Marieke Thomas
SEDC 73600

# Lesson Plan 1-2: Analog Motors

**Unit:** Arduino Motors Unit

**Previous lesson:** LCD Project
**Next lesson:** Intro to Digital Motors

**Main objective:** Students will be able to build functioning simple motors. Students will be able to explain how motors convert energy and explain how a motor works based on the hand rules for magnetism.

**Standards:** Note that this is an engineering standard from the New York State Science Learning Standards rather than a Computer Science standard.

*HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.*

**Timing:** This is a 2-period lesson. It is strongly recommended to do the entire lesson in a double period rather than on two consecutive days.

**Prior knowledge:** Students have previously learned the hand rules for magnetism.

**In-class exercises:** The students will complete the motors assignment, below.

**Notes:** To test the wire coils, you can buy one of these commercially available kits and have students place their coils on it: https://www.teachersource.com/product/worlds-simplest-motor

The wire coil should be as close as possible to the magnet without touching it.

You can try having students add more magnets and see how that affects the motor.

**Resources:** This is a great video on simple motors: https://www.youtube.com/watch?v=4CGjs-Z7bDE

See this commercial lesson plan for more details and ideas for extensions:
https://cdn.commercev3.net/cdn.teachersource.com/downloads/lesson_pdf/SS-11.pdf

**Materials:** D cell battery, paper clips, sand paper/coin, magnet wire, magnet, tape

**Assignments:** The class assignment for students is below, with the answer key on the following page.

**Formative assessment:** The entire worksheet is a formative assessment, but especially the summary where students explain how a motor works.

**Lesson:**
5 min: Do Now: Identify 2 uses of motors in your daily life
- Pair-share with neighbor
- Share with class (5 examples)

5 min: What are motors?
- In our new unit, we will be working with motors. In the next lessons, we'll program motors with the Arduino to perform more complicated tasks like responding to user input, moving a certain amount, etc. But today we are

going to introduce the basics of what a motor is and how a basic motor works. You'll build your own simple motors.

- Ask class: what is a motor?
- Notes: Motor: a device that converts electrical energy to mechanical energy
- For the fan in the classroom, where does the electrical energy come from? Wall outlet. What sort of mechanical energy is generated? Kinetic energy of fan blades spinning.
- Today we're going to make our own motors!

60 min: Motors Activity

- Students construct motors following the directions on the handout below.
- Once students successfully get their motor moving:
    - Optimize by changing wire shape, number of coils, number of magnets, type of magnet (neodymium vs iron)
    - Help neighbors
    - Complete worksheet

20 min: Explain

- Go over answers to the worksheet with the class (answer key is provided below)
- For Q4, show the class a commercially-available motor:

- If there is extra time at the end, show part of this video on simple DC motors: https://www.youtube.com/watch?v=4CGjs-Z7bDE

The Bronx High School of Science
R. Hoyle, Principal

Physical Science Department
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**Name** ________________________________________ **Partner(s)** ______________________________________

**Day/Periods** _________ **Date** ______________________

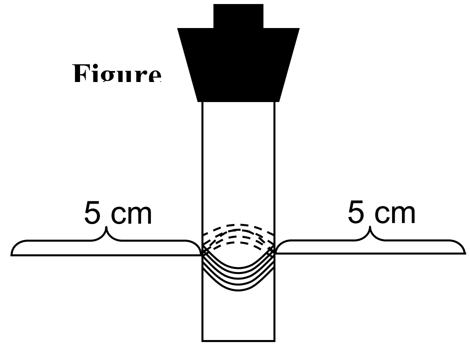
# Motors Activity

**<u>Problem:</u>** How do motors work? How can we build a simple motor?

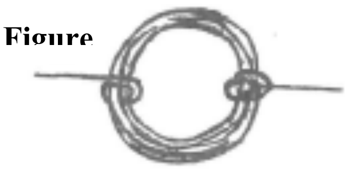
**<u>Materials:</u>** D cell battery, paper clips, sand paper/coin, magnet wire, magnet, tape

**<u>Procedure:</u> Part 1: Constructing a simple motor**

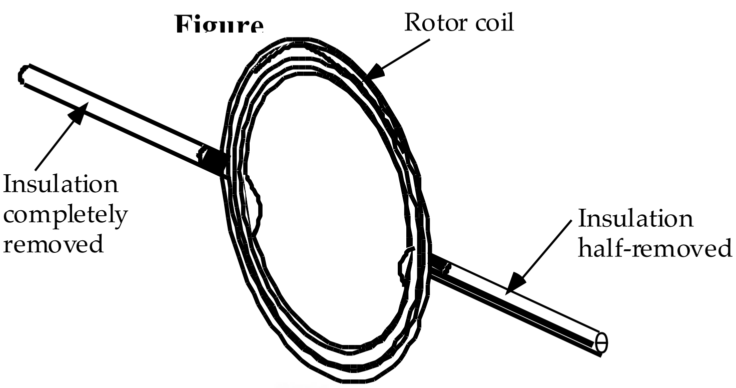
a. Wrap a magnet wire (#24) around a marker or your D-cell battery, as shown to the right, to serve as the coil. Leave about 5 cm of wire on sticking out from either side. [Figure 1]




b. On opposite sides of the coil, wrap the two loose 5 cm ends around the coil for 2 turns to keep it tight. You should have some leads sticking out to spin on. To check if it will work (spin), place these ends between thumbs and pointer finger and make sure it will spin evenly. If not, bend leads accordingly. [Figure 2]



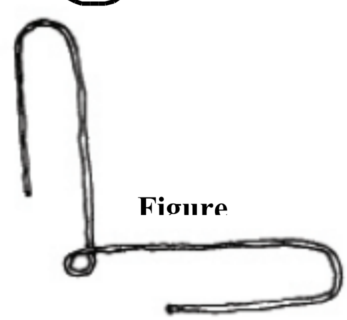

c. The leads sticking out must be altered. Use sand paper or the side of a dime to strip off the insulation off one of the leads and only sand the top side on the other. Make sure the stripped side points up when the loop is vertical, not horizontal. [Figure 3]




**Part 2: Final Motor Assembly.**

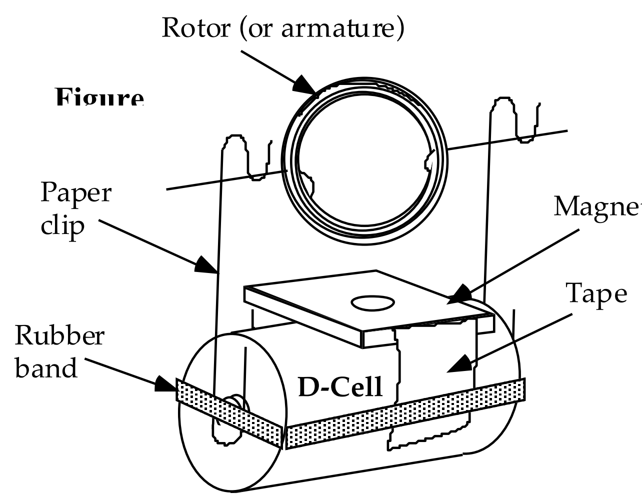
d. Tape a flat magnet to a D-cell as shown in the figure on the right. (To stabilize the D-cell, you may want to tape it to the desk or to an upside-down foam cup.)

e. Bend the paper clips as shown in the diagram. [Figure 4]




f. Attach the paper clips to the D-cell with tape (or your fingers). Align the notches at the top of the paper clips so that the armature/coil will be level. The bottom of coil should be as close to the magnet as possible without touching the magnet.

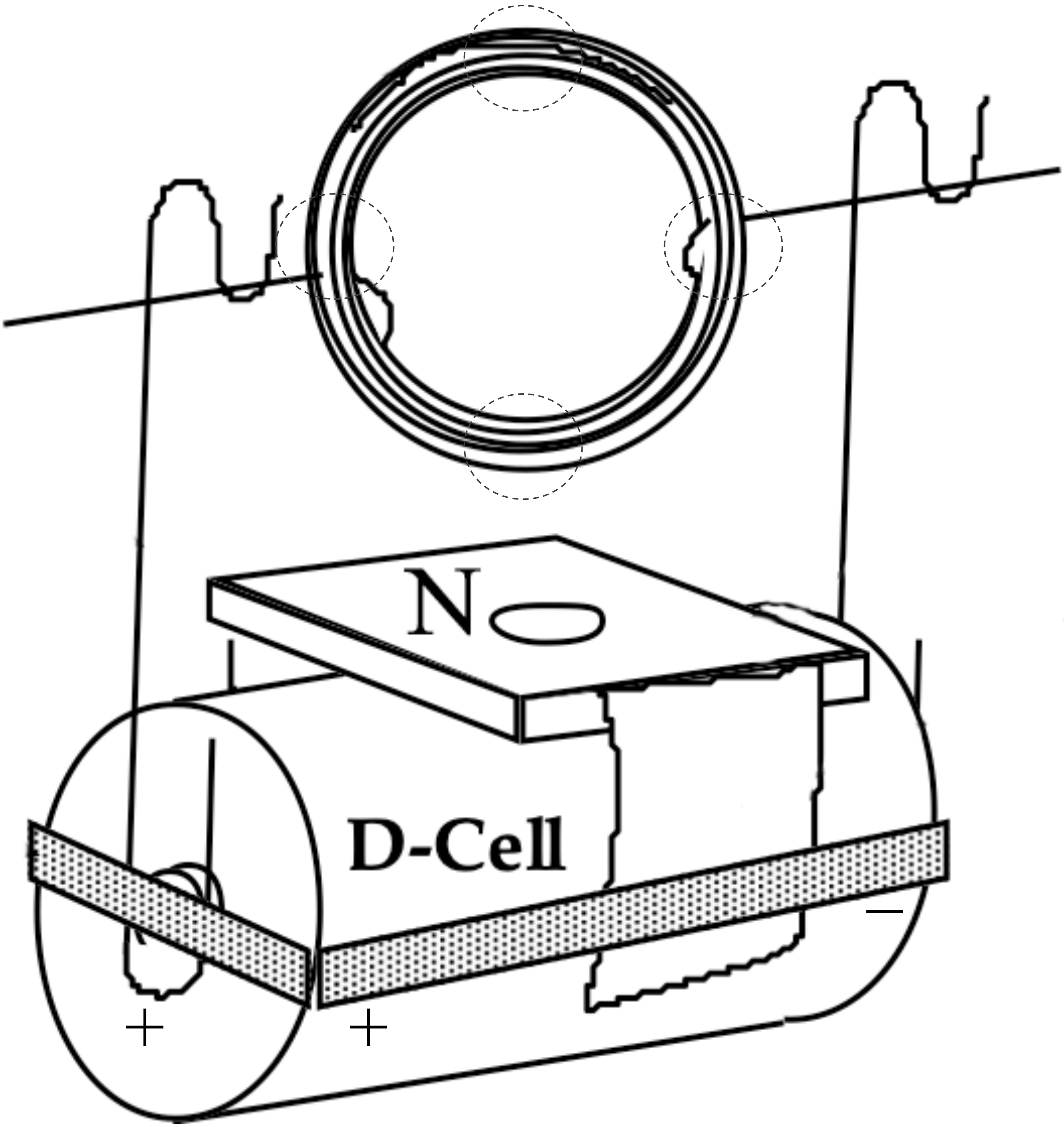
g. Place the coil in the paper clip supports. Give the coil a spin to get it started and it should continue to spin by itself – a working motor. [Figure 5]




**<u>Summary Questions:</u>**

1. What changes in energy are happening as the motor operates?

2. On the diagram, label:
a. The direction of the current flow through the paper clips and wire loop
b. The direction of the magnetic field lines due to the permanent magnet. Assume the top face of the magnet is N. (The field should be roughly constant near the wire loop.)
c. The direction of the force on the top, bottom, left, and right points of the wire loop (circled on the picture) [hint: use the right-hand rule]. If the force is zero, write F=0 next to that point.
d. The direction that the wire loop will spin



3. Feel your wire coil. Did it heat up as the motor ran? Why do motors often heat up while running?

4. Examine a picture of a commercially available motor. Compare and contrast your motor and the commercial motor.

5. Identify 2 potential applications for the motor.

6. In class, we discussed how connecting a wire to both ends of a power source can “short” the power source, causing an extremely large current, dissipating an enormous amount of energy in a short time, and ruining the power supply. Why is the wire coil in a motor NOT shorting the battery? (Hint: recall the equations $V=IR$ and $R = \rho L/A$.)

7. Why was only half of the insulation was removed from one side of the coil? (Hint: If we removed all of the insulation from both sides, what would happen?)

8. What would change in the motor if the battery were reversed so the current ran the opposite direction? Explain your reasoning.

9. What would change in the motor if the magnet placement were changed so that the south pole of the magnet was facing upward? Explain your reasoning.

**10. Summarize**: Write a detailed explanation for how a motor works.

**ANSWER KEY:**
**Summary Questions:**
1. What changes in energy are happening as the motor operates?
*The motor is converting chemical potential energy into kinetic energy (a type of mechanical energy)*

2. On the diagram, label:
a. The direction of the current flow through the paper clips and wire loop: *clockwise around the circuit*
b. The direction of the magnetic field lines due to the permanent magnet. Assume the top face of the magnet is N. (The field should be roughly constant near the wire loop.) *Up the page and then curving around towards the south pole*
c. The direction of the force on the top, bottom, left, and right points of the wire loop (circled on the picture) [hint: use the right-hand rule]. If the force is zero, write F=0 next to that point.
*Top: out of the page*
*Bottom: into the page*
*Left: F = 0*
*Right: F = 0*
d. The direction that the wire loop will spin
*The loop will spin so that the top moves towards the viewer and the bottom moves away from the viewer. It would be clockwise as viewed from the left (the + side of battery).*

3. Feel your wire coil. Did it heat up as the motor ran? Why do motors often heat up while running?

*The wire coil heats up because a lot of current is passing through the wire. When current passes through a wire (or resistor) it dissipates energy in the form of heat.*

4. Examine a picture of a commercially available motor. Compare and contrast your motor and the commercial motor.

*(responses my vary)*

*Both motors have magnets and coils of wire. When current is run through the wire coil, it creates an attraction that is used to generate rotational motion.*

*Our motor has only one magnet whereas the commercial motor has many. Our motor has one wire coil whereas the commercial motor has 4. The commercial motor is can be used to drive other objects by connecting to the axle, whereas our motor doesn't have an axle.*

5. Identify 2 potential applications for the motor.

*Cars, fans, blenders, etc.*

6. In class, we discussed how connecting a wire to both ends of a power source can "short" the power source, causing an extremely large current, dissipating an enormous amount of energy in a short time, and ruining the power supply. Why is the wire coil in a motor NOT shorting the battery? (Hint: recall the equations $V=IR$ and $R = \rho L/A$.)

*The wire in the coil is very long and relatively thin. As the length of a wire increases and its cross-sectional area decreases, the resistance of the wire coil increases. The result is that our wire coil has a relatively high resistance. Because the voltage is constant (1.5 V from the D-cell battery), as resistance increases the current decreases. A short occurs when a power supply is connected with insufficient resistance, resulting in a large current, but the resistance of our wire coil is enough to prevent this.*

7. Why was only half of the insulation was removed from one side of the coil? (Hint: If we removed all of the insulation from both sides, what would happen?)

*If the insulation is removed from both sides, then once the coil has spun 180 degrees, the current will be traveling in the opposite direction relative to the magnetic field, and the force will reverse. This causes the torque to reverse direction. Instead of rotating freely, the wire loop would just flip-flop back and forth. By removing only half the insulation from one side, the current stops flowing when the paint side of the wire is touching the contact lead. This prevents the battery from exerting torque in the wrong direction and the momentum of the wire coil carries it through until it is back in its original position and experiences another torque, allowing it to spin freely.*

8. What would change in the motor if the battery were reversed so the current ran the opposite direction? Explain your reasoning.

*The motor would spin the opposite direction. If the battery is reversed the current changes direction. This causes the magnetic force to reverse which creates a torque in the opposite direction as we originally had.*

9. What would change in the motor if the magnet placement were changed so that the south pole of the magnet was facing upward? Explain your reasoning.

*This would also cause the motor to spin in the opposite direction. Reversing the magnet reverses the direction of the magnetic field. When the magnetic field is reversed, the magnetic force is reversed causing a torque in the opposite direction.*

**10. Summarize**: Write a detailed explanation for how a motor works.

*A motor converts electrical energy to kinetic energy. A current is run through a coil of wire, which is placed in a magnetic field. The magnetic force on a current-carrying wire creates a torque which causes the wire loop to spin. In a commercial motor, this loop could then be hooked up to other parts in order to drive them.*