Electromagnetism Agenda

Updated 12/8/09

Goals of these Sessions

Session 1: Permanent Magnet Demonstration

- Electromagnets
  - Handout
  - Everybody Builds One
  - Comparison to Permanent Magnet
  - Nail Pickup Contest

Session 2: DC Motors

- Demonstration and Theory of Operation
- Electric Vehicle Motor Example
- Multi-Pole Series Wound DC Motor
- 2-Pole Series Wound DC Motor
- Questions

Goals of these Sessions

Prepare students to be viable contenders at the upcoming 4th through 6th grade Science Olympiad.

Build on classroom textbook, lecture and lab experiences to provide a deeper understanding of electromagnetism.

Provide an opportunity to learn scientific observation and note taking skills.

Motivate students to like science through fun, hands-on laboratory experiments.

Session 1: Permanent Magnet Demonstration

Mention the many uses of electromagnets, including speakers, buzzers and electric motors.

Briefly review the following:

- Show that permanent magnets have north and south poles, just like Earth.
- Show that like poles repel each other, and opposite poles attract each other.
- Show that permanent magnets can pick up objects that contain iron such as nails, but not copper wire or plastic.

NOTE: warn them that electricity can be lethal, and to never play with electricity. Encourage them to experiment with electronics, but always with adult supervision.

Electromagnet Handout

Print this out along with component and wiring diagram pages for each student.

1. Your name:
2. Number of turns of your electromagnet:
3. Relationship between electrical and magnetic polarity and direction of twist of wire of your electromagnet:

4. Number of nails picked up by the permanent magnet.
5. Number of nails picked up by your electromagnet:
6. Maximum number of nails picked up by an electromagnet and design, if different from yours:

Everybody Builds an Electromagnet

Provide the following materials to each student:

- Single 4’ insulated telephone wire, removed from bundle of 8 wires with ends stripped
- 1.5” finishing nail, with sharp point filed off

Divide students in to groups of 3 and provide each group with:

- 1.5V rechargeable NiMH AA battery
- Duct tape

Have each student neatly and tightly wrap the wire around the nail, counting the turns as they go and ***recording the number of turns on their handout***, leaving 2” not wrapped and twisted together so it doesn’t unravel. See field and armature windings in subsequent DC motor picture for example.

Comparison of Electromagnet and Permanent Magnet

Have each student mark one wire of their electromagnet with a small piece of duct tape.

Then lend them a permanent magnet and have them determine which end of their electromagnet is north and which is south depending on which wire is taped to which end of a battery. ***CAUTION: WIRE MAY GET HOT!*** ***Have them record the relationship between electrical and magnetic polarity and direction of twist of wire on their handout.***

Have someone share their results. See how many people derived the same relationship by a show of hands.

Nail Pickup Contest

Explain to the students that we are preparing for a competition, but to not worry if they don't win, but instead observe the winners to see how they did it and then take that in to account when they are at the competition.

Put a large pile of small finishing nails on a table and have one or two students see how many nails they can pick up with a permanent magnet. ***Have them record the number of nails picked up by the permanent magnet on their handout.***

Have each student try to pick up as many nails as they can with their electromagnet. ***Have them record the number of nails picked up by their electromagnet on their handout.***

Determine the winner. Analyze their design and note if anything is different from other designs. ***Have them record the maximum number of nails picked up by an electromagnet and differences with their design if applicable on their handout.***

Extra credit, if time permits: divide number of turns by number of nails picked up for each student and see if the ratio is consistent.

Session 2: DC Motor Demonstration and Theory of Operation

Share with the class examples of electromagnetic devices such as DC motors bare and inside toys, a wind-up flashlight and a shaking flashlight. Power up the items when possible.

Share with the class the insides of a DC motor, showing them the main components listed on the components page.

Demonstrate for the class a hand built series wound 2 pole DC motor made from household items as shown on the components page.

Describe how the timing and dwell of the brushes contacting the commutator and the wiring sequence of the windings apply repulsive or attractive forces that rotate the motor. Go over the wiring diagram page.

Electric Vehicle Motor Example

For more EV information, see the North Bay Electric Auto Association website, www.nbeaa.org

1966 Mustang EV conversion:
70 MPH top speed
40 mile range
5 hour charge time

9” Fork Lift Series DC Motor attached to the transmission and motor mounts

Multi-Pole Series Wound DC Motor

Field Windings, Armature Windings, Brushes and Commutator are inside.

Armature Terminal #2

Field Terminal #1

Output Shaft

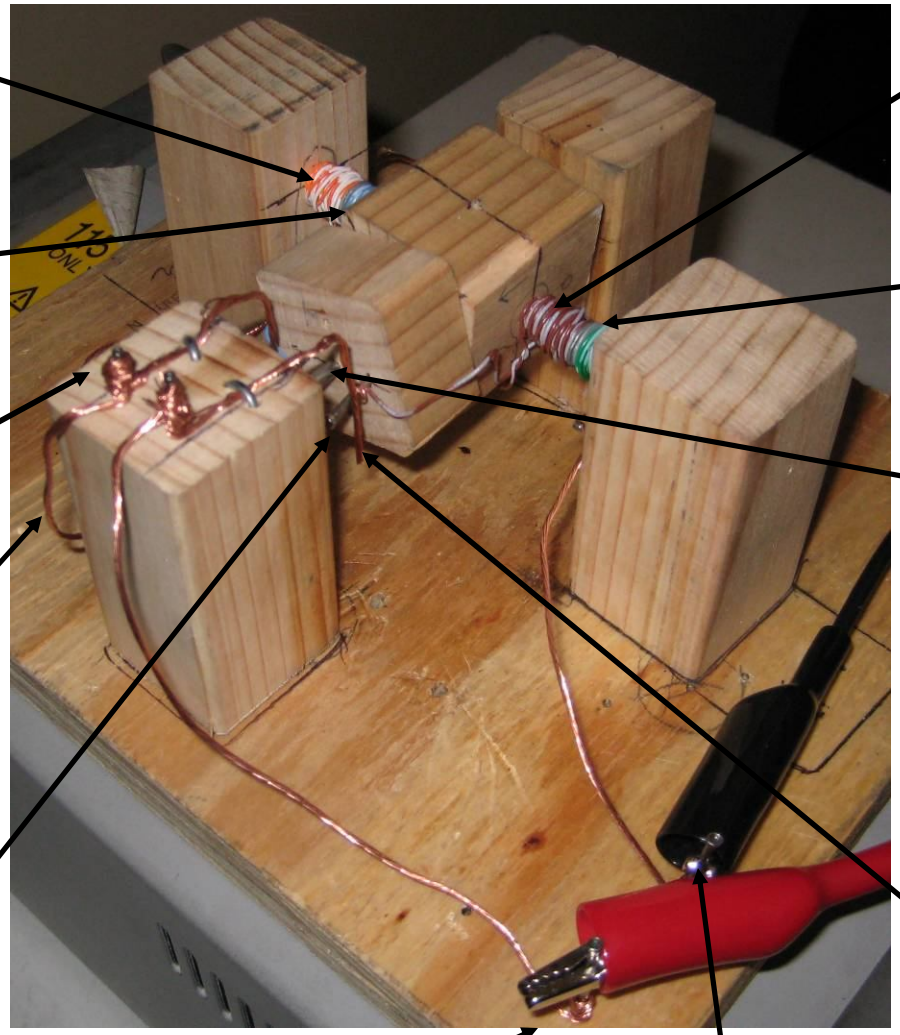
Bearings (2)

Armature Terminal #1

Field Terminal #2

2-Pole Series Wound DC Motor

Components



Field Winding #1

Armature Winding #1

Armature Terminal #2

Field Terminal #1

Commutator (2 pole)

Armature Terminal #1

Field Terminal #2

Brushes (2)

Bearings (2) (not visible from this angle)

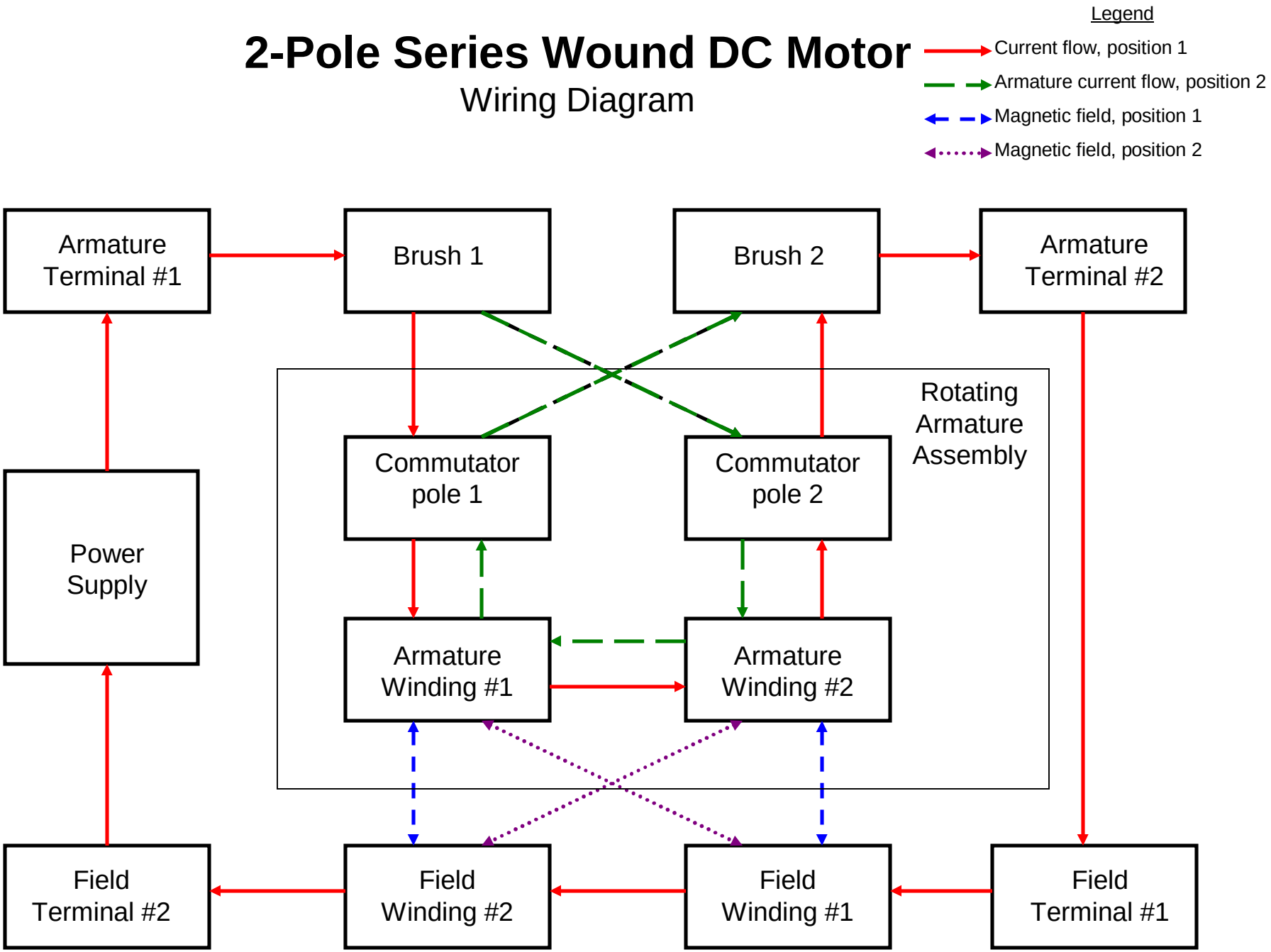
Output Shaft

Field Winding #2

Armature Winding #2

2-Pole Series Wound DC Motor

Wiring Diagram



DC Motor Questions

1. Look at the motor in the dark. Why are the brushes sparking brighter than say the contacts in a flashlight?
2. What direction is this motor turning? How can you reverse the direction of the motor? Try it.
3. What happens when you make small adjustments to the timing, and why? Try it.
4. What would happen if you reversed the wiring of one of the field or armature windings? Try it.
5. What would happen if you reversed the wiring of two of the field or armature windings? Try it.
6. What would happen if more turns were added to the windings? Note: it depends on the power supply.
7. What would happen if less turns were in each winding: Note: it depends on the power supply and the wire diameter.
8. This motor can barely turn itself. How could you make a better motor? Brainstorm ideas. Look at production designs. NOTE: if anyone builds a better home made design, please share it with the author and the greater community!
9. Extra credit: discuss terms such as peak and average torque, power, current and voltage, as well as temperature, weight and environmental stability. Then compare to the motor in an electric vehicle.

Addendum: Things to add to this Document

1. More detailed theory of operation
2. Disassembled annotated EV DC motor, matching components in hand made motor
3. Answers to all of the questions
4. Parts list and instructions on how to make the motor
5. A better motor design that can run off of a small number of batteries