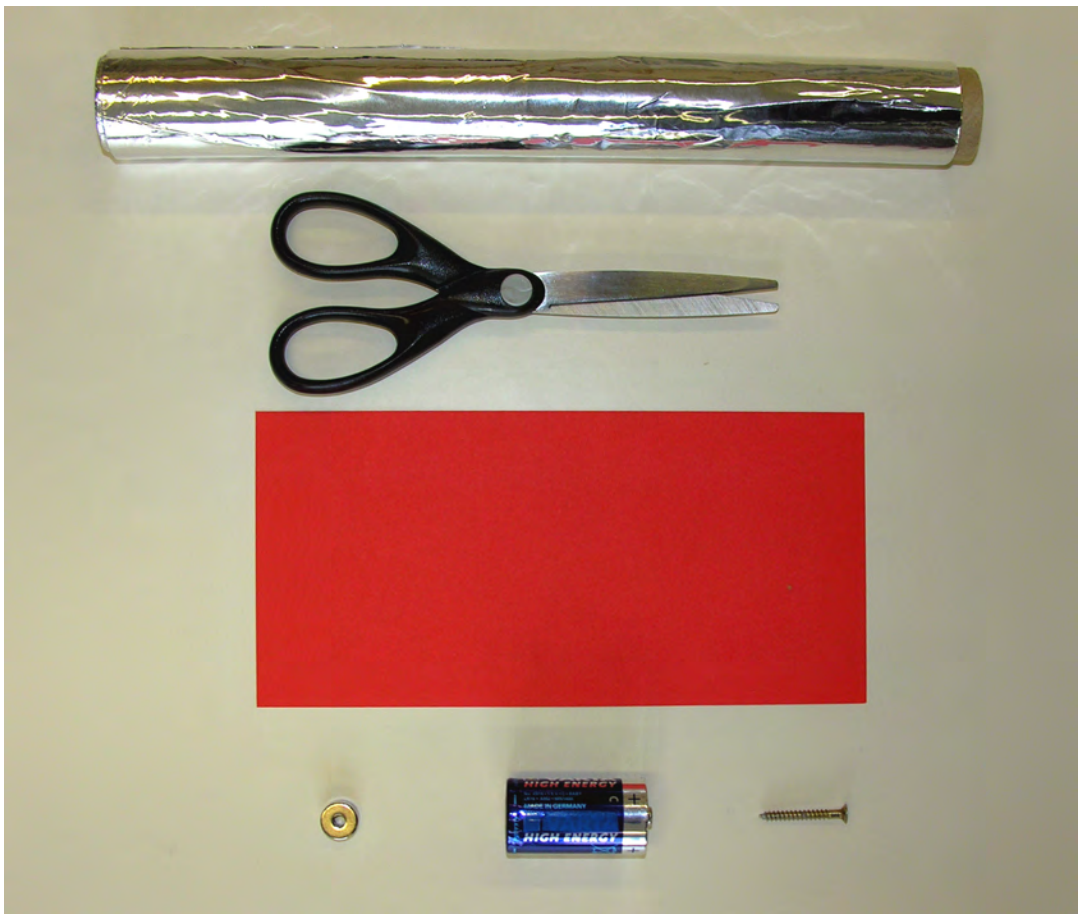


Fig. 1: A set of tools necessary for making a motor with a rotating magnet

In case of a **motor** with a **rotating frame** you will also need:

- ➔ copper wire without insulation with a diameter between 0.5 and 1 mm,
- ➔ neodymium magnet,
- ➔ sharp knife to scrape insulation off the wire.

Fig. 2: A set of tools necessary for making a motor with a rotating frame

We will also how to build a DC **motor** with a rotating **coil**:

- ➔ two fair-sized safety pins,
- ➔ rubber band,
- ➔ considerable section of an enamelled copper wire 0.25 – 0.5 mm,
- ➔ neodymium magnet.

Fig. 3: A set of tools necessary for making a motor with a rotating coil

2. Performance

- **version with a rotating magnet** (M. Dobkowska, A. Majcher)

Cut a narrow, 3 cm wide and 15 cm long strip out of the aluminium foil. The strip shall be folded in length to make it stiffer.

Cut a fan out of paper, which will help you to observe the direction of a magnet's rotation. We suggest you to cut a circle out of paper with diameter about 4-5cm and notch the margins in such a way to form rotor blades. In the centre of the circle make a small hole and put your fan over a screw (or a nail). It is of great importance that the screw was steel and not brass.
Press a round neodymium magnet against the screw (or nail) head and a blade against one of the battery poles (e.g. against "+"). The battery shall be kept vertically in your hand or fixed to a tripod stand. The screw remains at the battery pole and it does not come off thanks to a strong magnetic interaction.

Press one of the ends of the aluminium foil strip against the other battery pole ("-"), whereas the second end of the strip press against the side wall of the suspended magnet. That strip end shall be pressed against the wall in a way to make it slide like a "brush" over the magnet wall.

Beware: current flowing through a foil strip can have a big amperage and the foil can become very hot. For that reason try to fix with a small ferrite magnet (e.g. such as used in magnet boards) the foil end that constantly touches the battery pole.

That is all. Now you can see how your satisfied students watch a quickly rotating magnet (with a screw and fun). Make your students experiment with a motor to see the direction of a magnet rotation when changing location of poles in a battery (that is change of direction of a flowing current) and poles in a magnet.

The photo below shows an assembled and described motor ready for starting:

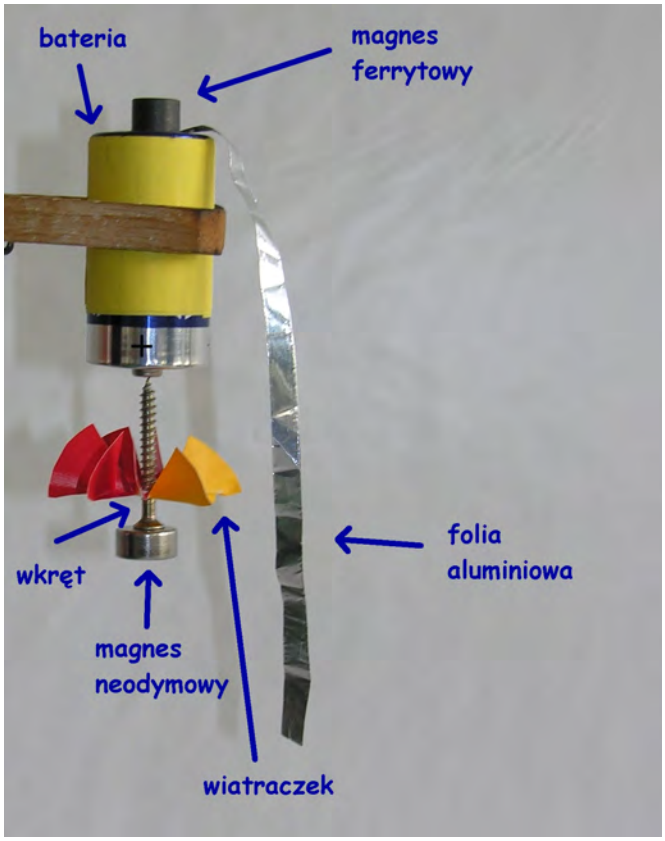


Fig. 4: An assembled and described motor with a rotating magnet

Click here to see a film showing assembly and starting of a motor. Check also what will happen if you reverse a battery cell.

- **a motor with a rotating frame** (Grzegorz F. Wojewoda)

Cut with scissors a piece of a copper wire about 40 cm long. Copper wires are usually covered with enamel that functions as an insulation. In half of its length, at the section of about 8 cm, remove (of course using scissors) an insulation. A copper wire can be "recovered" from any electric cable:

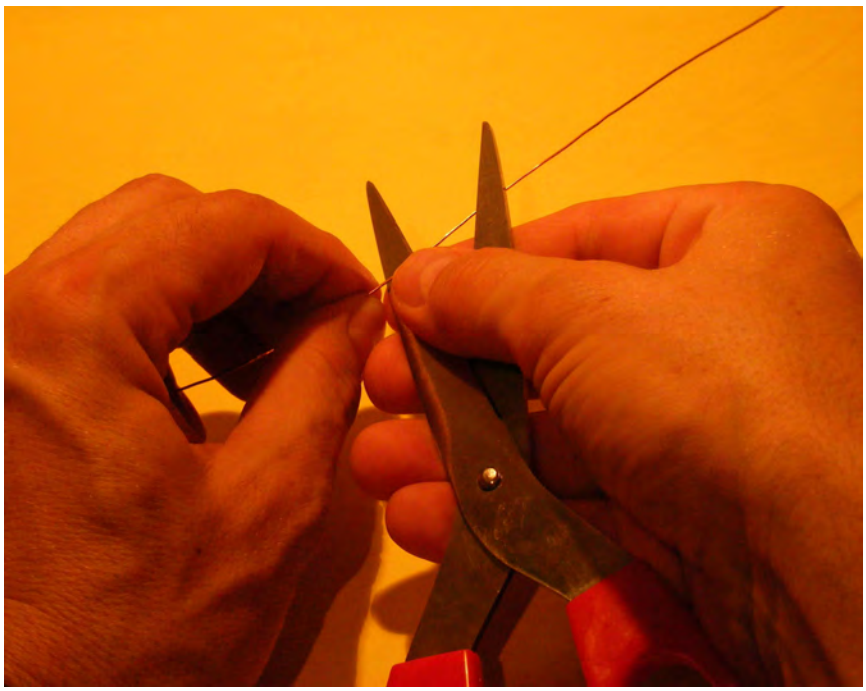


Fig. 5: Remove insulation from a segment of the wire

Start making a frame from forming a “loop”. The loop has to be made from the part of wire without insulation. Be careful not to let any parts of a wire to touch each other:

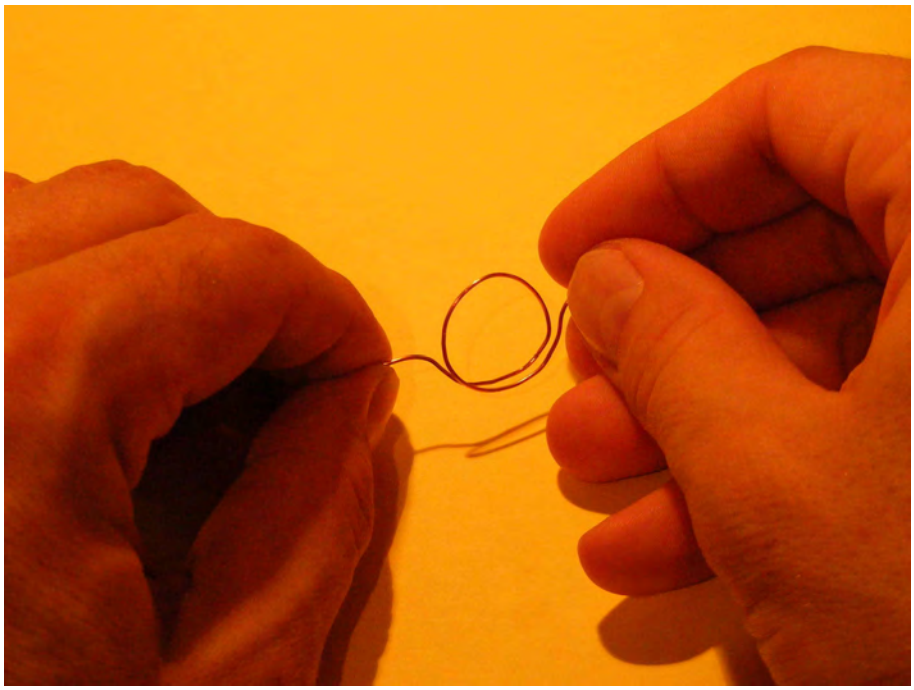


Fig. 6: Shaping your frame start from making a loop

Next, bend the sides of a frame. The frame dimensions shall be chosen in such a way that the frame wires were located about 0.5 cm away from a battery cell. Frame bending finish by preparing wire ends to slide on the top part of a battery cell. Cut away wire ends that are too long, of course using scissors:

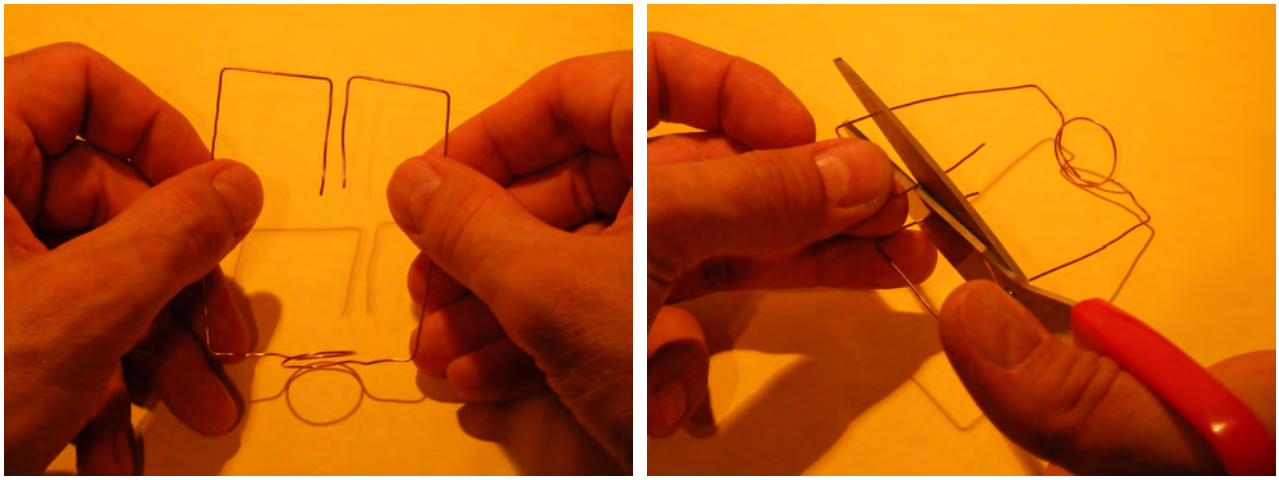


Fig. 7: Fully formed frame

Fix frame, prepared in that way, to a battery cell with a magnet:

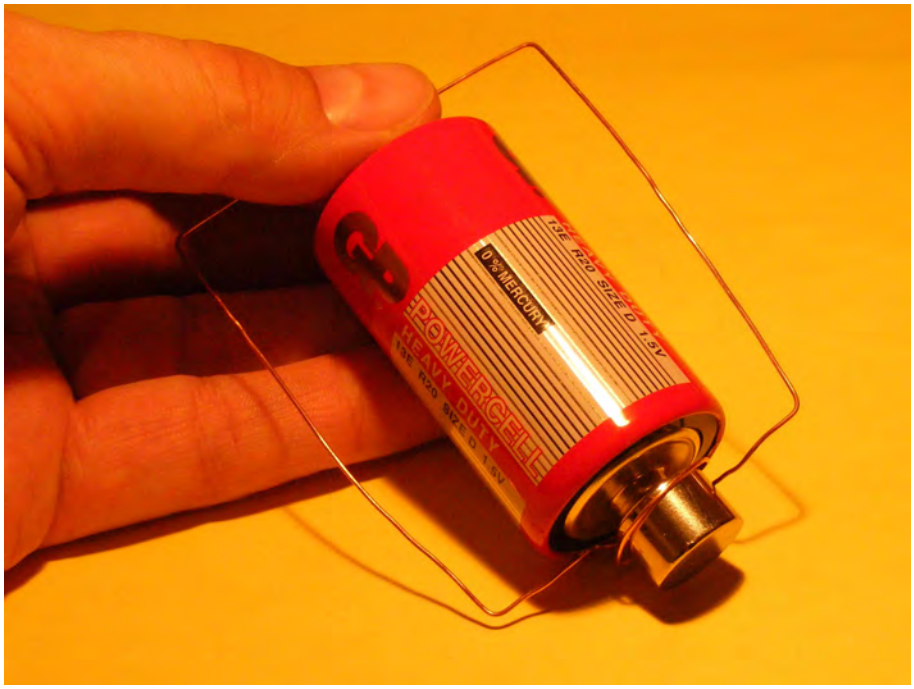


Fig. 8: Final stage of a motor assembly

And now you can already see a rotating frame, that is a working model of an electric motor (the photo of a motor in motion):

Fig. 9: A photo of a rotating motor with a frame

Click here to see the film showing an assembly and starting of an electric motor with a rotating copper frame.

When playing with the motor, try to check what will happen if you reverse a battery cell or a magnet.

- **DC motor with a rotating coil** (Arwind Gupta)

The assembly of a motor start from winding the coil of copper wire. The coil should have 10 – 15 turns. Too many turns will make the coil too heavy and too few turns will deteriorate motor functioning. For winding the wire you can use a battery cell, as shown at the photo below, or other tube of a similar or a bit smaller diameter. You can use even your own finger!

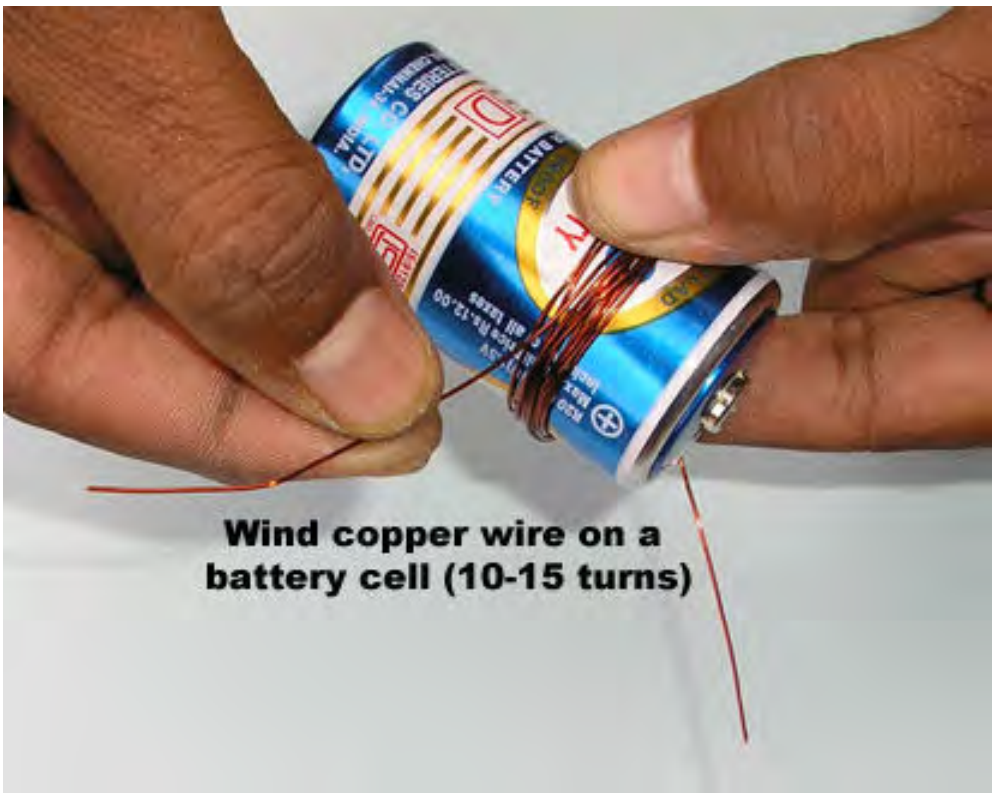


Fig. 10: Winding the coil

Tie the coil ends carefully and leave them outwards, as shown at the photo:

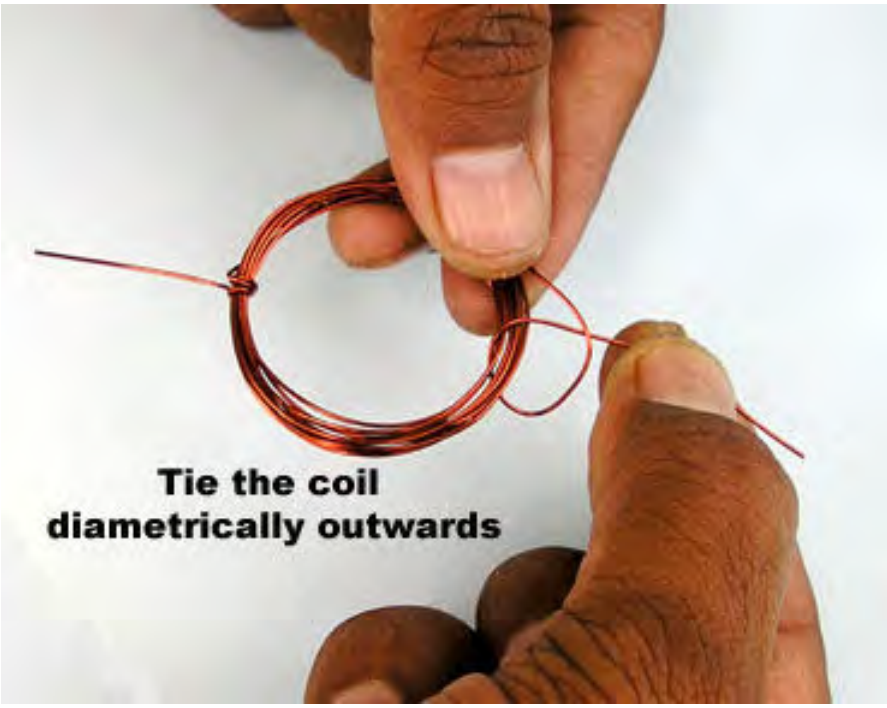


Fig. 11: Terminating the coil

Now scrape the enamel (insulation) from the coil ends but only from a half of diameter of a copper wire, as shown at the photo! If you remove enamel from the whole diameter, and put your motor in motion, the coil will be accelerated by the Lorentz force during half of its rotation and slowed down during the

other half of its rotation. Your motor will work unsteadily and it will rotate in two directions, depending on the direction in which you push the coil at the beginning. Image a tram that goes form its stop forward or backward, depending on which direction you push it... An electric motor of DC type is a device useful in everyday life exactly for giving possibility to control the direction of motor rotation. And that is the type of a motor we want to build. Remember to scrape the enamel (insulation) from the both coil ends **from the same side!**

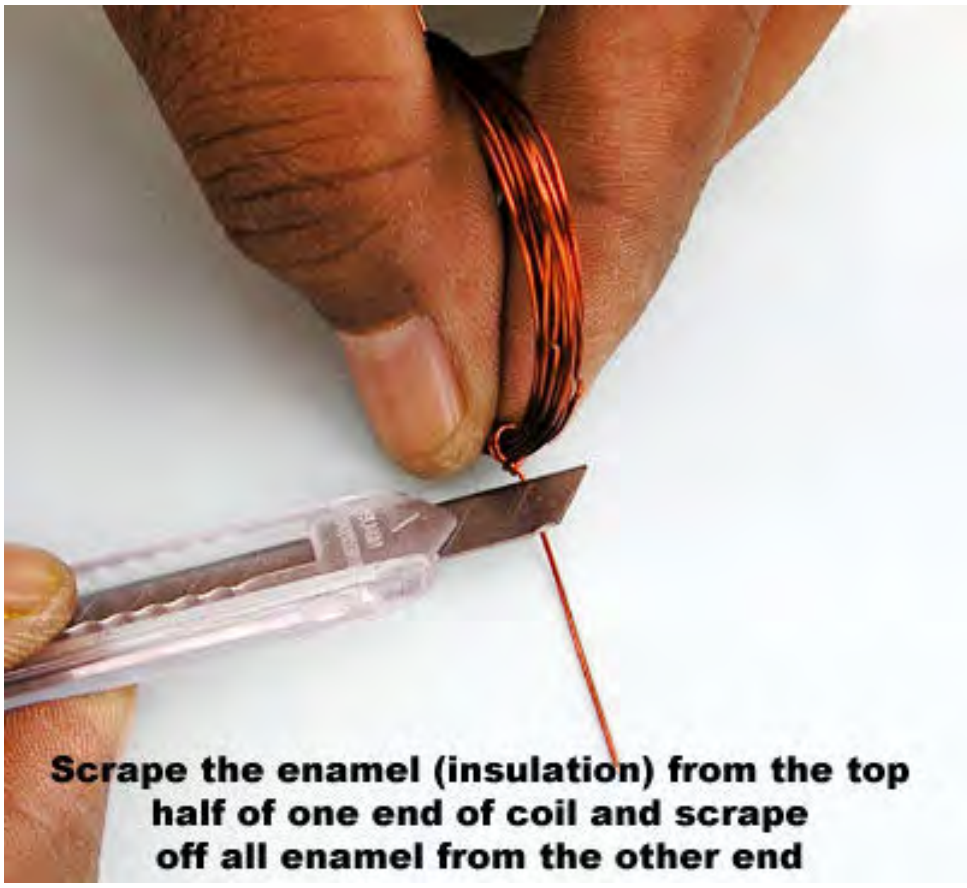


Fig. 12: Removing insulation.

Now fix safety pins and a magnet using rubber bands, as shown at the photo. Insert coil ends into “eyes” of the safety pins and the motor is ready!

Fig. 13: Assembly of a motor. If a battery cell has a metal case, the rubber band for keeping magnet in place will not be necessary.

Our motor at work!

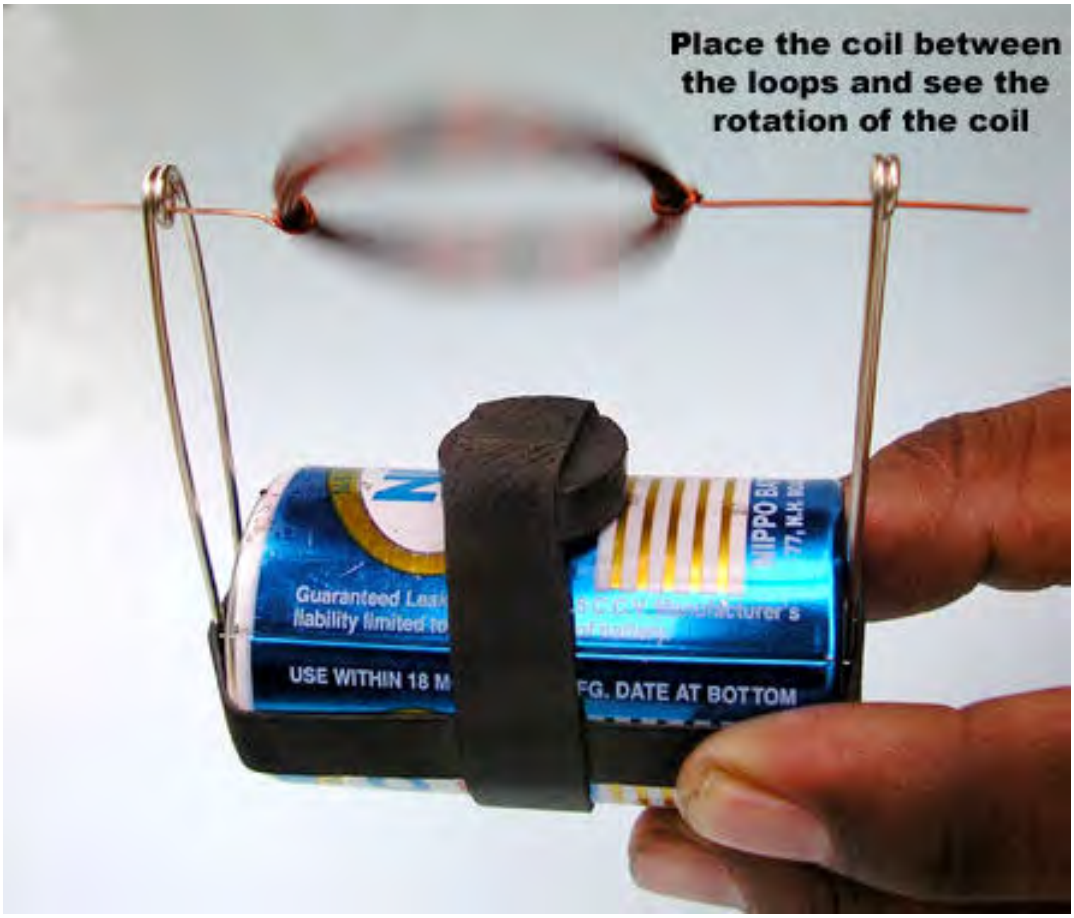


Fig. 13: Our motor at work.

If you have the second magnet you can hold it on the top of the rotating coil and see whether the motor accelerates or slows down. Or maybe speed changes depend on the position of magnet poles?

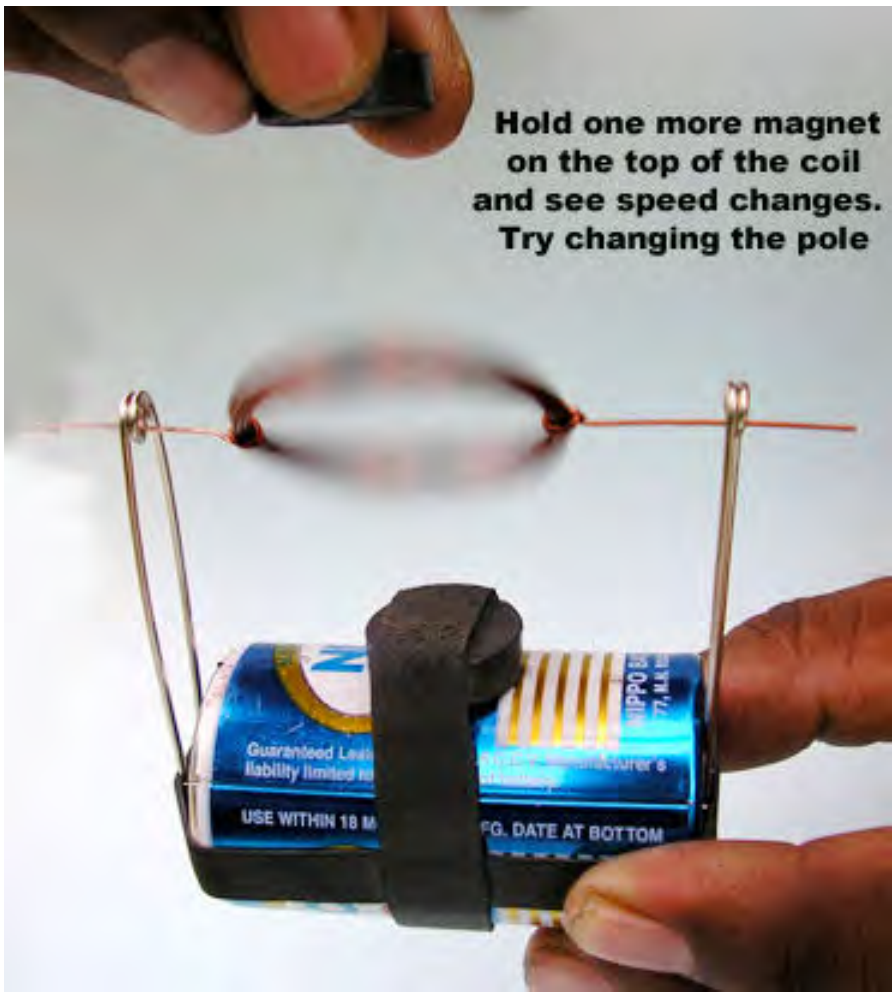


Fig. 14: Experiments with a motor

Have fun!