

Electrical System

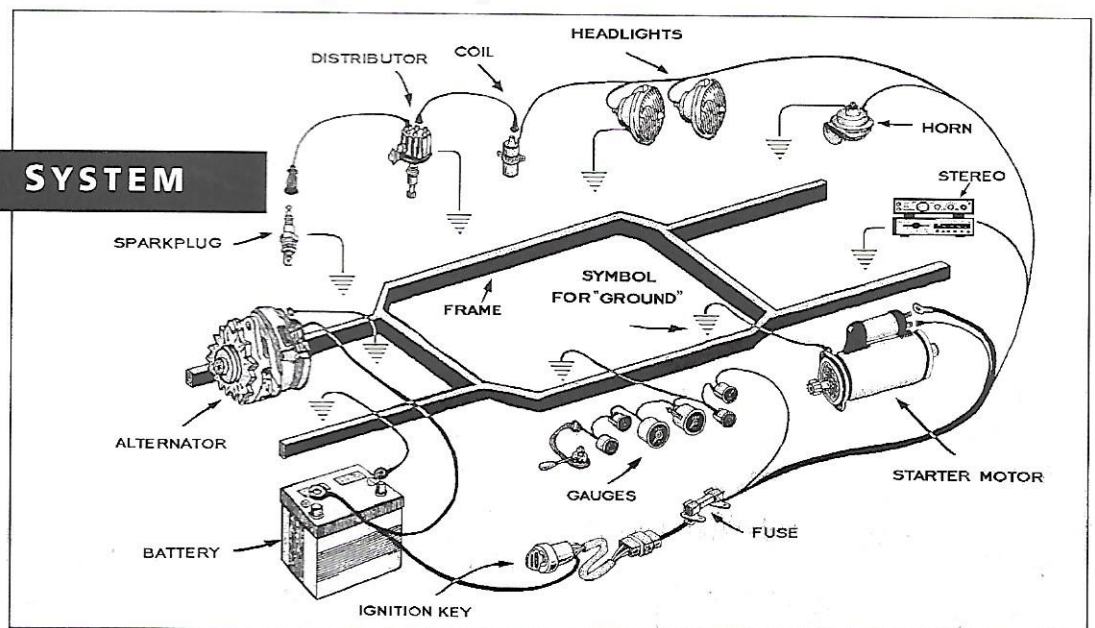
An automotive *electric system* is a collection of circular electrical pathways. Each pathway, called a *circuit*, includes a wire leading from a *battery*, to an electrical accessory, and then back to the battery. Each accessory has its own circuit, though most circuits share pathways. For example, many circuits use a car's frame as the "wire" for returning electricity to a battery. This return path, commonly called the *ground*, always connects to the *negative battery terminal*.

Circuits vary in their function, location, and physical size. Large wires lead from a battery to a *starter motor*, while almost microscopic wires make-up the *integrated circuits* of computers.

Some circuits are always active, such as, headlights, car alarms, clocks, radio station memory, and seat position memory. Other circuits receive current only when the ignition key is in the "on" position, such as, the radio, power windows, and fan. The *starting circuit* works only when the key is twisted to the "start" position. Other circuits operate only when an engine runs, for instance, the *charging circuit*.

If an electrical pathway breaks, current flow stops, and the accessory will not work. It is not enough for current to reach an accessory; it must also flow through it, and return to the negative battery terminal.

ELECTRICAL SYSTEM



Battery

All automotive circuits use a *battery* as the power source. The main job of a battery is to start an engine. Once running, an engine generates enough electricity to supply itself and all other accessories.

Batteries have two separate sides, the *positive* (+) and *negative* (-). Inside a battery, metal plates, one positive and one negative, are suspended in a liquid *electrolyte*. The electrolyte allows electrons to flow between the two plates without the plates ever touching. Electrons must travel through the electrolyte, usually sulfuric acid, to complete a circuit. The illustration below shows only two plates; in an actual battery, these plates are very close together and are carefully arranged to fill the entire inside of a battery.

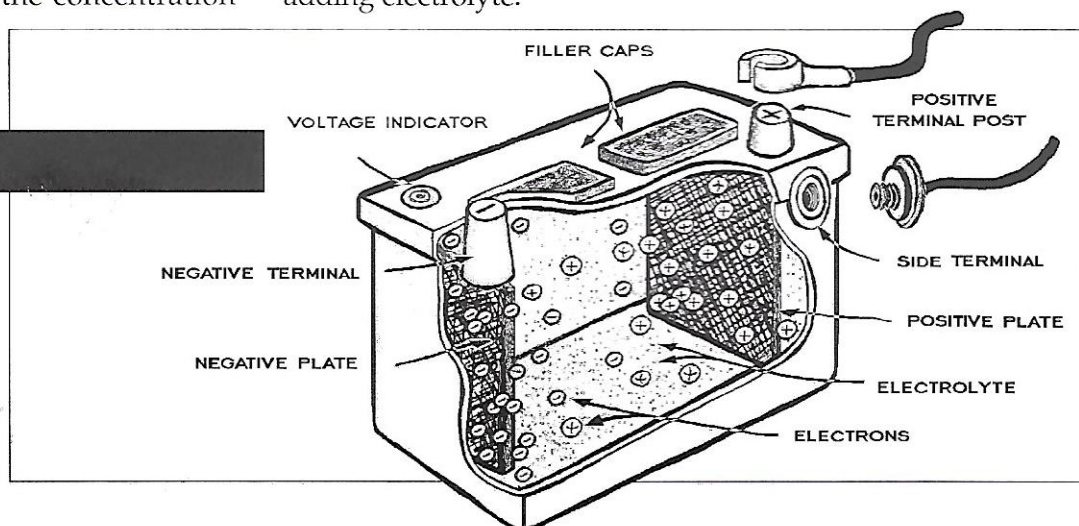
A battery works by maintaining a difference between the concentration

of electrons contained in these metal plates. This difference produces, in effect, a downhill flow of electrons through a circuit. It is common practice to describe this electron flow as moving from the *positive terminal*, to an accessory, and then back again to the *negative terminal*, or ground.

A large wire (often red) connects between the positive terminal and the starter motor. An equally large wire (almost always black) connects the negative terminal to a car frame. Smaller wires, *insulated* from the frame, branch from the positive terminal to supply all accessories with electric power.

Two types of connections are used with automotive batteries, the *post* variety and a screw-in *side terminal* type. Some batteries offer built-in voltage indicators, some have *filler caps* for adding electrolyte.

BATTERY



Starting Circuit

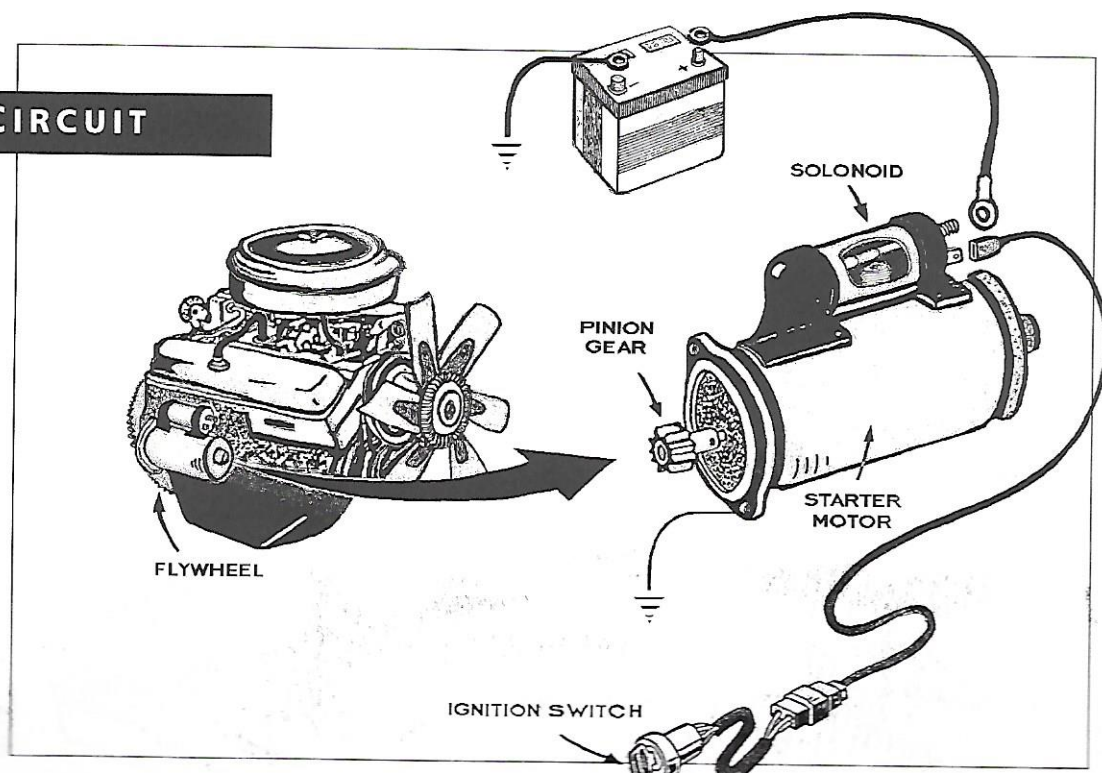
A *starting circuit*, with the help of gears, a flywheel, and *starter motor*, rotates an engine on electrical power alone until it can start and run by itself. This job requires more electric power than all the other accessories.

When an *ignition key* turns to the "start" position, a small electric current is sent to a *starter solenoid*. A *solenoid* is an electromagnetic switch, separating and protecting the small wires in an ignition key circuit from the huge electric loads used by a

starter motor. The solenoid acts as a gate, allowing large amounts of current to flow through a starter motor. A starter solenoid is often attached to the top of a starter motor.

Before electric starter motors, engines had to be started with a hand-crank at the front of a car, attached directly to the crankshaft. This was difficult and dangerous. The electric starter motor, more than anything else, opened motoring to the average person.

STARTING CIRCUIT



Ignition Circuit

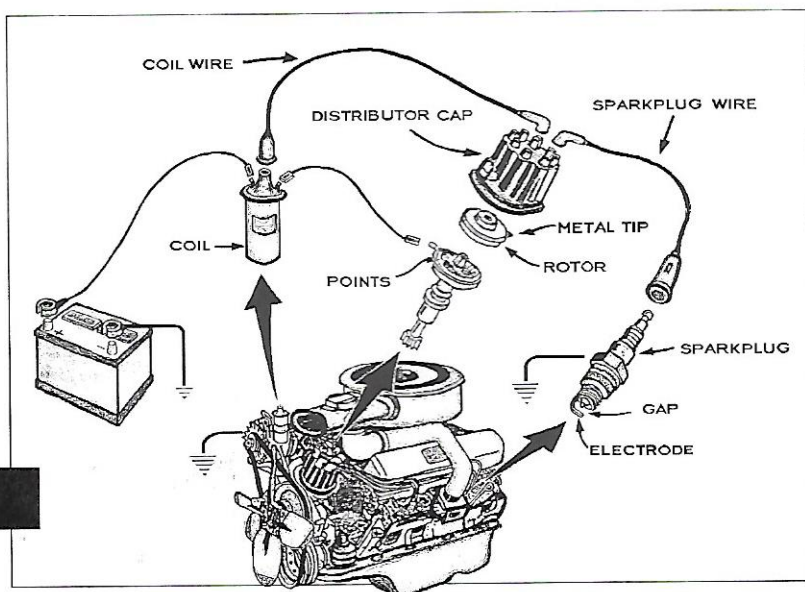
An *ignition circuit* delivers sparks to the combustion chambers. Spark *timing* must be precisely coordinated with the workings of an engine for proper engine performance.

A *distributor* synchronizes spark timing. As an engine turns, a *rotor*, under the *distributor cap*, spins in coordination with internal engine parts. As it spins, the metal tip of a rotor touches each *sparkplug wire*, one after the other. Sparkplug wires are attached in a circle around the outside of the distributor cap and extend through the cap to provide direct contact with a rotor tip. When contact is made, a charge of high voltage current is sent out to individual *sparkplugs*. This particular sequence is called the *firing order* of an engine.

Sparkplugs screw directly through an engine head, with one sparkplug extending into each combustion chamber. When current is sent to a sparkplug, the current must jump the *gap* between the two *electrodes* to complete the circuit. A spark is created when electric current jumps this gap.

A *coil* changes the regular 12 volts from a battery into the 50,000 volts necessary for electric current to jump a sparkplug gap. Mechanical *points*, or in modern cars, an *electronic ignition module*, located inside a distributor cap, manage these different currents, as well as control spark timing.

The type of plug, the voltage delivered, and the size of the sparkplug gap determine the size and temperature of a spark. The size and temperature of a spark controls the speed and burn pattern in a combustion chamber. A single sparkplug will fire approximately 15 times a second with average driving, this equals about one million sparks every 1,000 miles.



IGNITION CIRCUIT

Charging Circuit

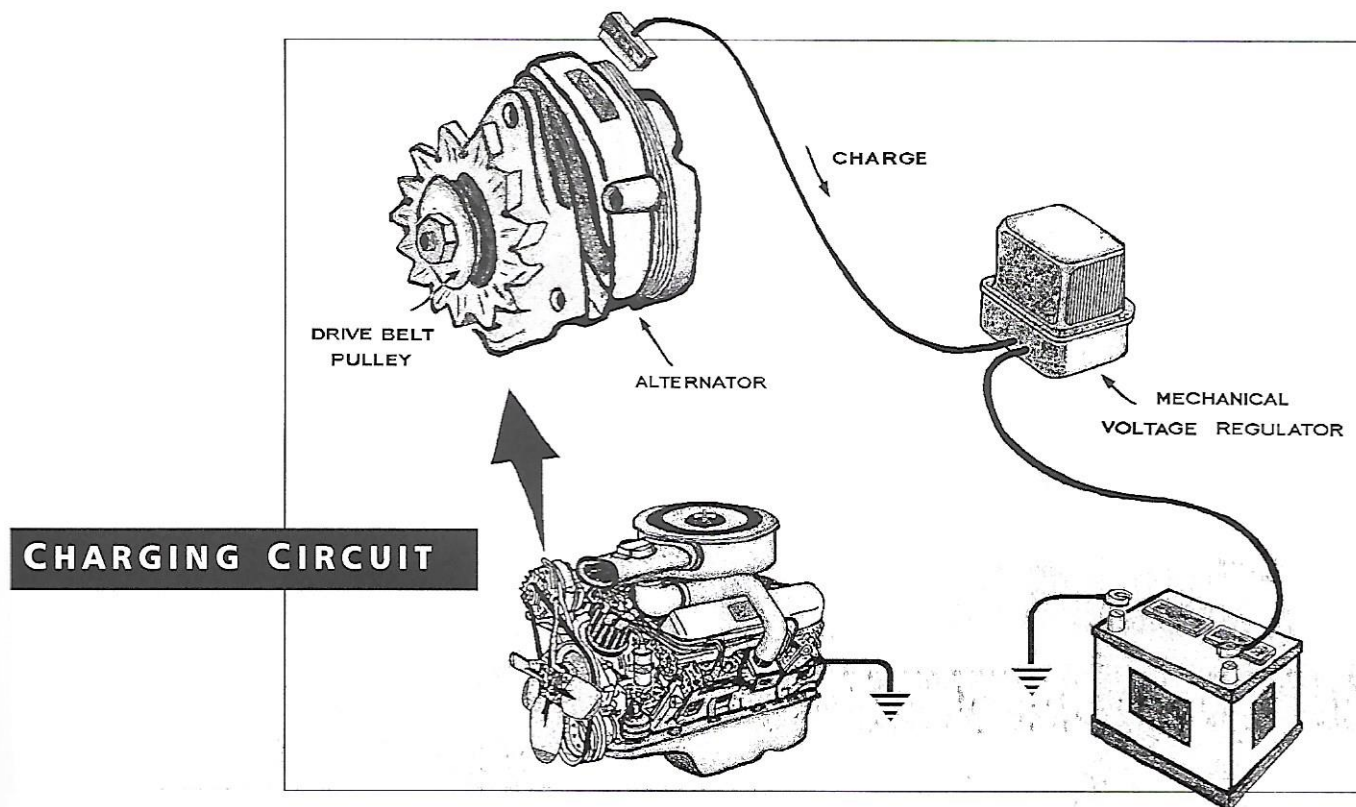
A *charging circuit* generates enough electricity to supply a car and all its accessories with electricity. This circuit also *charges*, or replaces, electricity lost from a battery when a car starts.

An *alternator* generates electricity the same way as dams and windmills, by rotating electromagnetic fields. In an automotive charging system, a drive belt from the crankshaft rotates electromagnets inside an alternator to create electric current.

A *voltage regulator* controls the electric current produced by an alter-

nator. The faster an engine runs, the more current is produced. At high speed, enough electricity is generated by an alternator to overcharge a battery and to damage the fragile circuits in a vehicle. A voltage regulator limits this current and distributes the right amount of current to the accessories, including the battery.

Modern voltage regulators are electronic and built into an alternator. Older, *mechanical voltage regulators*, are often located to the side of an engine compartment.



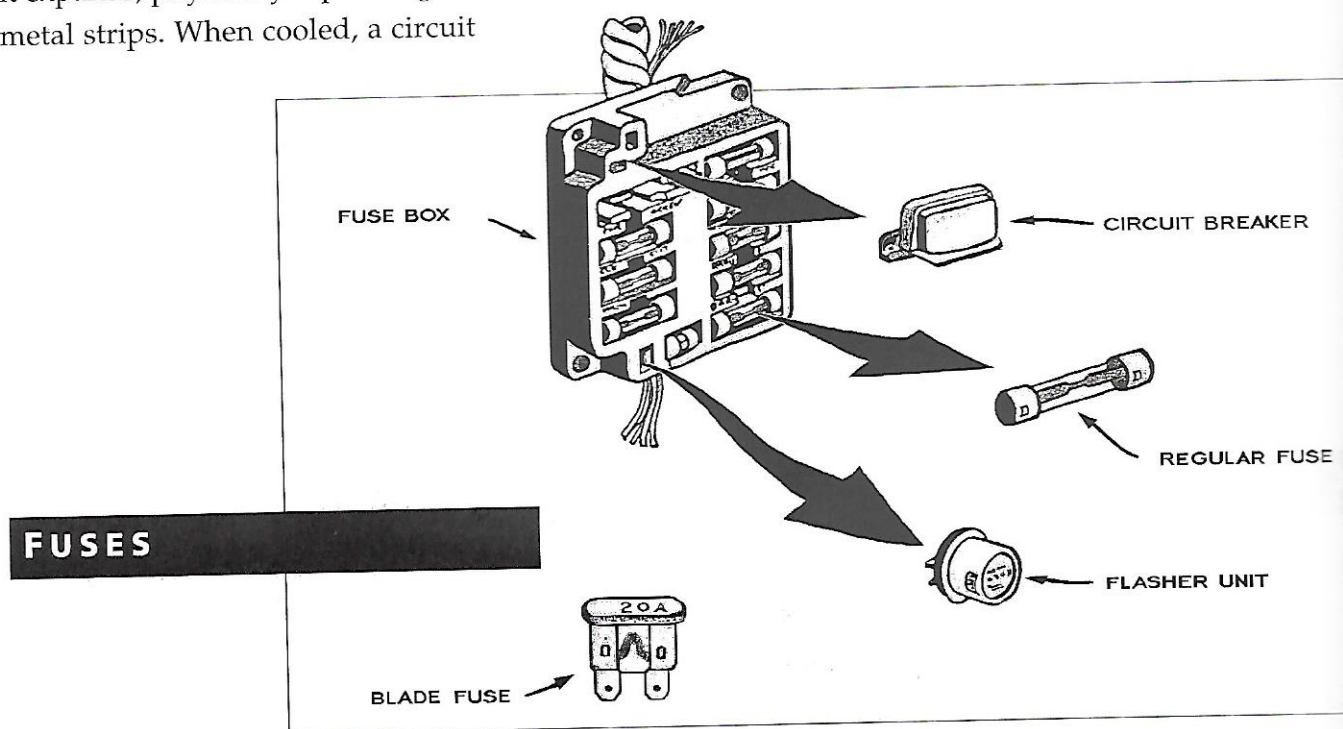
Fuses

A *fuse* is a thin metal strip that melts if excessive current is drawn through. Fragile circuits have very thin wire strips as fuses; circuits that require larger electric loads use correspondingly larger wires as fuses. When a fuse melts, the circuit breaks and current flow stops or *shorts*. This protects circuits from damage caused from excess current and provides a built-in and easily replaceable weakest link for a circuit. Most fuses are found in *fuse boxes* located underneath a dashboard.

A *circuit breaker* is a reusable fuse. Rather than melting when overloaded, it expands, physically separating two metal strips. When cooled, a circuit

breaker shrinks back, reconnecting the circuit. Some circuit breakers need to be reset by hand. In other circuits, such as the headlight circuit, a circuit breaker automatically resets itself, reestablishing night visibility as soon as possible if a headlight shorts-out while driving.

Fusible links add further protection to major electrical circuits if catastrophic electric failure occurs. When a fusible link melts, some basic circuitry may be saved, but a new fusible link(s) and often significant sections of the wiring must be replaced, to eliminate the original problem.



Accessories

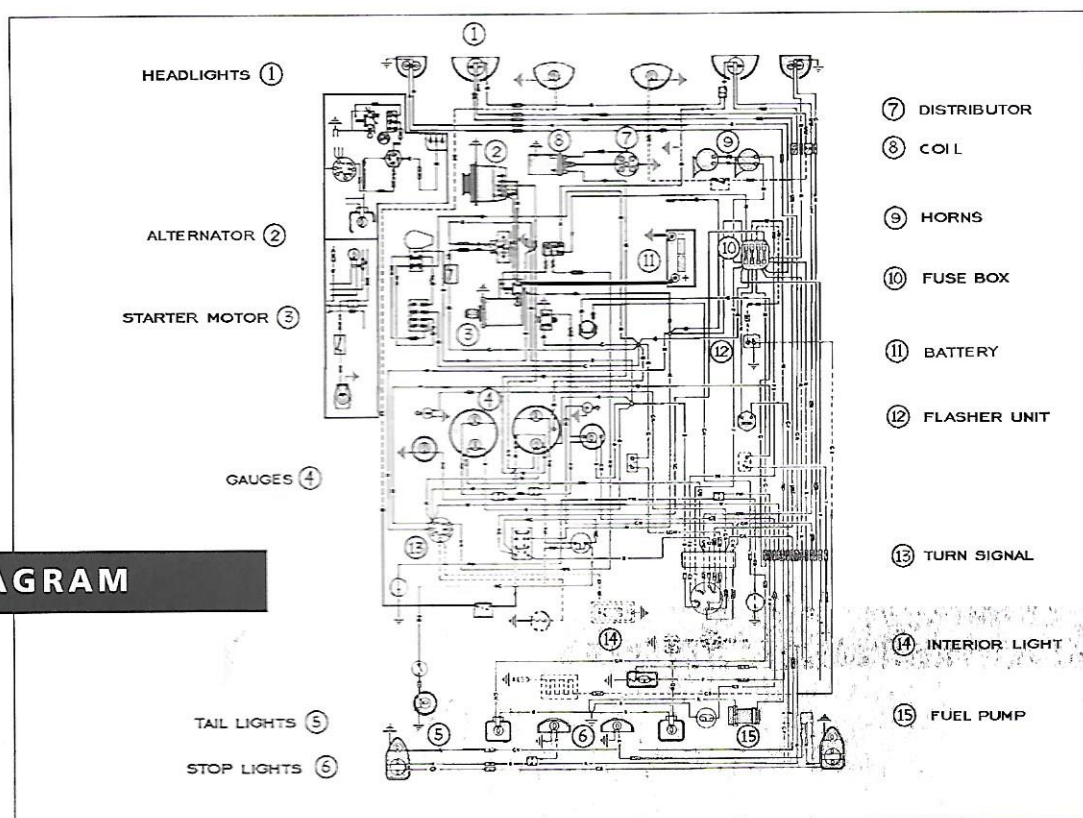
Electrical *accessories* include the many devices that make motoring a little more comfortable, safe, and fun. From windshield wipers to satellite navigation and infrared *night-vision*, automotive gadgetry is both practical and on the cutting edge of technology.

A simple *schematic wiring diagram*, from the author's vintage 1964 British MGB is shown below. Studying this diagram serves as an introduction to the complex diagrams of today's vehicles.

Even the basic incandescent light bulb, used for all the lighting in the diagram below, has been replaced. For example, halogen, or HID (high intensity discharge) bulbs are now used in most headlamps, tail lights, and emergency lights. Instrument panel and applique lights use liquid crystal displays (LCD), light emitting diodes (LED), vacuum florescent displays (VFD), and neon gas lighting.

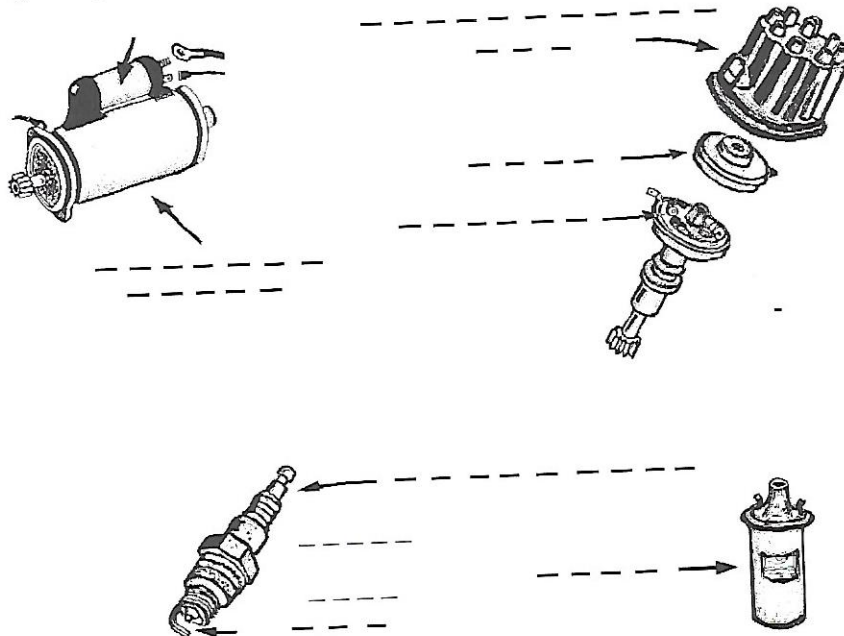
The ultimate electric accessory, of course, is the electric engine.

WIRING DIAGRAM



ELECTRICAL TEST

Identify the parts:



1. The liquid inside a battery is called _____. (p. 72)
2. An _____ generates electricity. (p. 75)
3. Electric current flows from the _____ terminal to the _____ terminal. (p. 72)
4. An automotive coil transforms 12 volts into _____ volts. (p. 74)
5. High voltage is necessary for electricity to _____ a sparkplug gap. (p. 74)
6. Sparkplugs extend into the _____. (p. 9)
7. In cars, a "ground" is also considered the _____ battery terminal. (p. 71)
8. The pinion gear of a starter motor meshes with the gears of a _____. (p. 73)
9. What creates the heat that melts a fuse? _____
10. The radio works but the engine will not turn-over. This suggests? _____