MASTER TECHNICIANS SERVICE CONFERENCE 66-3

REFERENCE BOOK

ELECTRICAL FUNDAMENTALS

CHRYSLER CORPORATION

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We are beginning to suspect that automotive electricity is here to stay! Every model year new electrical options, units and circuits are introduced which make driving safer, more comfortable, or more convenient. No doubt about it, our car's electrical systems are becoming increasingly sophisticated and circuits are becoming increasingly complicated. There's a lot more to electrical service these days than tracing a wire in search of a loose connection or short.

You don't have to be an electrical engineer to do a top-notch job of servicing electrical circuits and units. However, a certain amount of *practical theory* will help you understand modern electrical circuits, units and accessories so that you'll be much better prepared to diagnose and correct electrical troubles. A working knowledge of electrical fundamentals will also help you keep pace with new electrical circuits and units as they are introduced on future models.

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THE BEHAVIOR OF ELECTRICITY AND MAGNETISM

At one time or another, most of us have been exposed to some basic education on the fundamentals of electricity and magnetism. However, remembering these fundamentals is like remembering algebra or a foreign language . . . it's apt to slip away from you unless you use it regularly. Unless you are a practicing electrical service technician, the chances are that you're a bit rusty on the fundamentals of electricity and magnetism. Reading the following pages will help you rub off the rust and refresh your memory on the nature and behavior of electricity and magnetism.

BASIC ELECTRICITY

Electricity is an invisible force which behaves according to definite rules and produces predictable results and effects. Although we have learned to produce, store, use and measure electricity, no one knows just what electricity is. In recent years, scientists have developed the electron theory to explain the nature of electricity. It explains more thoroughly than any other theory, the *behavior* of electricity *and magnetism. However, it is difficult to* understand because electrons can't be seen or easily illustrated.

ELECTRON THEORY vs. WATER ANALOGY

As a service technician you are more concerned with the actual behavior of electricity than you are with theories. If you understand how electricity is supposed to behave in a circuit or unit you'll be well equipped to recognize out-of-line conditions when electricity misbehaves. The electron theory is a highly scientific way of explaining the behavior of electricity. The flow and behavior of electricity can also be explained by comparing it with the flow of water. In fact, comparing water flow with electrical flow is undoubtedly the easiest and quickest way to explain volts, amps and ohms. For one thing, when we use water flow to explain electrical flow we are using something you can see to explain something invisible. So, we'll stick to the water analogy . . . comparing the behavior of water with the behavior of electricity.

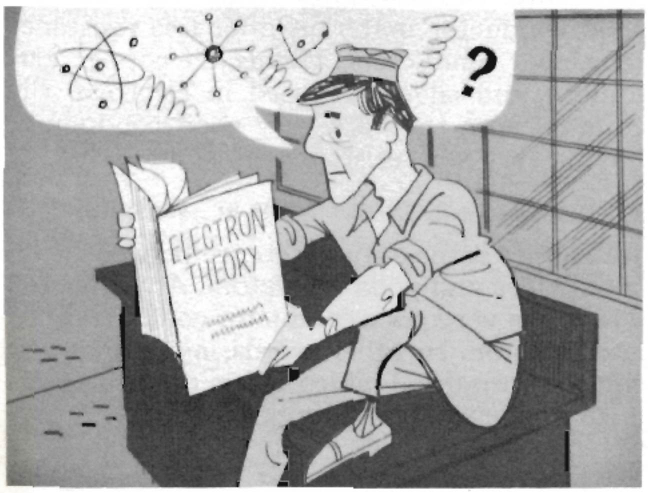


Fig. 1—The electron theory explains electricity

Fig. 2—Water flow helps explain electrical flow

VOLTAGE IS PRESSURE

A storage battery and a water tower have a lot in common . . . they both provide pressure. The battery is a source of electrical pressure and the water tower supplies water pressure. *In other words, voltage is simply electrical* pressure. And, it's voltage that pushes electricity through the wires in a circuit just as pressure pushes water through the pipes in a plumbing system.

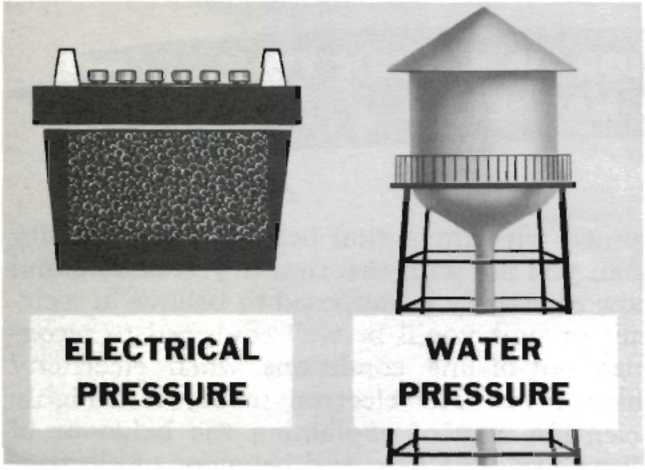


Fig. 3—Both a battery and water tower provide pressure

AMPERAGE IS FLOW

The flow of electricity and water can also be compared. An electric current is the movement or flow of electricity through a circuit just as water flow is the movement of water through a pipe.

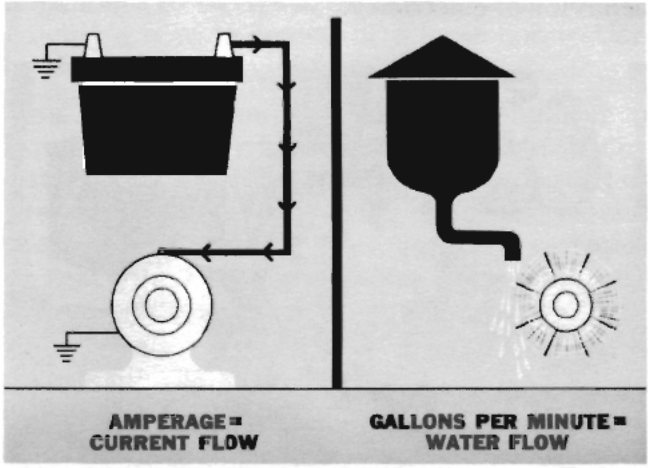


Fig. 4—Amperage and gallons per minute measure flow

Amperage is the electrical unit that tells you how much current is flowing through the wires of a circuit. Just as gallons-per-minute is the measure of the rate of water flow, amperage is the measure of rate of current flow. When a current of one ampere is flowing through a wire it means that a definite amount of electricity is moving through that wire each second of each minute. If the flow in another wire is six amperes, it means that six times as much current is flowing in the second wire.

OHMS MEASURE RESISTANCE

Electrical resistance is just that . . . resistance to the flow of an electric current. For example, a small wire offers more resistance to the flow of electricity than a large wire of the same material. In much the same way, a small pipe in a water system offers more resistance to the flow of water than a large pipe.

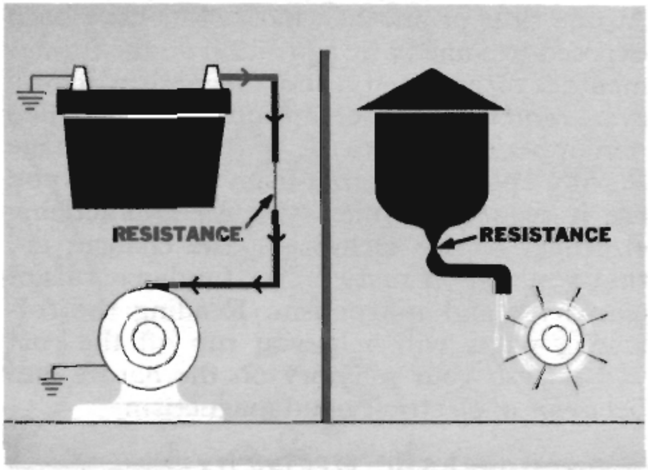


Fig. 5—Resistance reduces flow

The ohm is a unit of measurement which indicates the amount of resistance offered to the flow of an electrical current. The amount of current flowing through a wire depends on the electrical pressure or voltage pushing the current and the amount of resistance in the wire. Wires or conductors which let the current flow easily have low resistance and wires which slow down or limit the flow of current have high resistance.

Wire size is only one of the things that affects the amount of resistance in a circuit. The length of a wire and the material from which the wire is made also affect resistance. Short wires offer less resistance than long wires and good conductor materials offer less resistance than poor conductors. Metals like copper, aluminum and silver are used in electrical circuits because they are very good conductors, having very low resistance.

AN INSULATOR IS SIMPLY HIGH RESISTANCE

Resistance is the only difference between good conductors and good insulators. Any material which is a very poor conductor could be called an insulator. In other words, an insulator is simply a material which offers enough resistance to prevent the flow of electricity.

OHM'S LAW

Ohm's Law is the most fundamental equation in electrical science. It very accurately defines the relationship between volts, amps and ohms. Ohm's Law states that voltage equals amperage times the resistance in ohms. This simply means that one volt will push one ampere of current through one ohm of resistance. Since Ohm's Law is an equation, it can be written three different ways so that if you know any two facts about a circuit you can calculate the third or unknown fact by using one of the following equations:

Voltage = Amperage x Resistance

Amperage = Voltage ÷ Resistance

Resistance = Amperage ÷ Voltage

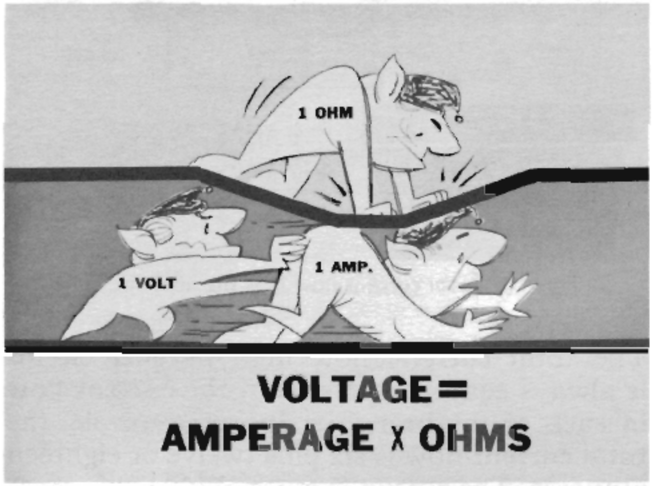


Fig. 6—Ohm's Law defines electrical behavior

A CIRCUIT IS AN ELECTRICAL PATH

Batteries and alternators apply electrical pressure and cause an electric current to move through a circuit from the high-pressure side to the low-pressure side. But there must be a complete circuit or electrical path made up of wires or other conductors or a current will not flow. If a wire is broken or disconnected, current stops. Circuits are not all alike and electricity does not behave exactly the same in different types of circuits. Therefore, it is important for you to understand the basic kinds of circuits found in an automobile and the way the volts, amps and ohms behave in these circuits.

A SIMPLE CIRCUIT

The easiest way to explain the basic circuits is to use a battery, some wire and electric lamps which serve as resistance units. In the simplest kind of circuit, current flows from the battery, through a lamp and back to the battery to complete the circuit. Most automotive circuits have more than one lamp or resistance unit and aren't quite this simple.

CURRENT FLOW IN A SERIES CIRCUIT

In a series circuit, two or more lamps or resistance units are connected so that there is only one continuous path for current flow. Since, in a series circuit, all of the current must flow through each of the resistance units, the current flow is always the same everywhere in the circuit. This is always true regardless of how many resistance units you connect in series.

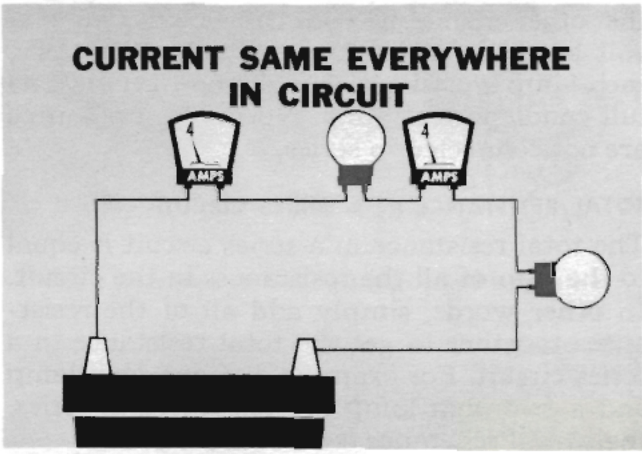


Fig. 7—A series circuit means one continuous flow path

The important thing to remember is that in a series circuit there is only one path for current flow. If you remember this, you'll have no trouble recognizing a series circuit when you see it in a wiring diagram.

VOLTAGE DROP IN A SERIES CIRCUIT

Electrical pressure is always reduced by resist-

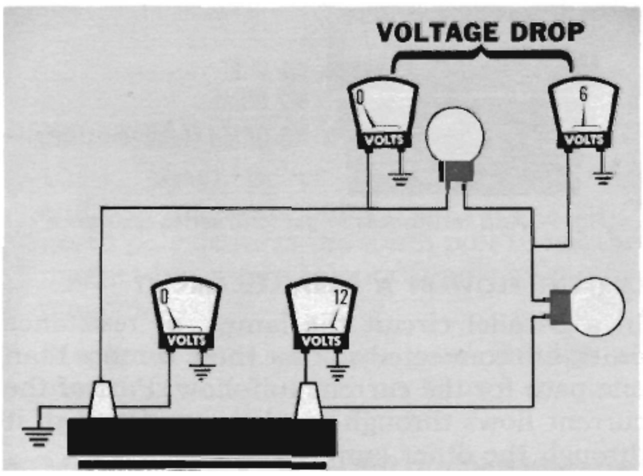


Fig. 8—A voltage drop means a voltage difference

ance in a circuit. This reduction in electrical pressure is usually referred to as voltage drop. Voltage drop is simply the difference between the voltage at one point in a circuit and the voltage at another point in the same circuit.

Incidentally, if you were to connect two twelve-volt lamps in series to a twelve-volt battery, the lamps would glow dimly. That's because neither lamp would get a full twelve volts. If both lamps were the same candlepower, the voltage drop across each lamp would be the same . . . six volts. But, six volts wouldn't push enough current through the circuit to make the lamps glow with full brilliance. On the other hand, if you connected two six-volt lamps in series to a twelve-volt battery, each lamp would get six volts and produce its full candlepower rating. Normally, car lamps are not connected in series.

TOTAL RESISTANCE IN A SERIES CIRCUIT

The total resistance in a series circuit is equal to the sum of all the resistances in the circuit. In other words, simply add all of the resistances together to get the total resistance in a series circuit. For example, if a one-ohm lamp and a two-ohm lamp are connected in series, their total resistance is three ohms.

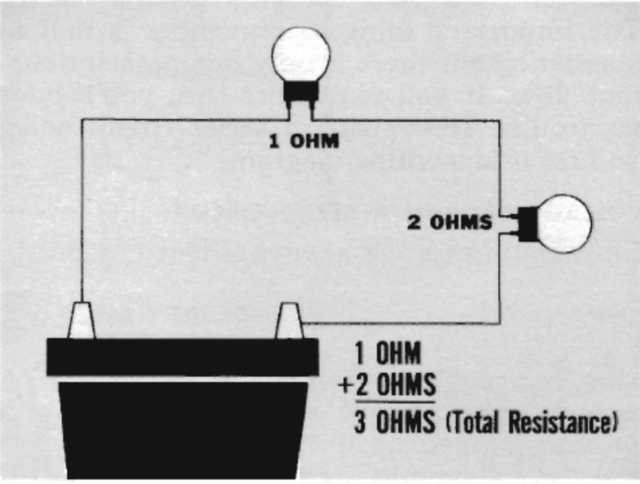


Fig. 9—Add resistances to get total series resistance

CURRENT FLOW IN A PARALLEL CIRCUIT

In a parallel circuit the lamps, or resistance units, are connected so that there is more than one path for the current to follow. Part of the current flows through one lamp and part of it through the other lamp.

Let's suppose that a one-ohm lamp and a two-ohm lamp are connected in parallel to a twelve-volt battery. You can use Ohm's Law to figure out that in this twelve-volt system, twelve-amperes will flow through the lamp having one-ohm resistance but only six-amperes will flow through the two-ohm lamp. Unlike a series circuit, the current flow is not the same in all parts of a parallel circuit.

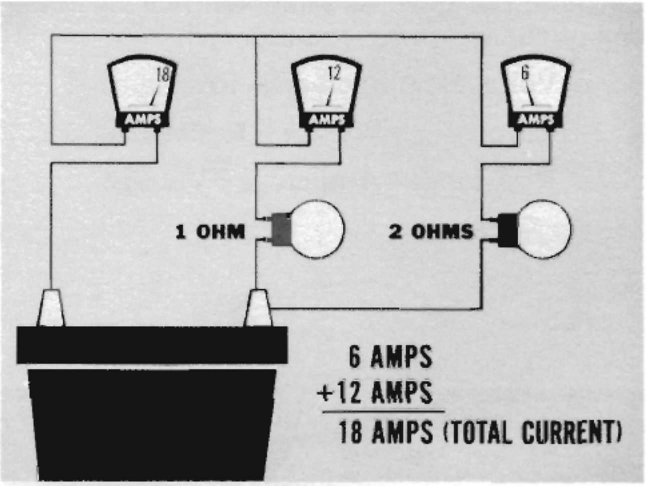


Fig. 10—Total current flow in a parallel circuit

The total current flow in a parallel circuit is always equal to the sum of the current flow in each of the branches. In our example, the total current flow is six plus twelve or eighteen amperes. The reason is quite obvious . . . more current can flow through two paths than can flow through one path.

VOLTAGE IN A PARALLEL CIRCUIT

When two resistance units are connected in parallel, the same voltage is applied to each resistance. If two twelve-volt lamps are connected in parallel, the voltage applied to each lamp and the voltage drop across each lamp will be twelve volts. Lamps are normally connected in parallel rather than in series so that each lamp produces full rated candlepower and continues to provide light even if a lamp in another branch of the circuit is burned out or turned off.

RESISTANCE IN A PARALLEL CIRCUIT

The total resistance in a parallel circuit is always less than even the smallest resistance in the circuit. This is explained by the fact that there is less resistance to current flow when two paths are provided than there is when only one of these paths is available.

There are several ways to calculate the total resistance in a parallel circuit. One practical way to find the total resistance offered by two resistances in parallel is to multiply the two resistances and then divide this product by the sum of the same two resistances. Let's take that a bit slower using a circuit having a two-ohm lamp and a four-ohm lamp in parallel. The accompanying circuit illustration with its resistance calculations clearly explains that the total resistance of two-ohms and 4-ohms in parallel is 1⅓ ohms. Note that the total resistance is less than either of the individual resistances.

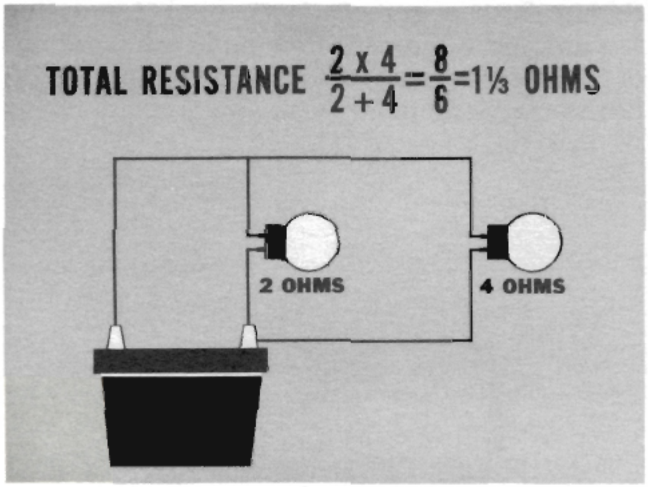


Fig. 11—Total resistance in parallel circuit

We will discuss the electrical measuring instruments and the measurement of voltage and amperage as soon as we have covered some basic facts about magnetism.

MAGNETISM AND MAGNETS

If it weren't for magnetism, electrical energy would have very few practical applications. Magnetism is essential to the operation of the alternator, the ignition coil and the starter. As a matter of fact, the lights and the cigar lighter are the only electrical automotive units we can think of that operate without magnetism.

THE NATURE OF MAGNETISM

Magnetism, like electricity, can be explained most readily in terms of what it does and the way it acts. The simplest type of magnet is a permanent bar magnet. Lines of force leave the magnet at the north pole and enter again at the south pole. The magnetic field is all of the space, outside of the magnet, containing *lines of magnetic force.* If a bar magnet is bent into the shape of a horseshoe, the magnetic field becomes stronger because the distance between the north and south poles is greatly reduced and the lines of force are more concentrated.

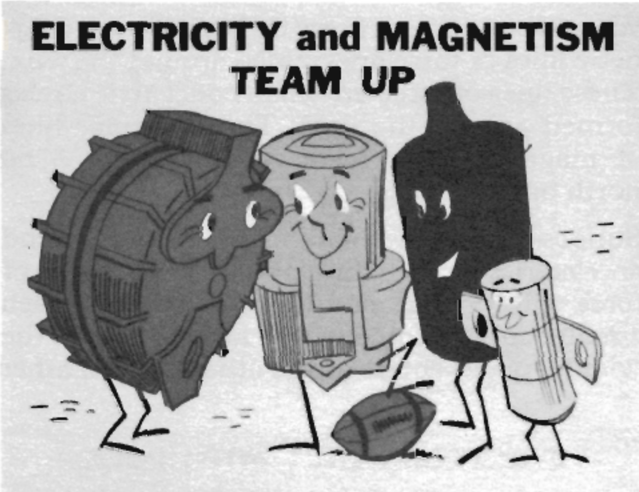


Fig. 12—These units need electricity and magnetism

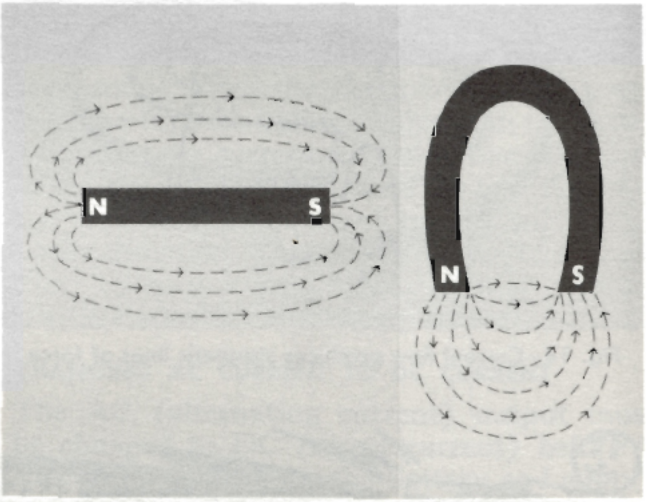


Fig. 13—Horseshoe magnet field is more concentrated

QUICK FACTS ABOUT MAGNETISM

- Unlike magnetic poles attract each other and like magnetic poles repel each other. A north pole attracts the south pole of another magnet but repels the north pole of another magnet.
- Magnetic lines of force pass through all materials and there is no known insulator against magnetism.
- Magnetic lines pass easily through materials that can be magnetized, such as iron or steel.

They pass much less readily through air or across an "air gap".

- Hard steel alloys are used in permanent magnets because they retain high magnetic strength when they are magnetized.

CURRENT FLOW CREATES MAGNETISM

Whenever a current flows through a wire, magnetic lines of force are created around the wire. These lines of force are small concentric circles formed around the wire. These circular lines of magnetic force have no polarity . . . no north or south pole.

Suppose we form a wire into a loop and send an electric current through the wire. Lines of force will form around the wire but now each circular line of force leaves at one side of the wire loop and enters at the other side. In other words, the lines of force all pass through the center of the wire loop. This action creates a weak electromagnet having north and south poles. The magnetic lines all leave the inside of the loop at the north pole, flow around the outside of the loop and reenter at the south pole . . . just like a bar magnet.

A PRACTICAL ELECTROMAGNET

A practical electromagnet has many turns of wire wound around a soft iron core. The more turns of wire, the more lines of magnetic force and the stronger the electromagnet. The soft iron core is a good "magnetic conductor" and helps concentrate the lines of force to increase the strength of the magnetic field. Increasing the amount of current flowing in the windings of the electromagnet also increases the strength of the magnetic field.

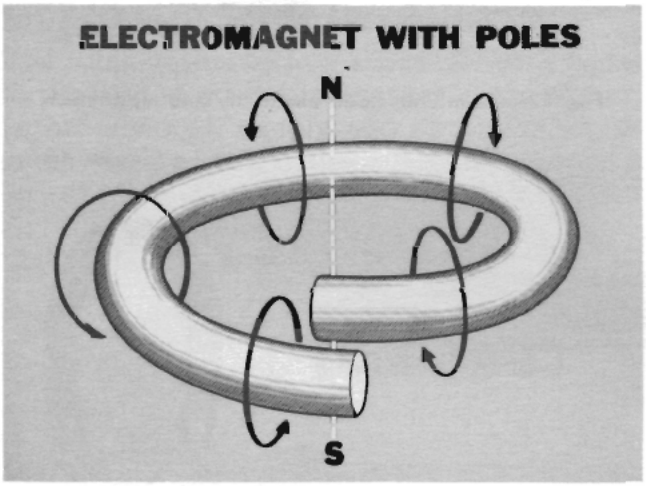


Fig. 14—Current flow produces magnetic lines of force

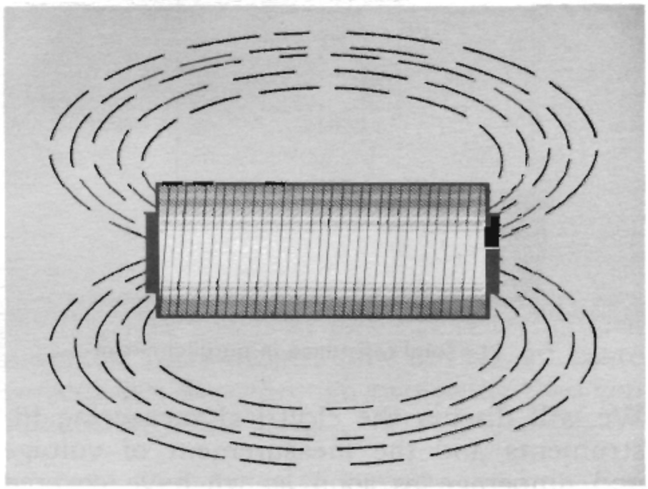


Fig. 15—An electromagnet with an iron core is stronger

It takes both electricity and magnetism to generate a voltage, make an electric motor run and turn low voltage into high voltage for the ignition system. Understanding how an alternator changes torque into electricity, how a starting motor changes electricity into torque and how an ignition coil steps up voltage will help you do a better job of diagnosing trouble in these units and their circuits.

GENERATING A VOLTAGE

In a generator or alternator, mechanical energy is changed into electrical energy. The basic principle of generating a voltage is the same for generators and alternators.

ELECTROMAGNETIC INDUCTION

Earlier we explained that a magnetic field is created around a wire when current passes through the wire. This action can be reversed. When a magnetic field is moved so that its lines of force cut across a wire or conductor, a voltage is generated in the conductor. This can be demonstrated by connecting the conductor to a lamp so that the lamp will light when the field is moved rapidly across the conductor.

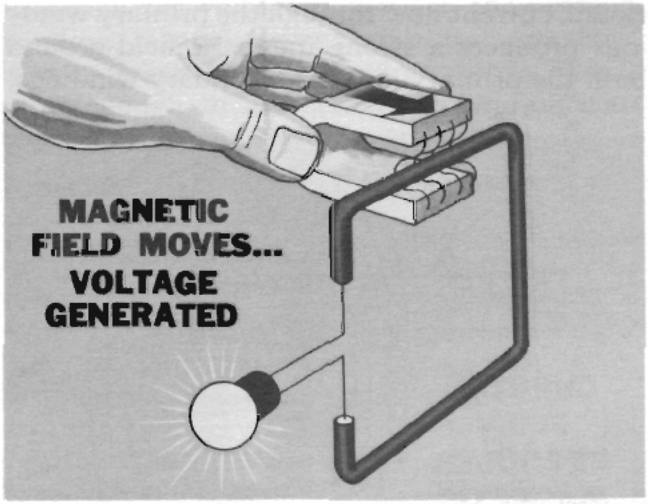


Fig. 16—Voltage generated by electromagnetic induction

When a voltage is generated by magnetic lines of force cutting across a conductor, the process is called *electromagnetic induction*. It doesn't make any difference whether the field and lines of force move across the conductor or the conductor moves across the field. As long as there is relative motion between the two, a voltage will be induced in the conductor. In an alternator, the field moves and the conductor is stationary. In a generator, the conductor moves and the field is stationary.

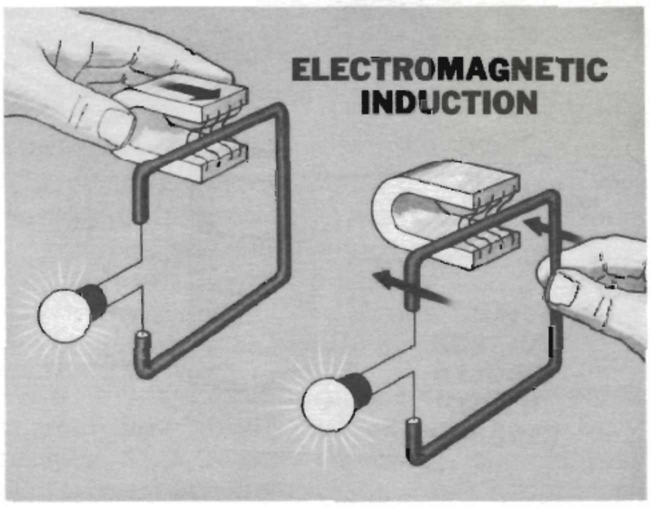


Fig. 17—Relative movement induces the voltage

A SIMPLE ALTERNATOR

In an alternator, a magnet is rotated inside of the stationary conductor so that lines of force cut across the conductor. A voltage is induced in the stationary conductor . . . called a *stator*. The rotating magnet is called the *rotor*.

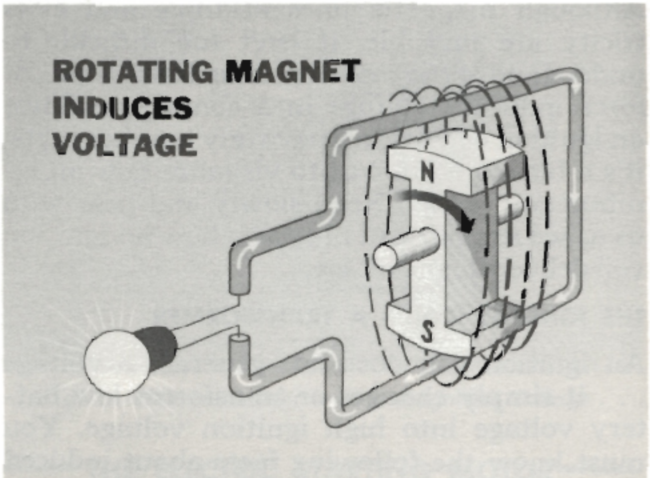


Fig. 18—An alternator has stationary conductor windings

The direction of the current flow produced in our simple alternator changes every half-revolution. When the north pole of the rotor is at the top, the voltage induced in the stator will cause the current to flow in one direction. When the south pole reaches the top, the voltage will cause the current to flow in the opposite direction. Thus the direction of current flow reverses every half-revolution. That's why it's called an alternating current.

CHANGING AC CURRENT TO DC CURRENT

The AC (alternating current) output must be changed to DC (direct current) before it can be used to charge the battery and supply the other circuits found in present-day cars. Six integrally mounted rectifiers are used to change the output of Chrysler-built alternators from AC current to DC current. A complete explanation of how these rectifiers change alternating current to direct current is too lengthy to cover in this session. However, you will find it interesting and helpful to understand how a rectifier works.

A rectifier is a one-way electrical valve. It allows current to flow in only one direction. When a rectifier is connected into the output circuit of an alternator, current will flow through the rectifier in only one direction.

When the direction of the current tries to reverse, no current will flow through the rectifier. As a result, we get one-way or direct current which does not reverse or alternate its direction of flow.

THE IGNITION COIL

Although magnetic lines of force and electricity are invisible, it isn't too difficult to understand how *moving* magnetic lines of force induce a voltage in a conductor. Since an ignition coil doesn't have any moving parts, it's a bit more difficult to visualize how an ignition coil works. Read slowly and bear with us as we explain and illustrate how an ignition coil delivers high voltage.

THE IGNITION COIL'S A TRANSFORMER

An ignition coil does not generate a voltage . . . it simply changes or transforms low battery voltage into high ignition voltage. You must know the following facts about induced voltage before you can understand how an ignition coil works:

- Increasing the speed at which magnetic lines of force cut across a conductor increases the voltage induced in the conductor.
- The greater the number of turns of wire cut by the moving lines of magnetic force, the greater the voltage induced in these turns of wire.

The foregoing facts apply to induced voltages . . . generators, alternators and ignition coils.

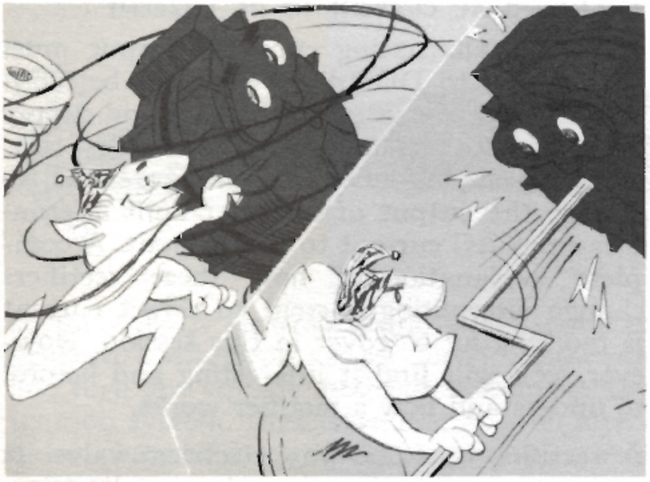


Fig. 19—Increasing speed or windings increases voltage

TWO SETS OF WINDINGS PER IGNITION COIL

An ignition coil has two sets of windings. The primary winding has fewer turns of relatively heavy wire and is connected to the battery through a switch . . . the ignition contacts. The secondary winding has many more turns of fine wire and is connected to a circuit leading to the spark plugs. Both the primary and secondary windings are wound on the same soft iron core. When the ignition contacts are closed, current flow through the primary windings produces a strong magnetic field around both the primary and the secondary windings.

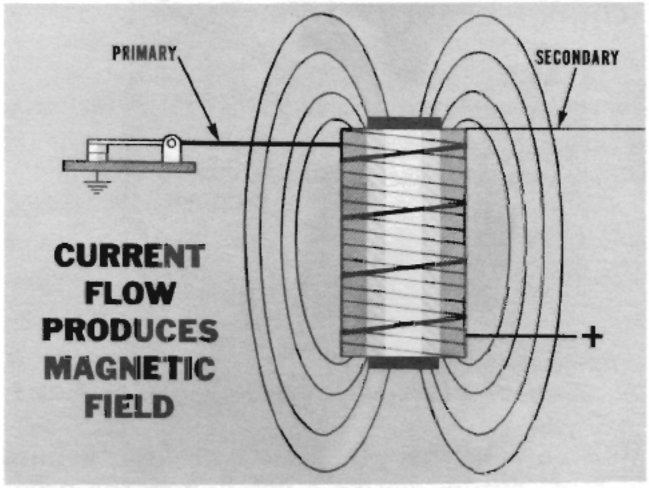


Fig. 20—An ignition coil has two sets of windings

WHEN THE CONTACTS OPEN

When the ignition contacts open, current flow through the primary windings stops. The magnetic field collapses and literally shrinks back into the iron core of the coil. The movement of the collapsing lines of force is very real and very rapid. It is the movement of the collapsing lines of force which induces a volt-

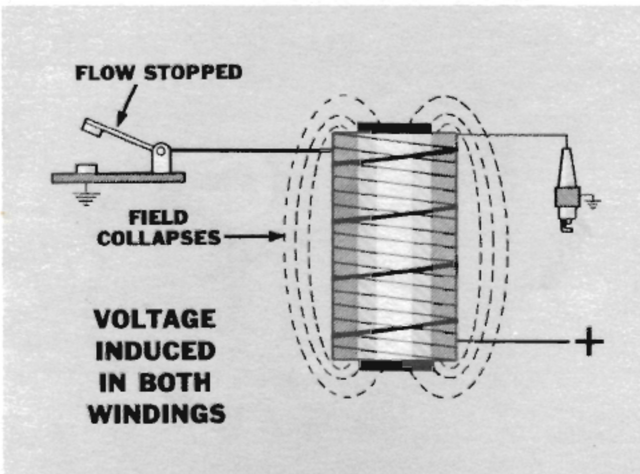


Fig. 21—The magnetic field collapses when contacts open

age in both the primary and the secondary windings of the coil.

Since there are thousands of turns of fine wire in the secondary windings, the voltage induced in these windings is very high. Since there are far fewer turns in the primary winding, the voltage induced is much lower.

Although the voltage induced in the primary windings is much lower than in the secondary, it may reach several hundred volts. This is great enough to arc across the ignition contacts as they open and burn them.

THE CONDENSER PROTECTS THE CONTACTS

The condenser is connected in parallel across the ignition contacts. It absorbs and stores the current flow caused by the voltage induced in the primary when the field collapses. By the time the condenser is fully charged, the space between the contacts is wide enough to prevent the induced voltage in the primary windings from pushing a spark across the gap between the contacts.

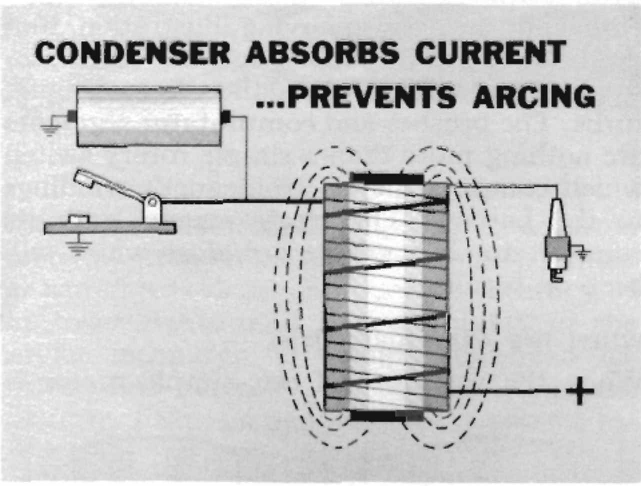


Fig. 22—The condenser is connected in parallel

CONDENSER INCREASES IGNITION VOLTAGE

The condenser does something even more important than protecting the ignition contacts . . . it helps the coil produce even higher ignition voltage. That's why a car won't start or run without a good condenser. Here's what the condenser does to step up voltage.

When the contacts open, the condenser stops current flow in the primary windings very rapidly. This in turn speeds up the collapse of the magnetic field, increasing the speed at which the lines of force cut across the secondary windings. By increasing the speed at which the magnetic field collapses, the condenser increases the induced secondary voltage.

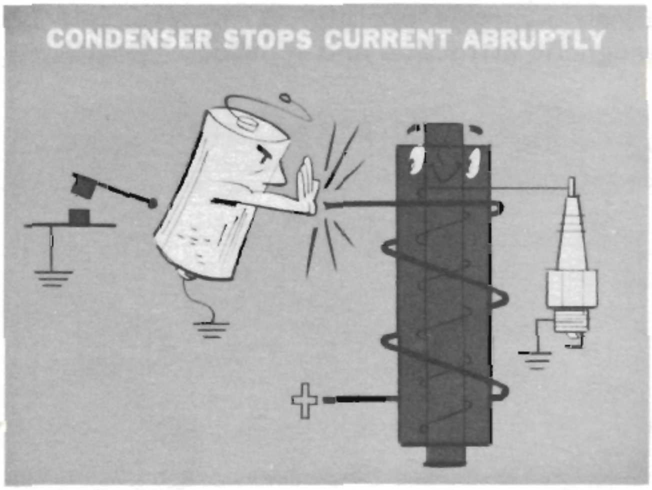


Fig. 23—The condenser increases ignition voltage

THE ELECTRIC STARTING MOTOR

The electric starting motor did more than anything else to put the little woman in the driver's seat. No doubt about it, electric starters contributed greatly to the popularity of motor cars. So, let's take time to explain how an electric motor works.

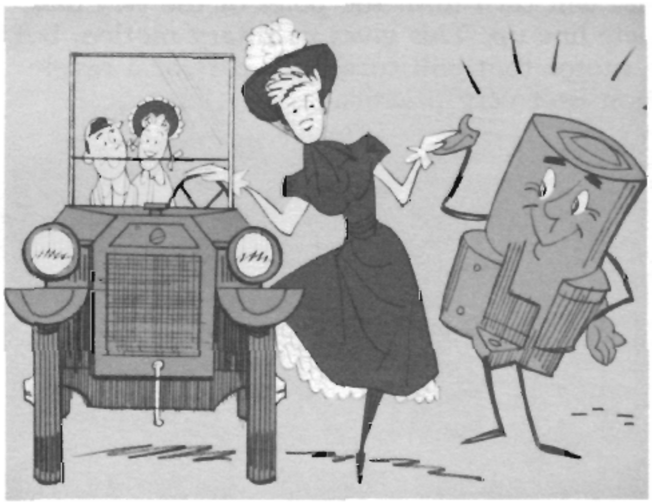


Fig. 24—The starter helped make cars popular

MAGNETS MAKE A MOTOR RUN

An electric motor is simply an electromagnetic device that turns electrical energy into mechanical energy . . . and it's all done with magnets. If you bring the north pole of one magnet close to the south pole of another magnet, magnetic attraction will finish the job of pulling the two magnets together. If you put the two like poles of two magnets together, the like magnetic poles will repel each other, pushing the two magnets apart. Electric motors operate on the principle of magnetic attraction and repulsion.

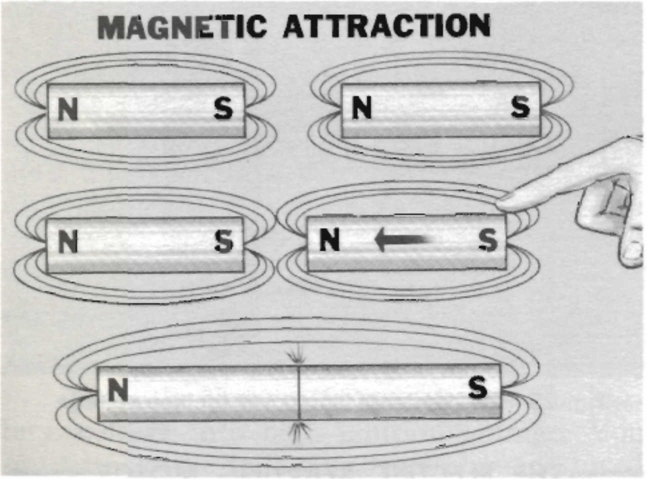


Fig. 25—Magnetic attraction can produce motion

In order to use the principle of magnetic attraction to obtain rotary motion, a bar magnet and horseshoe magnet can be used instead of two bar magnets. If we put a bar magnet in the field of a horseshoe magnet, the bar magnet will turn until the poles of the two magnets line up. This gives us rotary motion, but a motor that will turn only part of a revolution isn't very practical.

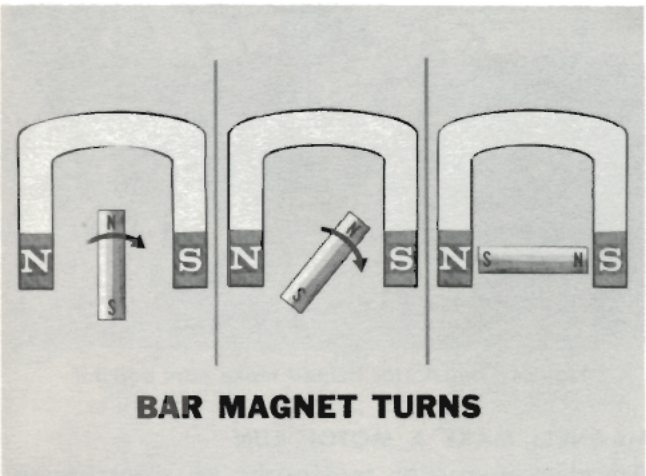


Fig. 26—Magnet rotates until poles line up

LET'S USE AN ELECTROMAGNET

In a very simple electric motor an electromagnet is used in place of the permanent bar magnet. The horseshoe magnet can be either an electromagnet or a permanent magnet. To simplify things, we'll use a permanent horseshoe magnet.

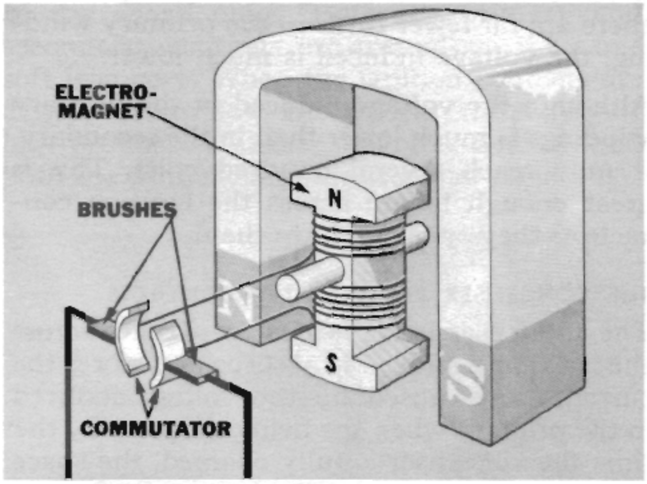


Fig. 27—The working parts of a simple motor

The windings of the electromagnet are connected to a battery through brushes and electrical contacts called *commutator segments.* Notice, in the accompanying illustration, that the brushes are stationary and the commutator segments turn when the electromagnet turns. The brushes and commutator segments are nothing more than a simple rotary switch which connects the electromagnet's windings to the battery. The electromagnet with its commutator is a simple *armature* which will keep on turning.

WHEN THE ARMATURE TURNS

When the armature of our simple motor is

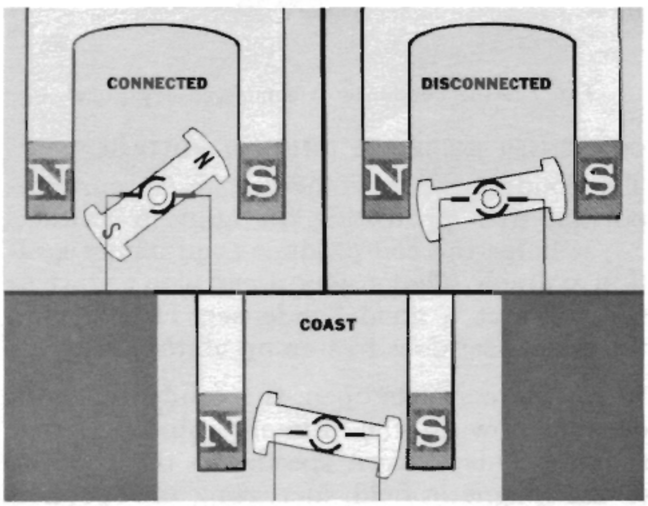


Fig. 28—The commutator disconnects the armature

connected to a battery, the armature will start to rotate. When the poles of the armature start to line up with the poles of the horseshoe magnet, the commutator is momentarily disconnected from the brushes. The armature's magnetic field is temporarily interrupted and the armature coasts past the point where the armature and horseshoe magnet poles line up.

Shortly after the poles of the armature coast past the poles of the horseshoe magnet, the commutator is reconnected to the brushes. The armature again becomes an electromagnet but now the magnetic polarity of the armature is reversed. The poles of the horseshoe magnet are now repelling instead of attracting the armature so it keeps on turning.

In our simple example, the magnetic poles repel each other for a quarter revolution and then attract each other for a quarter revolution. Then, the polarity of the armature is reversed and the poles repel each other for the next quarter revolution and attract each other for the final quarter revolution. Of course a starting motor has many more armature windings, more commutator segments, and an electromagnetic field in place of the horseshoe magnet. However, the basic principle remains the same.

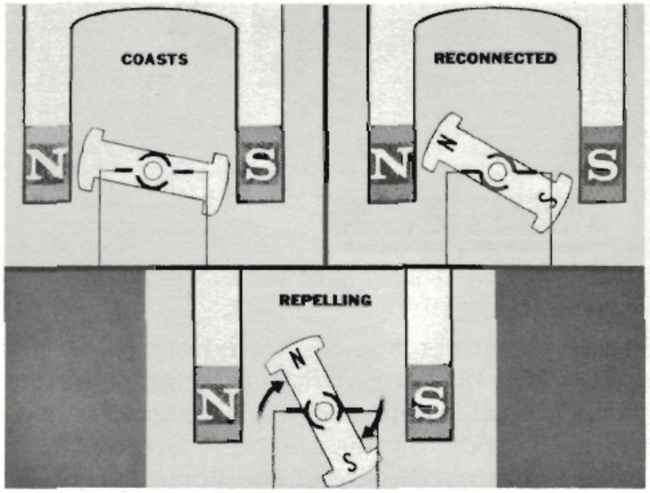


Fig. 29—The commutator reverses the polarity of the armature

ELECTRICAL MEASURING INSTRUMENTS

The basis of electrical diagnosis is accurate electrical measurements. The value of these measurements depends upon the accuracy of the instruments used and the ability of the service technician to connect and read his instruments correctly. In the final analysis, accurate diagnosis depends on the correct interpretation of accurate measurements. If you understand how electrical measuring instruments work you'll find it easy to understand how they must be connected and used when testing electrical circuits.

VOLTMETER CONSTRUCTION & CONNECTIONS

The basic working parts of ammeters, ohmmeters and voltmeters are the same or very similar. These instruments have a permanent horseshoe-type magnet, a pointer attached to a movable coil, and a graduated scale. However, the internal circuitry is quite different for each of these instruments. Voltmeters and ammeters differ primarily in the way the test leads are connected to the movable coil.

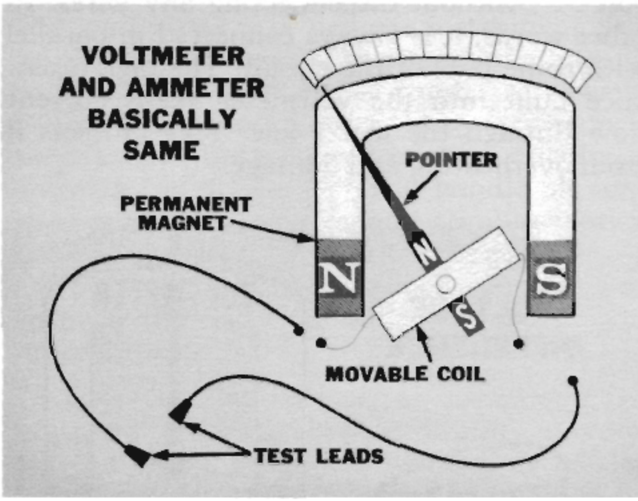


Fig. 30—The working parts of a voltmeter or ammeter

AN INSIDE LOOK AT A VOLTMETER

In a voltmeter, the windings of the movable coil are connected to the test leads through a high resistance. This resistance unit limits the amount of current flow through the meter.

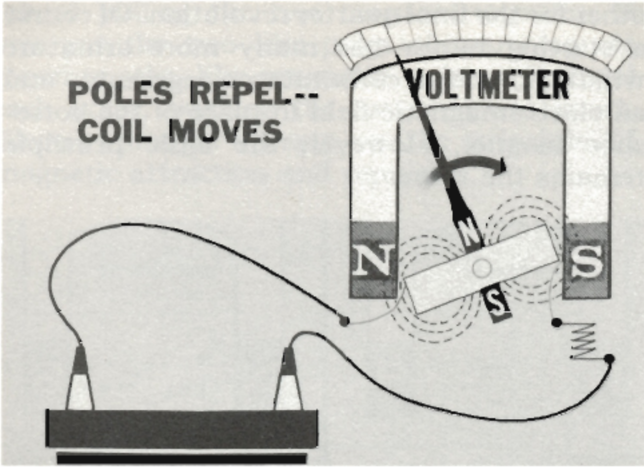


Fig. 31—Like poles repel and the coil moves

When a voltmeter is connected across a battery or circuit, current flow through windings of the movable coil produces a magnetic field. The north pole of this magnetic field is fairly close to the north pole of the horseshoe magnet. Since like poles repel, the coil and pointer move anytime current flows through the windings of the coil. The higher the voltage, the greater the current flow through the coil, the stronger the magnetic field around the coil and the greater the movement of the coil.

CONNECT A VOLTMETER ACROSS THE CIRCUIT

A voltmeter is always connected across a circuit . . . without disconnecting any wires. In other words, it is always connected in parallel with some part of the circuit. The high resistance built into the voltmeter keeps current flow through the meter low. This protects it from overheating and damage.

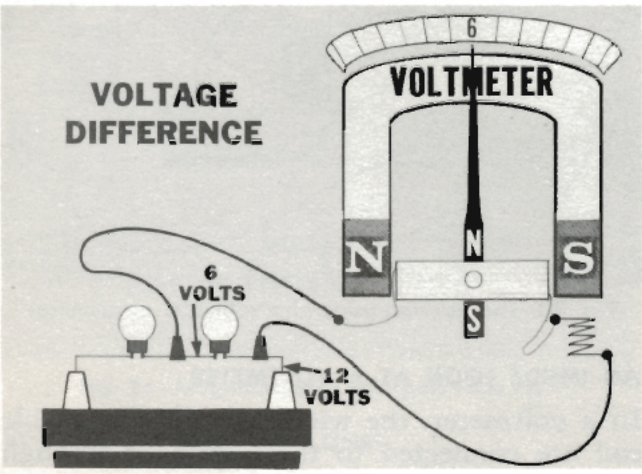


Fig. 32—Measuring the voltage difference between terminals

The voltmeter measures the *voltage difference* between the two terminals the meter leads are connected to. In other words, it measures the *voltage drop* between two points in the circuit.

If one voltmeter lead is connected to a terminal in a circuit and the other lead is connected to a good ground, the voltmeter will register the *voltage available* at that terminal. That's because it's actually measuring the voltage drop across the circuit from the terminal to the battery ground post.

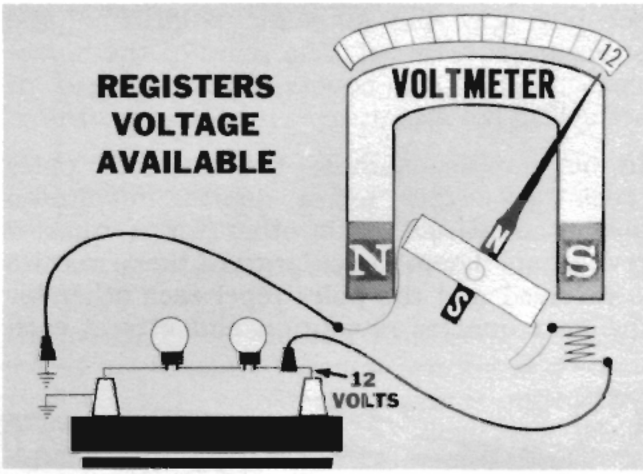


Fig. 33—Measuring the voltage available at a terminal

AMMETER CONSTRUCTION AND CONNECTIONS

Like a voltmeter, an ammeter has a permanent horseshoe magnet and a movable coil with pointer. However, its internal circuitry is entirely different.

AN INSIDE LOOK AT AN AMMETER

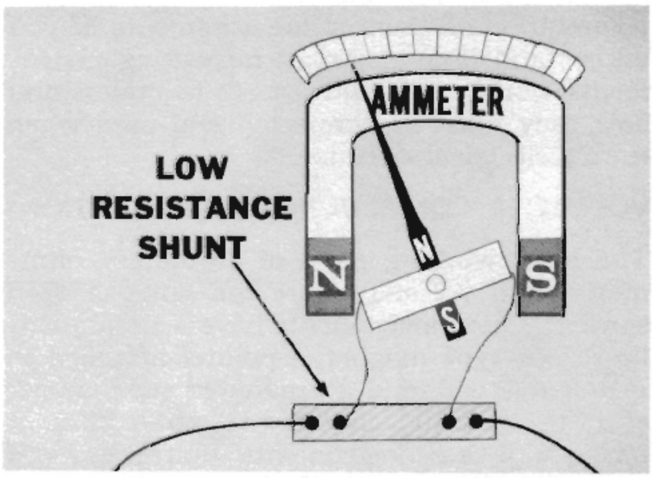


Fig. 34—Most of the current flows through the ammeter shunt

The movable coil windings of an ammeter are connected to the external test leads through a low-resistance shunt. The internal meter connections are made so that the movable coil is connected in parallel with the shunt. As a matter of fact, a shunt circuit is nothing more than a parallel circuit. When the ammeter is connected into a circuit, most of the current flows through the low resistance of the shunt and only a small amount flows through the movable coil.

CONNECT AN AMMETER IN SERIES

An ammeter must *always* be connected directly *into* the circuit . . . in series . . . so that all of the current flowing in the circuit you are testing will flow through the ammeter. That means you must disconnect at least one wire and break into a circuit in order to connect an ammeter correctly.

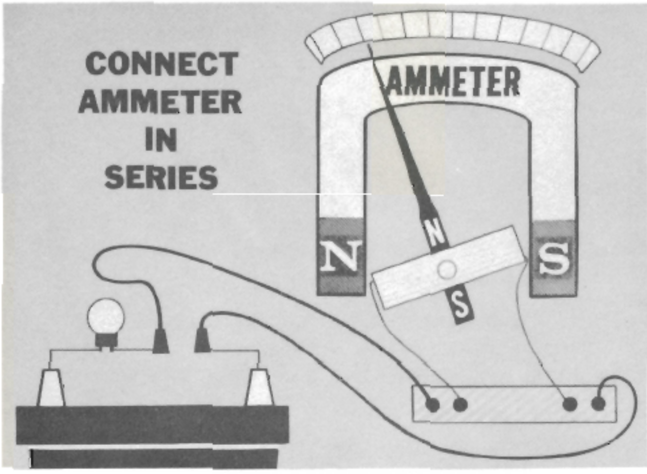


Fig. 35—An ammeter is always connected into the circuit

THE CIRCUIT MUST PROTECT THE AMMETER

Never connect an ammeter into a circuit unless there is enough resistance in the circuit you are testing to limit the amount of current flow through the meter. For example, suppose you connect an ammeter into a twelve-volt circuit having a lamp in it with a twelve-ohm resistance. Ohm's Law will tell you that the resistance of this lamp will let only one-ampere flow through the circuit. This couldn't damage an ammeter rated at one ampere or more. However, *if the resistance was less than* twelve ohms, the ammeter would have to have a capacity of more than one ampere. Just remember, the external circuit resistance must protect the meter . . . it doesn't have enough internal resistance to protect itself.

NEVER CONNECT AN AMMETER ACROSS A CIRCUIT

Never connect an ammeter the way you connect a voltmeter. If you connect an ammeter in parallel, across the circuit instead of in series, you'll fry it!

Fig. 36—Never connect an ammeter across a circuit

Connecting an ammeter across a circuit would let full battery voltage push too much current through the low resistance of the shunt. Too much current would also flow through the coil windings and damage them.

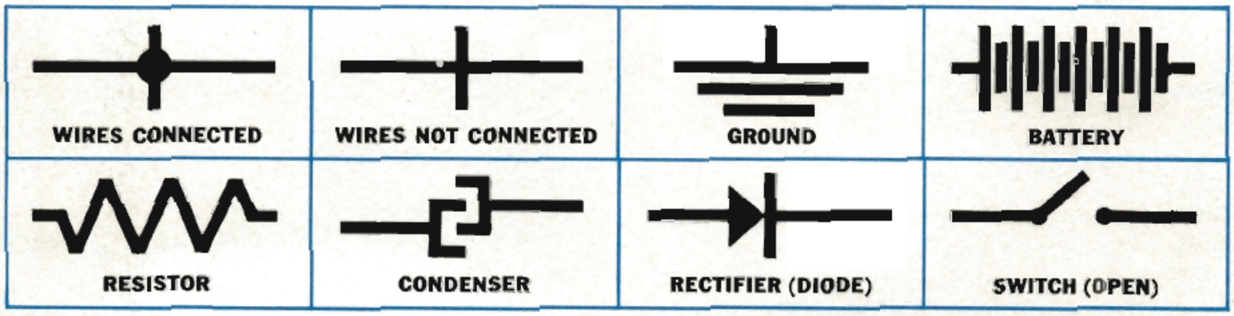
A WORD OR TWO ABOUT OHMMETERS

The ohmmeter is a delicate instrument used to obtain very precise resistance readings. It is frequently used by electronic servicemen but is used far less frequently by service technicians for checking automotive circuits. A voltmeter and ammeter will handle all common-type automotive circuit troubleshooting. Unless you want to measure the exact resistance of an electrical component, such as a resistance-type ignition cable, you won't need an ohmmeter.

In case you are curious, an ohmmeter is a voltmeter that has been carefully calibrated to read ohms. It has its own supply of electricity, usually small batteries mounted in the ohmmeter. These batteries have a known voltage and are used to send a "test" current through the electrical component being tested. An ohmmeter is never connected into or across a "hot" circuit. In other words, the circuit or electrical component being tested must be "dead" when using an ohmmeter.

WIRING DIAGRAM ELECTRICAL SYMBOLS

Commonly used electrical symbols are shown below
to help you understand the average wiring diagram.



ELECTRICAL TERM DEFINITIONS

Alternating Current: Electrical current which continuously reverses its direction of flow at regular intervals.

Ammeter: An instrument used to indicate rate of electrical current flow in a circuit.

Ampere: A unit of the electrical flow rate.

Coil: A continuous winding arrangement of a conductor which combines the separate magnetic fields of all the winding loops to produce a single, stronger field.

Conductor: A path for electrical current flow.

Core: The metallic center section of a coil which serves to concentrate magnetic lines of force.

Current: The flow of electricity in a circuit.

Direct Current: Electrical current which flows continuously in one direction.

Electromagnet: A coil which produces a magnetic field when current flows through its windings.

Ground Circuit: The return side of an electrical circuit. Usually the frame or body of a single-wire automotive system.

Inductance: The reaction which produces voltage when a conductor passes through a magnetic field.

Load: An electrical device or resistance connected into a circuit.

Magnetic Field: The area surrounding the poles of a magnet which is affected by its attraction or repulsion forces.

Magnetic Lines of Force: Lines of magnetic influence which produce the magnetic field. Force lines are stronger and more concentrated at the magnetic poles.

Ohm-Ohmmeter: A unit of electrical resistance—measured by an ohmmeter.

Open Circuit: Any break in an electrical circuit, either intentional or accidental.

Parallel Circuit: A circuit having two or more paths for current flow.

Permanent Magnet: Material (especially iron and steel) which, after exposure to a magnetic field, will retain the ability to attract or repel other similar materials.

Rectifier (diode): An electrical device which permits current flow in one direction only. Used to change alternating current to direct current.

Resistance: The characteristic of an electrical unit or circuit which prevents or reduces current flow.

Series Circuit: A single continuous circuit.

Short Circuit: Commonly, an accidental contact between two conductors which bypasses the normal flow of current in a circuit.

Volt: A unit of electrical pressure—measured by a voltmeter.

Voltage: The electrical pressure which causes current flow in a circuit.

Voltage Drop: The loss of electrical pressure which is caused by resistance in a circuit.

Litho in U.S.A.