Name: Date: Class:

Exploring Electric Motors Worksheet Answer Key

Activity 1: Beakman Electric Motor Design Challenge

1. **Ask:** How can you design a Beakman motor to achieve the most consistent coil spin?

2. **Research:** How does a Beakman Motor work? Watch this video of a simple electric motor to find out! (https://www.youtube.com/watch?v=it_Z7NdKgmY&list=PL1B2B0F87955817C8; 2:17 minutes).

   Write down your observations of the motor's components and how the wire coil moves when connected to the battery.
   Possible answers: Students may observe that the Beakman motor includes a battery, wire coil, permanent magnet, and paper clip supports that also act as electrical contacts. When the coil is connected to the battery, electric current flows through the wire, creating a magnetic field around the coil. This magnetic field interacts with the magnetic field of the permanent magnet, producing a force that causes the coil to rotate. Students may also notice that the coil sometimes needs a gentle push to begin spinning and that it continues to rotate when it is balanced, makes good electrical contact, and has low friction. The partially removed insulation on one wire end acts as a simple switch, allowing current to flow during only part of each rotation and helping the coil continue spinning.

3. **Imagine:** Brainstorm 4–5 ideas for how changing the wire gauge or number of coil wraps might help you achieve the most consistent coil spin. Sketch your ideas below.
   Answers will vary.

4. **Plan:** Select one design variable to investigate:
   a. Wire gauge (e.g., 20-, 22-, or 24-gauge)
   b. Number of coil wraps (e.g., 5, 10, or 15 wraps)

   Plan three motor designs by changing your selected variable while keeping the other design features as consistent as possible. Why did you select this design variable? Predict which of your three designs will produce the most consistent coil spin and explain why. Then sketch your three designs below.
   Answers will vary.

5. **Create:**
   a. **Make the coil:** Wrap your selected gauge of wire around a cylinder, such as a glue stick or marker, for your chosen number of wraps to form a circle.
   b. **Secure the wire ends:** Keep about 2 inches of straight wire on both sides. Loop each end lightly around the coil at opposite ends and thread the end through the loop to hold it together.
   c. **Remove wire insulation (important):** Use sandpaper to lightly scrape off the red coating on the straight ends of the wire. Scrape all the way around one wire end, and scrape only one side of the other wire end.
   d. **Build the coil stand:** Slide one end of each of the two large paper clips upward to create a loop in the middle of each paper clip (this loop will support the wire coil). Use electrical tape or a wide rubber band to hold two paper clips upright on opposite sides of the D-cell battery. To avoid creating a short circuit, DO NOT touch the paper clips together once attached to the battery!
   e. **Set the coil:** Rest the coil ends in the paper clip loops. Check that the paper clip supports are straight and the wire is level and can spin freely. Reshape the wire coil if necessary.

f. **Add the magnet and test the design:** Place the magnet on the battery off to the side between the two paper clips. Gently push the coil to help it start spinning. If the wire coil does not spin, check that the wire insulation is fully removed on one side and only half-removed on the other, adjust the magnet placement, and slightly tilt the motor setup forward or backward. To avoid a short circuit, DO NOT place the magnet so it connects with the paper clips attached to the battery leads.

g. **Turn the motor off:** Remove the wire coil from the motor stand to turn off the motor and conserve the battery. Use care when removing neodymium magnets from the battery to avoid pinched fingers.

6. **Test:** Test your motor design and record the results in the data table below.
Classify the coil's performance as constant coil spin (continues spinning without assistance), intermittent coil spin (spins but stops or requires additional pushes), or no coil spin (does not continue spinning after the initial push).

Beakman's Electric Motor Design #1	Beakman's Electric Motor Design #2	Beakman's Electric Motor Design #3
Gauge of wire:	Gauge of wire:	Gauge of wire:
Number of coil wire wraps:	Number of coil wire wraps:	Number of coil wire wraps:
Results (constant coil spin, intermittent coil spin, no coil spin):	Results (constant coil spin, intermittent coil spin, no coil spin):	Results (constant coil spin, intermittent coil spin, no coil spin):

Answers will vary. Notes for the instructor: Both wire gauge and number of coils affect spin rate, but the fastest Beakman's motor uses fewer turns with thicker wire because this reduces resistance and weight.

7. **Reflection Questions:**

a. How did changing your selected design variable (wire gauge or number of coil wraps) affect the consistency of the coil spin? Use evidence from your test results to support your answer.
Answers will vary based on the variable investigated and students' test results. Students should use evidence from their three designs to describe the relationship they observed.

Number of Wire Wraps

- Fewer wraps → lighter coil, better balance → faster spin
- More wraps → more weight + resistance → slower spin

Wire Thickness

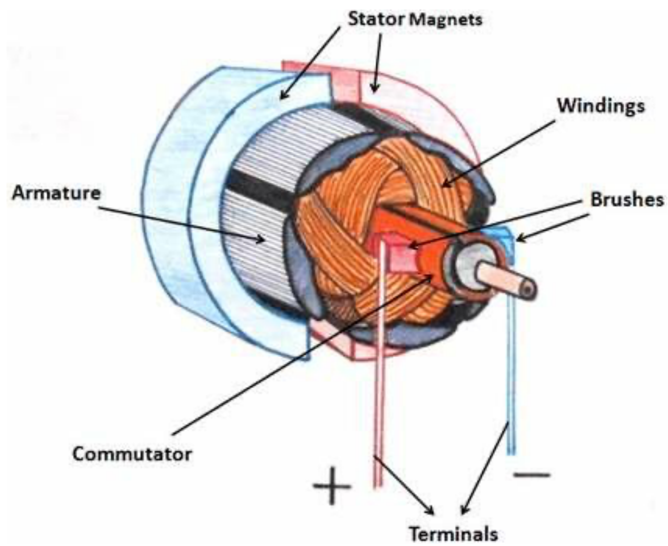
- Thicker wire (lower gauge) → less resistance, more current → faster spin
- Thinner wire (higher gauge) → more resistance → slower spin

b. What other factors may have affected the performance of your motor?

Answers will vary. Possible answers: The shape and balance of the coil, friction between the wire and paper clip supports, magnet strength or placement, battery condition, quality of the electrical connections, alignment of the paper clips, and how accurately the insulation was removed from the wire ends may have affected motor performance.

c. Which of your three motor designs performed best? What 2–3 modifications would you make to improve that design and achieve more consistent coil spin?
Answers will vary. Possible answers: Students should identify the design that produced the most consistent coil spin based on their test results. Possible improvements include making the coil more balanced and evenly shaped, reducing friction at the supports, improving electrical contact, adjusting magnet placement, or modifying the selected wire gauge or number of coil wraps.

Activity 2: Dissect a DC Motor



Watch and Learn

1. Watch this video on how DC motors work: https://www.youtube.com/watch?v=1AaUK6pT_cE (4:49 minutes).

2. Answer the following questions based on the video:
   a. What is the stator? Does it act as a permanent magnet or an electromagnet?
   The stator is the stationary part of the motor that produces the magnetic field around the rotor. In a small DC hobby motor, the stator typically contains permanent magnets, so it acts as a permanent magnet and does not rotate.

   b. What is the armature (rotor)? Does it act as a permanent magnet or an electromagnet?
   The armature, or rotor, is the rotating part of the motor and contains coils of wire. When electric current flows through these coils, they produce a magnetic field, causing the armature to act as an electromagnet. Its magnetic field interacts with the stator's magnetic field, producing torque that causes the rotor and motor shaft to turn.

   c. What is the commutator, and what is its purpose in an electric motor?

The commutator is a segmented electrical contact attached to the rotating armature. As the rotor turns, the commutator changes which armature coils receive current and/or reverses the direction of current through the appropriate coils. This changes the armature's magnetic field at the proper time so that magnetic forces continue producing torque in the same direction and keep the rotor spinning.

d. What are the brushes, and what role do they play?
The brushes are stationary electrical contacts that press against the rotating commutator. They transfer electric current from the motor's terminals to the commutator and armature coils while allowing the rotor to turn. Together, the brushes and commutator maintain the changing electrical connections needed to keep the motor rotating.

Disassemble and Investigate

3. You will now investigate the inside of a DC motor to determine how its components work together to produce rotation.
   a. **Mark the case.** Draw a small alignment line across the seam between the motor case and back cap. This mark will help with correctly aligning the components if the motor is reassembled.
   b. **Remove the gear.** If a gear is attached to the motor shaft, carefully remove it using a small screwdriver.
   c. **Bend back the tabs.** Locate the metal tabs securing the back cap to the motor case and carefully bend the tabs straight using your fingers or a small screwdriver.
   d. **Open the motor case.** Carefully pull the back cap away from the motor body. If necessary, gently pry it open with a small screwdriver.
   e. **Remove the armature.** Carefully slide the armature (rotor) out of the motor case.
   f. **Using the DC motor diagram,** identify as many motor parts as possible. Your motor may not include all parts shown, but aim to identify the armature (rotor), brushes, commutator, stator, and terminals.

Reflection Question

4. These small motors do not include a cooling fan. Why do you think a cooling fan is not needed?
Small DC motors generally produce relatively small amounts of heat compared with larger, more powerful motors. Their small size and metal casing also allow some heat to dissipate naturally into the surrounding air. Because they are designed for relatively low-power applications, a separate cooling fan is typically not necessary. Students may also note that larger or more powerful motors may require additional cooling because they generate more heat.

Electric Motors and EVs

1. Watch this video to learn more about how electric motors move electric vehicles: https://www.youtube.com/watch?v=nMqt9isT00M (9:15 minutes).

2. Identify connections between the motors you investigated and the electric vehicle motor shown in the video. Discuss how both use interactions between electricity and magnetic fields to produce mechanical motion.
Both the simple motors investigated in the activity and electric vehicle motors use electric current and magnetic fields to produce rotation. Current flowing through coils creates magnetic fields that interact with other magnetic fields, producing forces and torque that cause part of the motor to rotate. This rotation converts electrical energy into mechanical energy. In an electric vehicle, electrical energy supplied by the battery is converted by the motor into mechanical motion that ultimately helps turn the vehicle's wheels. EV motors are more complex and use advanced electronics and motor designs to

control rotation efficiently, but they rely on the same fundamental relationship between electricity, magnetism, and motion.