615-4705 (10-100) Motor Generator

Additional Materials Needed:

- Galvanometer
- 3 - 6 volt power supply

Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

Description:

The Motor Generator can operate either as a motor, using electrical energy to perform mechanical work, or as a generator, converting mechanical work to electrical energy. Depending on parts used, the electrical energy may be in the form of alternating (AC) or direct (DC) current.

Now with modular design sharing common parts with our related **10-155 St. Louis Motor**, the Motor Generator is completely and easily dissectible and is a fast and effective way for student and teacher to demonstrate:

- Nomenclature and function of parts of both motor and generator
- Field magnet
- Armature
- Commutator and slip rings
- Electromagnetic field

Accessories Recommended:

The following accessories are useful in performing the experiments described in these instructions. They are available from your distributor or manufacturer **Science First®.**

615-4065 Battery Kit - low voltage power supply with clip leads.

611-1045 Table-Top Pulley - clamps to table, adjusts in height, rotates. Use with Motor Generator to lift weights, demonstrate how work is performed.

For best results:

- Experiment with brush shape, pressure and angle to obtain best performance
- Remove unused brushes to reduce fiction and wear
- Lubricate bearings and sliding contact areas of brushes, commutator and slip rings with light oil periodically

Basic Motor

Permanent field magnet - DC only

Mount the north and south pole pieces to the base by simply sliding through slits in circular clip. Permanent magnet consists of 2 ceramic disc magnets attach to bracket. Connect your power supply across the pair of brushes that touch the commutator, as shown in **Diagram 1.**

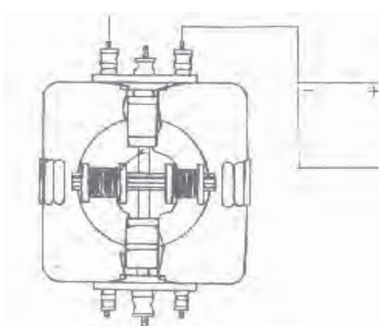

Diagram 1 - Basic DC Motor - Top View

How the Basic Motor Operates:

Current flows down one brush into the commutator segment and through the armature windings. It then flows back by means of the second commutator segment and brush to the batter.

As the current passes through the windings of the wire coil of the armature, it magnetizes the soft iron in the armature.

One end of the armature becomes a *north* pole, the other end *south.* Because like poles repel and unlike poses attract each other, the north pole of the armature will be pulled toward the south pole of the field magnet. The armature and commutator rotate.

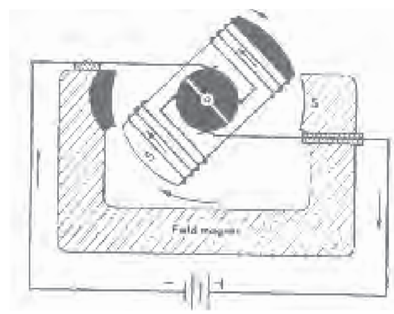

Diagram 2. Two-pole motor - poles of field magnet attract opposite poles of armature Upper armature is always a north pole

Once the armature poles are close to the field pole, the brushes lie across the gaps between commutator segments. The armature is then short-circuited briefly. The armature freewheels until the short circuit is broken. Each brush then touches the commutator segment opposite to the one on which it began. Current again flows through armature windings but in the opposite direction. The polarity of the armature is reversed; the north pole has become a south and is pushed toward the other (north) pole. Every half revolution the poles become aligned, the polarity is reversed and the armature moves.

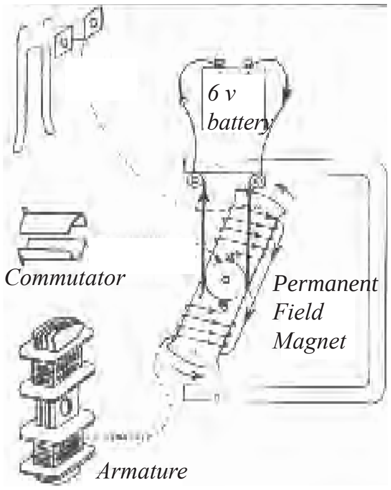

Diagram 3 - Basic DC Motor

If connections to battery are reversed, current direction and armature polarity are reversed. Motor then runs backward.

This motor will not run on alternating current. When AC is used, the armature merely vibrates backward and forward in sympathy with the current reversals. Compare the rotation direction of your motor. Take into account polarity of the battery, polarity of the magnet and winding direction on the armature.

Basic DC Generator

Permanent Field Magnet - DC

- To run as a generator use the configuration in *Diagram 1*, but without the *battery*.

Turn the armature by external means - spin by hand or devise pull string of fine cord or fishing line onto unused slip rings. The iron core of the armature is magnetized by the field magnet. The closer each armature end is to a field pole, the more strongly it takes on the polarity opposite to that of the field pole. As the armature rotates, it is magnetized first in once sense, then, half a revolution later, in the opposite sense.

According to the *law of induction* formulated by Michael Faraday, this change in magnetization induces an **electromotive force (EMF)** in the windings around the armature. The faster and larger the change, the larger the induced EMF which is experienced as a voltage between the ends of the windings. Connecting the brushes to an external circuit allows current to flow through both that circuit and the armature winding.

Lenz' Law states that the direction of the induced EMF is such that it tries to cause a current that would oppose the change causing it. As the iron is magnetized in one direction, the current generated is such that, as it flows in the armature windings, it tries to magnetize the iron in the opposite direction. Therefore the EMF must alternate in direction as the armature is magnetized in alternate senses.

However because the commutator reverses connections to the brushes every half revolution, it is able to correct for the alternations of the EMF and therefore to produce a unidirectional voltage at the brush terminals. **Connect a galvanometer** to the brushes to observe a series of pulses in the same direction.

Basic AC Generator

Alternating current - AC

The motor generator has a second set of brushes sliding on two continuous rings knows as *slip rings.* Each ring is connected to one end of the armature winding. By connecting to the slip ring brushes instead of the commutator brushes, the reversing action of the commutator is bypassed and the generator provides AC as can be verified by connecting the galvanometer.

Because the same machine acts as both motor and generator, it follows that the two functions are not completely separable. The generator will act partially as a motor and vice versa.

Take Lenz' Law as applied to the DC generator. The current generated tends to oppose that which caused it. When an armature end becomes a North pole as it approaches the field South pole, the induced current suppresses development of that North pole. If that current were driving the machine as a motor, it would produce a South pole to cause the motor to rotate in the opposite direction.

In the DC generator, the induced current will produce a torque that opposes whatever is driving the generator. The higher the current drawn from the generator, the more difficult it is to turn. This is to be expected from *conservation of energy principles* since the extra electrical energy must come from mechanical work done in the generator; otherwise Lenz' Law would not be true. Verify this by **connecting the brushes** together. Note that the generator is harder to spin.

On the other hand, consider the *basic motor.* As it increases speed after being switched on, it behaves like a generator, inducing a "back EMF" - a voltage in opposition to the battery voltage. Once this voltage, plus the voltage dropped across the resistance in the wires, equals the applied battery voltage, the speed settles to a constant. If the mechanical load on the motor is increased, the motor slows and the induced voltage drops. The battery is then able to supply more current and the motor more torque. This can be demonstrated by **slowing the motor** down with your fingers.

Because of the symmetry between motor and generator, you may wonder why a motor version of the AC generator using the slip ring brushes is not presented above. Although it is in principle a possibility, in practice it requires precise timing of the current reversals

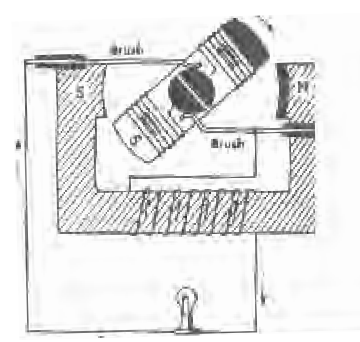

Diagram 4. Simple DC generator - as armature revolves, its wires cut magnetic lines and generate alternating voltage. Current in coil alternates. Commutator reverses connections to outer circuit so current through lamp is direct.

in relation to the armature position under varying load conditions. This type of motor - called a *synchronous* motor - requires that speed of rotation by synchronized with the speed of reversal of the AC source, in order to supply a continuous torque in the same direction as that of the rotation. For this reason the motor generator is not a workable synchronous motor.

High power motors

Electromagnet Fields

The development of strong rare earth magnets (such as neodymium, iron, boron) greatly enhanced the power output and the usefulness of motors with permanent field magnets. Nonetheless, for high power application, the *permanent field magnet* is best replaced by an electromagnet in which a core material such as iron is magnetized by a current carrying coil.

Replace the 2 permanent (ceramic disc) magnets in the *basic motor* with the wound field coil/ electromagnet pair to demonstrate two such motors - the **series** and the **shunt** motor - which differ only in their electrical connections. It should be noted that a motor designed to operate in two modes is not as efficient or as powerful as one designed to operate in just one of these modes.

Slide the electromagnet attachments as far into the slit in the circular clip as possible without the armature hitting the windings. In both series and shunt motors, the voltage drop across the windings times the coil current is approximately equal. Likewise, the coil current times the number of turns also remains the same at normal operations.

Series Motor

Connect the electromagnet attachment/field coil in *series* with the commutator brushes so the same current passes through the armature and then the field coil. Increasing the mechanical load slows the motor and lowers the back EMF resulting in a higher current.

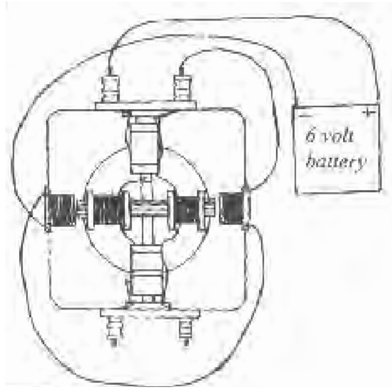

Diagram 5 - Series Motor - Top View

Although this occurred in the *permanent field motor,* now, in the series motor, the strength of the field magnet is also increased. The resultant torque is therefore automatically increased when needed. Series motors are for high torque, low speed applications such as the starter motor for a car. They are characterized by **few turns, heavy wire** and **low resistance**.

Shunt Motor

Connect the field magnet so that the field current is *independent* of the armature, having been diverted ("shunted") through its own separate circuit. A 10 ohm variable resistor may be included to facilitate adjustment of the field current. In most shunt motors, increasing the field current causes the motor to **slow down.** Remember, the speed of a motor becomes steady when the induced back EMF reaches a certain level. That same level is reached at a lower speed if the field magnet has been strengthened by increasing its current. Although the speed is lower, the torque and power developed are higher, as your intuition may imply.

In this demonstration motor you may find that the speed remains fairly constant as the field current is increased. This is because - with only two poles - the sped is determined by a number of factors, not just the back EMF. At any rate the speed does not increase in proportion to the field current.

Shunt motors are characterized by **many turns, small** (fine) **wire** and **high resistance.** The speed of the shunt motor varies less than that of the series motor under varying load conditions.

Reversing the battery connections reverses both armature and field currents and therefore does not change the motor direction. Motor direction can only be achieved by reversing either the *brush* or *field connections.* Both shunt and series motor will therefore run on AC but not for long periods. The alternating magnetic fields induce currents ("eddy currents") within the iron cores which result in overheating. Ten or twenty seconds is safe for testing the use of AC with a source of about 10 volts.

Most motors and generators are constructed from "laminations". The field cores and armatures are made of thin layers of iron stacked together with insulating between layers. The laminations reduce the eddy currents, and hence the overheating. They also reduce the power loss that core heating represents. Proper laminated construction is expensive and therefore has been omitted from this demonstration model.

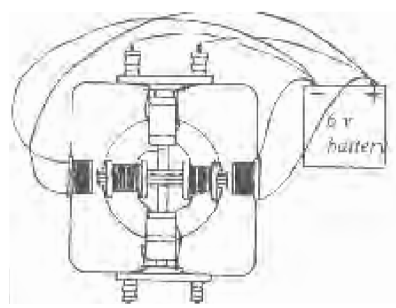

Diagram 6 - Series motor, top view

High Power Generators

Most high power generators produce AC which, if desired, can be changed to DC through the use of external electronics. DC generators are out of favor because the high currents burn out the commutator and brushes quickly.

In AC generators, on the other hand, the roles of the armature and field coils can be interchanged.

The armature becomes the *rotor* and is supplied with a small DC current ("exciter" current) via slip rings.

The field coils become the *stators.* The rotating electromagnet (rotor) induces large alternating current in the station stator without the need for high-current sliding contacts.

Virtually all generators over 1000 watts are AC. The reasons for this are: no brushes to replace, high efficiency, smaller size and lower cost. For instance, low-cost AC generators superseded DC "dynamos" in automobiles when low-cost electronics for control of the exciters current and rectification of the AC output became available.

New permanent magnet materials replaced the windings on the rotor. This removed all need for any sliding contact.

How To Teach With Motor Generator

Concepts Taught: Electromagnetic induction; magneto; DC and AC currents, generator vs. motor; armature; field magnet; commutator. Induced current. Series and shunt motors. Transformation of energy - electrical to mechanical and vice versa. Energy conservation.

Curriculum Fit: Physics Sequence/ Electricity and Magnetism. *Unit: Moving charge and magnets.* **Grade 9-10.**

Physics Sequence: Energy. *Unit: Energy Transformations.* **Grades 9-10**.

Accessories:

Science First manufactures many low-cost science labs. The following accessories and related products are carried by most science education distributors. For more information, please contact us.

615-4065 Battery Kit: Low-cost 1.5 to 6 volt DC power supply with clip leads. Use to run 10-100 Motor Generator.

611-1045 Table Top Pulley - Adjusts to 10 cm. Rotates 360°. Use with 10-100 Motor Generator to lift weights.

Related Products:

615-4585 Electromagnet Kit - Experiment with induced currents, reversed polarity and magnetic lines of force. Includes 2 copper coils with binding posts; round iron core; square iron core; U-shaped double core; plastic card; 4 clip leads; iron filings in reusable vial; instructions.

615-4700 St. Louis Motor - Converts energy from electrical to rotary. Similar to 615-4705 Motor Generator in design and components. Electromagnet attachment available separately.

615-4650 primary Secondary Coil -Study electromagnetic induction and transformer effects. 2 coils, one heavy, one fine; soft iron core; instructions.

615-0300 Lifting Magnet - Powerful compact electromagnet weights 2 pounds - lifts 200 pounds! Instructions with activities, theory and background.

615-4685 Toy Motor Kit - All you need to build a working DC motor in single kits or economical bulk packs. Sandpaper, pliers are only tools needed. Ages 12 up. Learn how each part of a motor works. *Needs single AA battery, not included.*

615-3100 Van de Graaff Generator - Create lightning up to 4 inches long. Experiment with electrostatic electricity. Also available in kit form - a great science fair project.

615-0310 Lenz' Law Classroom Kit- Drop neodymium magnet through our two-foot copper tube, then through the acrylic tube. Does the magnet fall as you would expect it to? Large enough for your whole class to see.

Check out our website at www.sciencefirst.com. Download instructions and free articles!

P/N 24-10110

©*Morris & Lee/*Science First®
Science First® *is a registered trademark of Morris & Lee Inc.*
All rights reserved.