Leyland Cars

Service

Service Technician Audio-Visual Information Programme

Training Workbook

Basic Electricity

INTRODUCTION

This workbook is to be used with the STAVI programme on BASIC ELECTRICITY.

In recent years, vehicle electrical systems have become highly sophisticated and complex. As a result, the demands on a technician's electrical skill have multiplied rapidly. Yet even the most elaborate systems operate according to basic electrical principles, of which this programme is a review.

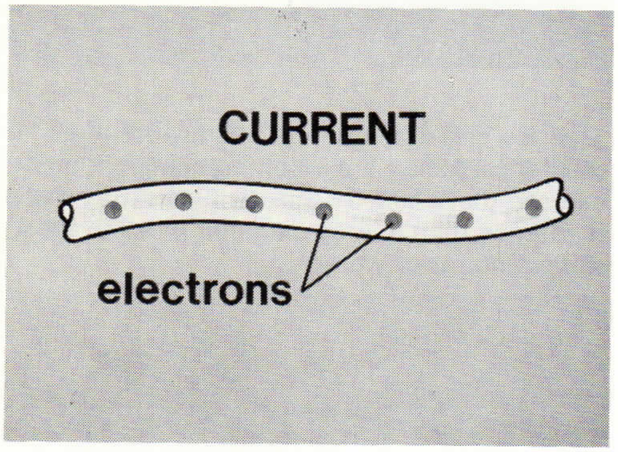
In a separate programme, we will consider methods of trouble-shooting.

TABLE OF CONTENTS

TERMS AND FUNDAMENTALS

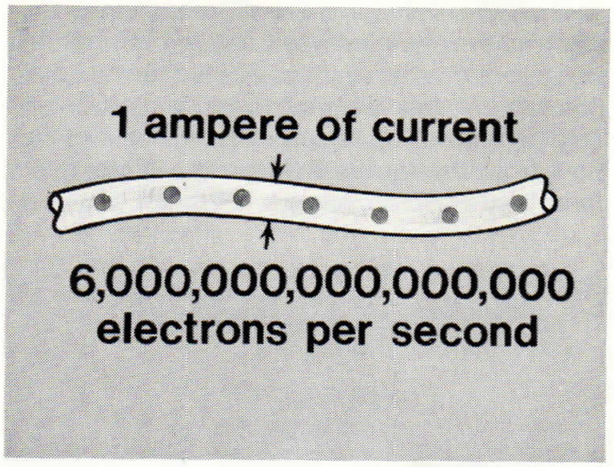
Electricity is an unseen force which can be studied only in terms of its effects. Those effects, of course, include the work we can harness it to do—such as operating the lights, horns, motors, and many other components of modern cars.

Current



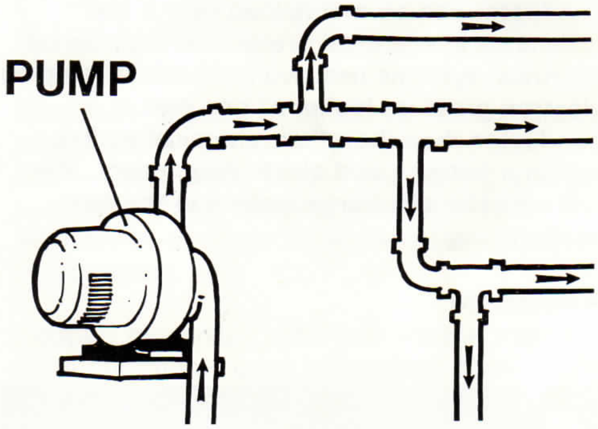
This work is done by electrical *current*, which is understood to be the movement of vast numbers of tiny, charged particles called electrons.

Electrical current can be compared to the flow of water. The greater the flow, the greater the amount of work that can be done. For example: the more water that flows over a water-wheel, the faster the wheel will turn. The actual amount of water flowing over the wheel can be measured.

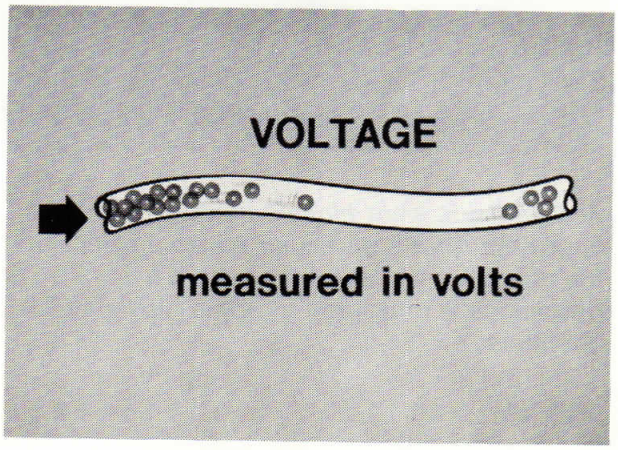


The flow of electrical current is also measurable—in *amperes*, using an ammeter. It has been calculated that a single ampere of current flowing for one second represents the motion of 6,000,000,000,000,000 electrons past any given point.

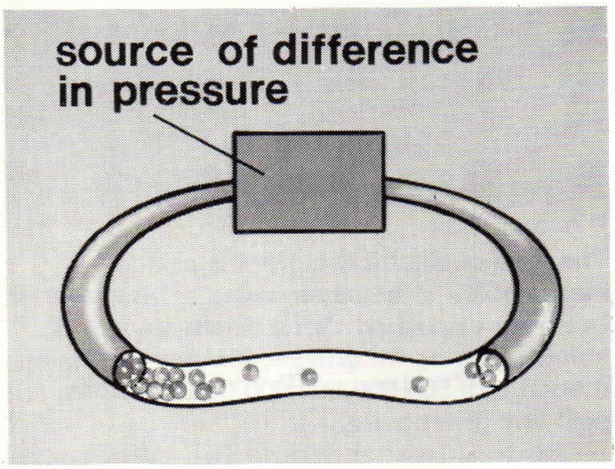
Voltage



Voltage is the *pressure* which causes current to flow. In terms of the comparison with water, voltage is like a pump which moves water through a pipe.

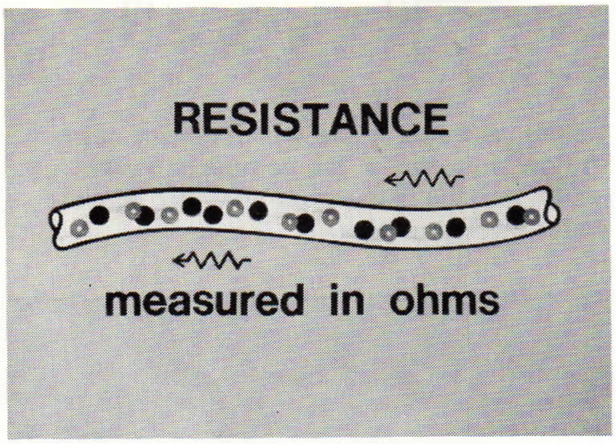


Technically, voltage is the difference in electron pressure between any two points. In any conductor, an excess of electrons at one point and a deficiency of them at another creates a pressure which causes electrons to flow from the former to the latter. Voltage is measured in volts, using a voltmeter.

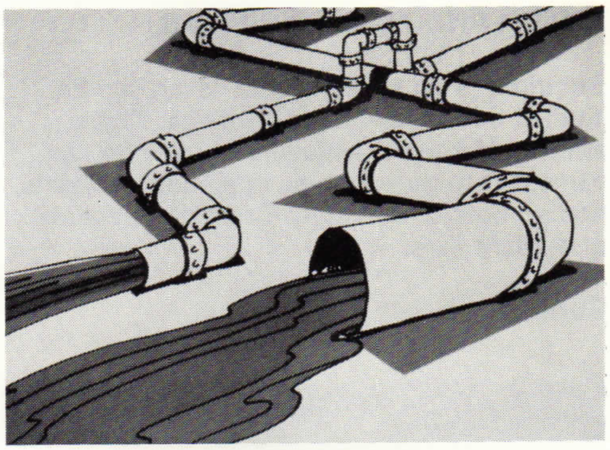


A constant flow of current through a conductor can be maintained only if the difference in electrical pressure is maintained. Electrical systems use two methods of keeping electron pressure higher at one end of a conductor than the other: chemical action, within a battery; and electromagnetism. We will consider electromagnetism in the next section.

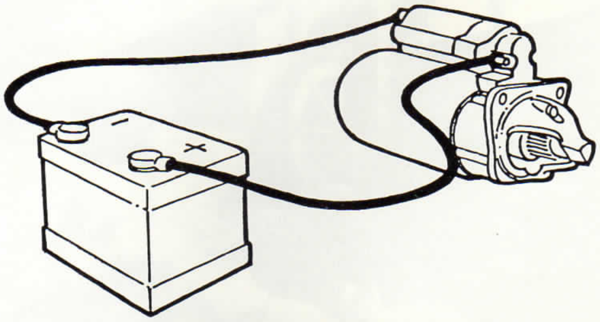
Resistance



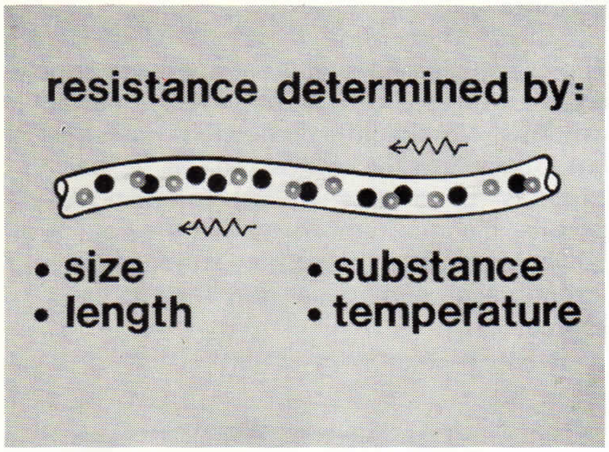
Resistance is what *hinders* current flow—the opposition that a particular material offers to the movement of electrons within it. Resistance is measured in ohms, using an ohmmeter.



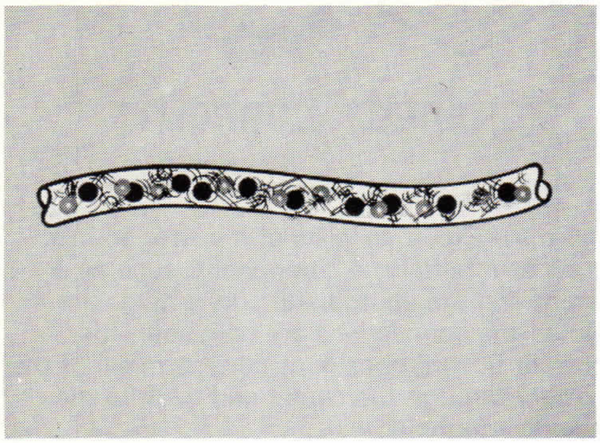
The size of a conductor is one aspect of its resistance. Using the water comparison, we can see that a small-diameter pipe offers more resistance than a large-diameter pipe, to the same amount of water.



A wiper motor needs only a relatively small amount of current to operate it—so the unit needs only a small-diameter cable. A starter motor needs much more current—so heavy cable is required.

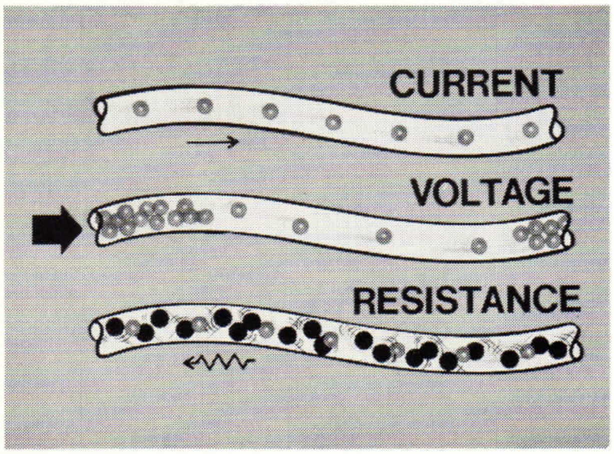


In addition to the size of a conductor, other factors affecting its resistance are its length, the substance it's made of, and its temperature.



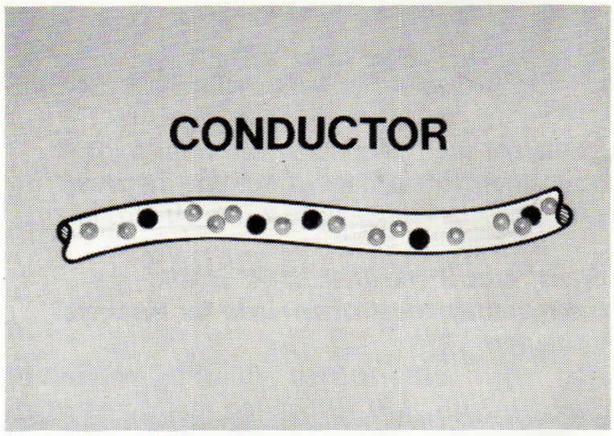
Why temperature? Because as temperature increases, the movement of all the particles within the conductor increases, and the increased frequency of collisions slows the flow of electrons.

IN SUMMARY



The three basic characteristics of an electrical circuit are current, the flow of electrons which performs work, measured in amperes; voltage, the difference in electron pressure between two points, which causes current flow, measured in volts; and resistance, the opposition which a conductor offers to the flow of electrons.

Conductors



Obviously, a good electrical conductor is one which offers very little opposition to current flow—which really means one having a large number of freely moving electrons. This abundance of electrons is characteristic of most metals.

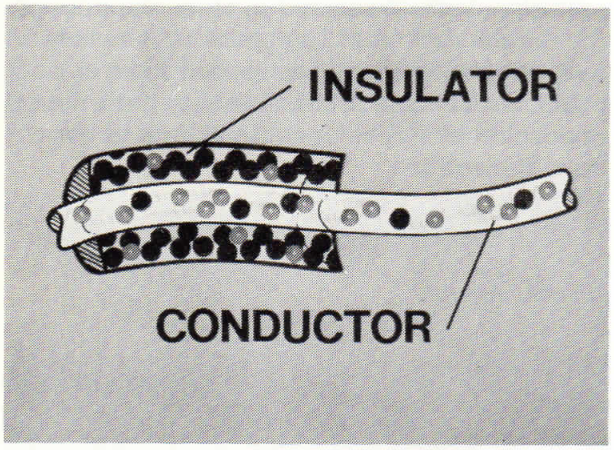
Copper, aluminium, and iron are the metals most commonly used to conduct current through a circuit.

Copper, silver, tungsten, and platinum are often employed as switch contacts.

Some non-metallic substances, such as carbon, are also good conductors. Carbon is used in H.T. leads.

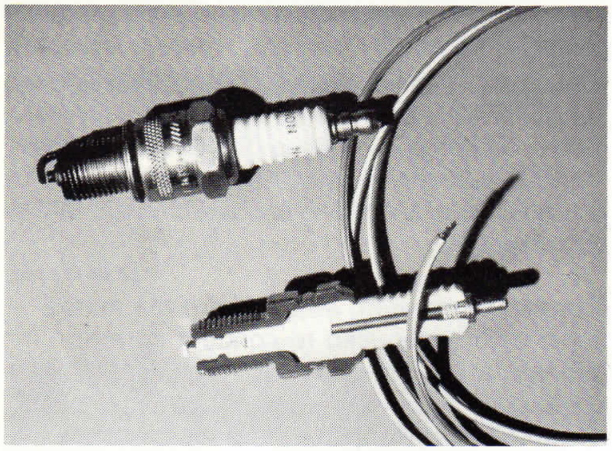
For efficient operation of any electrical component, it's important to keep the flow of current within the circuit and not allow it to leak away. For this purpose, insulators are used.

Insulators



Insulators are materials which offer a lot of opposition to the flow of current, because they possess relatively few free electrons.

Glass, rubber, ceramic, and plastic are the materials most often used for electrical insulation.



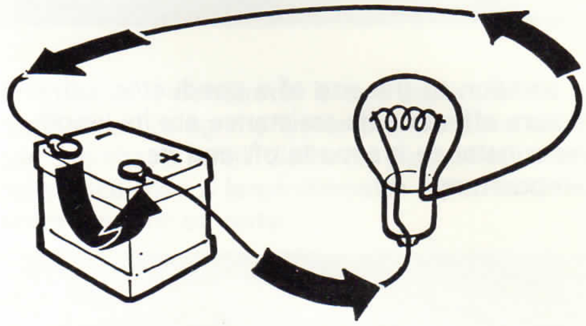
Their efficiency as insulators varies.

Because the insulator of a spark plug must withstand thousands of volts of electrical pressure, it is made of ceramic, one of the most effective insulating materials.

A wire carrying low-voltage current can be sufficiently insulated with only a thin coating of rubber or plastic.

Circuits

The essentials of a circuit are a voltage supply and a completed path through which current can flow. No circuit is complete if power is not returned to the source—that is, if the circuit is "open" at any point. In tracing circuits, it's important to start at the source of power and follow the path of current flow through each component and back to the source.



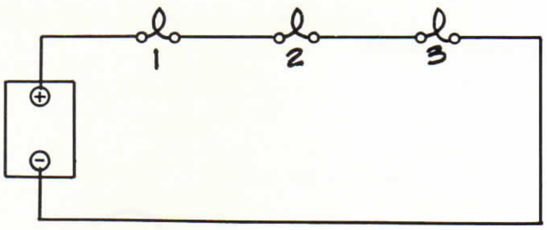
DIRECT CURRENT

A simple circuit consists of a power source, such as a battery; a component, such as a lamp; and the appropriate connecting wire. When the connections are complete, the current flows from the positive terminal of the battery through the circuit and back to the negative terminal.

Of course, few electrical circuits are as simple as that. Many include several components.

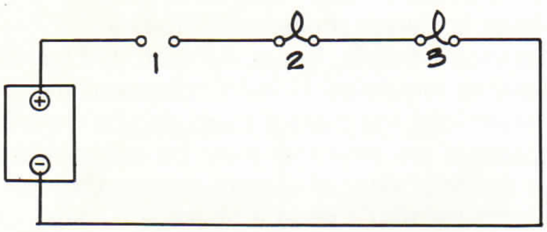
When all components are connected on a single path, so that current flows from the source to one component and then another until its return, the circuit is called a *series* circuit.

Series Circuit



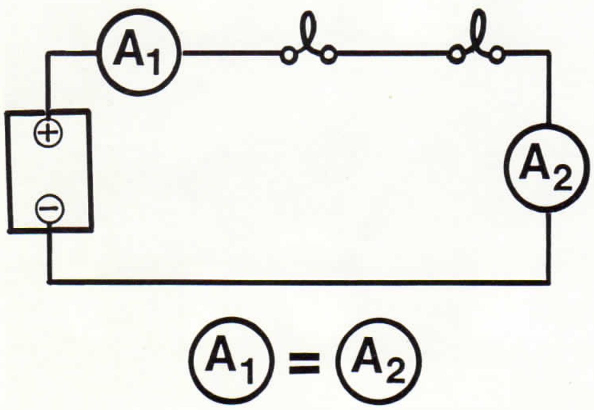
SERIES CIRCUIT

Notice that the components are indeed connected in *a series*—one after the other, in a single path.



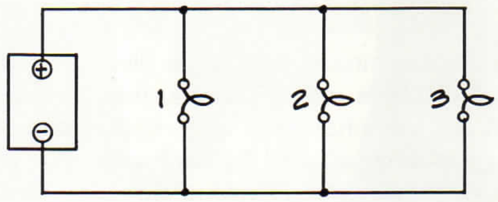
SERIES CIRCUIT

In a series circuit, the failure of one component will cause all components to fail, since the "open" means that no current can flow anywhere in the circuit.



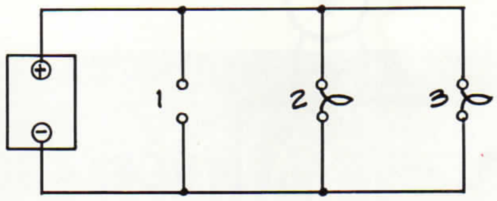
Since all current in a series circuit passes through the single path, the current in amperes—that is, the rate of electron flow—will be the same everywhere in the circuit. If two or more ammeters are connected at different places in the circuit, all will show the same reading.

Parallel Circuit



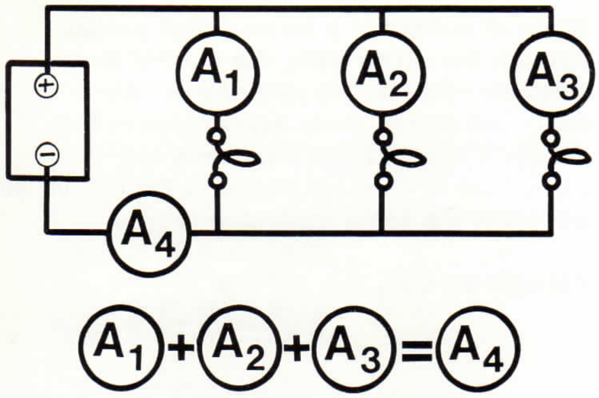
PARALLEL CIRCUIT

In the parallel circuit, two or more components are connected to the battery in such a way that the current has several paths to follow. Here the resistance units are independent of each other.



PARALLEL CIRCUIT

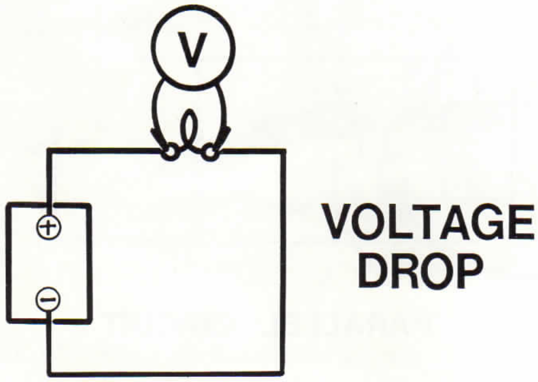
When one fails, the others don't, because the current can take a different course and return to the battery.



In a parallel circuit, current is divided in its travel. For this reason, the current through the different branches may vary, depending on the resistance offered by each unit. But the sum of the amperes flowing through the several branches will always equal the total circuit amperage.

Voltage Drop

What happens to *voltage* in the course of a circuit?

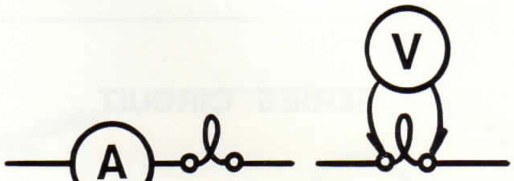


Whatever the type of circuit, voltage always drops across each electrical component. This happens because, as the voltage forces electrons through the component, some of the electrical pressure is expended. The "voltage drop" is measured by connecting a voltmeter across the unit. Only when voltage drop is *excessive* is there cause for concern.

Excessive voltage drop is caused by unwanted resistance in the circuit—the result of undersize wire, bad connections, defective switch contacts, or some other fault.

Excessive voltage drop in the lighting circuit will show up as dim lights. In the charging circuit it will cause a low charging current, permitting the battery to discharge.

Important Note



Remember this: current is always measured directly in the circuit—that is, in series. Voltage is always measured across a resistance—that is, in parallel with it. The rule is easy to remember if you understand the different jobs the meters must do. To measure amperage, the ammeter must be connected so that the *total flow* of current passes through it—because that's what amperage is. The voltmeter must measure the difference in electrical pressure between *two different points* in the circuit—because that's what voltage is.

Ohm's Law

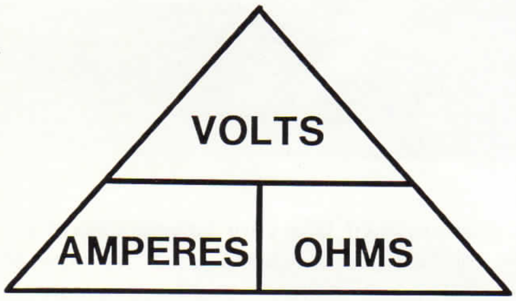
Obviously, in any circuit current, voltage, and resistance are closely related. One hundred and fifty years ago George Ohm discovered the equation which has remained the most important in electrical science:

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}$$

$$\text{Volts} = \text{Amperes} \times \text{Ohms}$$

$$\text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

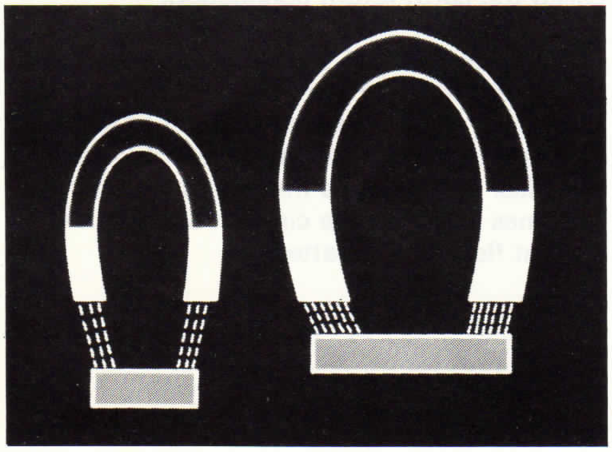
If you know any two of the three quantities, you can discover the third, by using the appropriate form of the equation.



You may find it helpful to remember Ohm's law as a pyramid, like this. It can be very useful in helping you understand electrical problems.

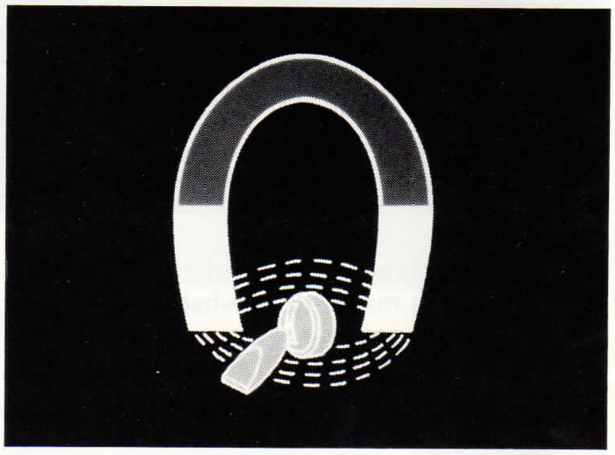
Electromagnetism

Many vehicle electrical systems incorporate electromagnetic features.



We all know that a magnet will attract any magnetic substance by means of magnetic lines of force.

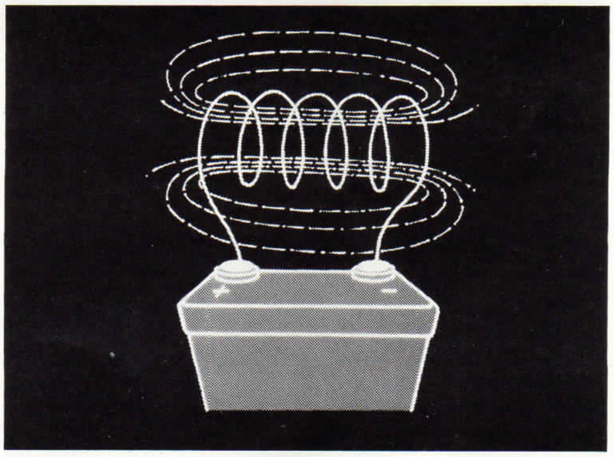
A powerful magnet has a large number of magnetic lines of force.



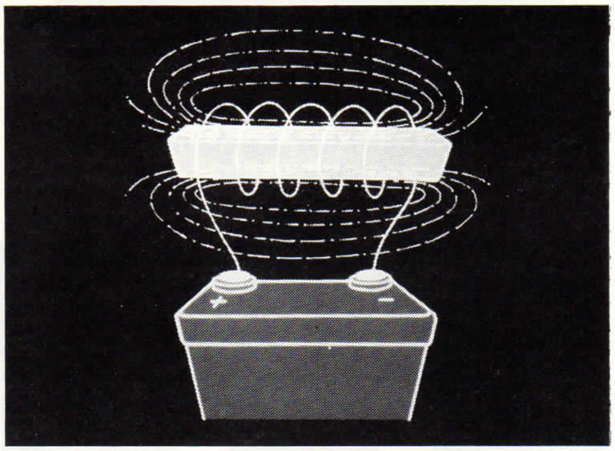
The area in which the magnetic lines of force operate is called the magnetic field.

Magnetic force is used in many electrical components. But in order to use it, we have to be able to regulate it—to switch it on and off, and vary its strength.

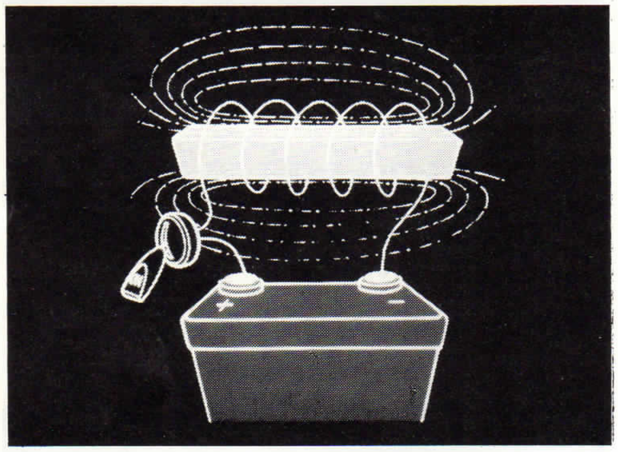
*Electro*magnetism can be regulated this way.



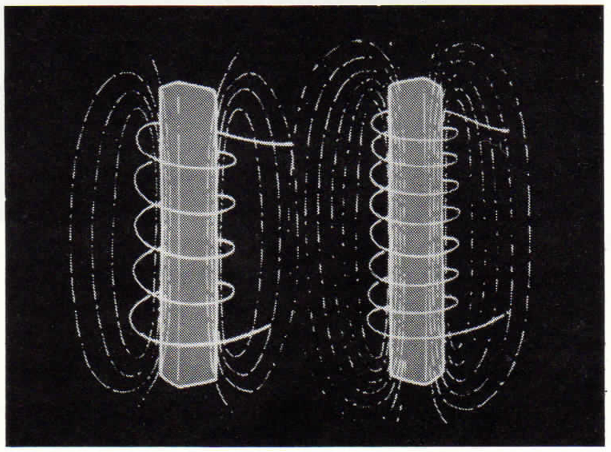
When a wire conductor is wound into a coil and both ends are connected to a battery or other electrical source, current passing through it sets up a magnetic field.



If a soft iron core is positioned inside the coil, it too becomes magnetized when current flows—and the result is a stronger magnetic field than could be created with the coil alone.



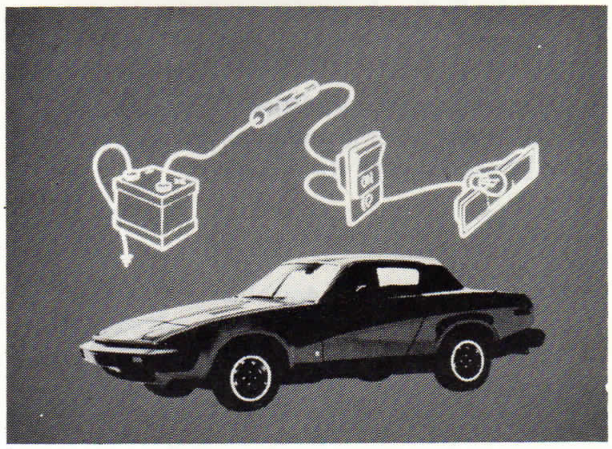
If we put a switch in the coil circuit, we can control the electromagnet. Current on, magnetic field; current off, no magnetic field.



The strength of the magnetic field depends largely upon the number of turns the coil makes around the iron core. The greater the number of turns, the greater the current flow.

The operation of many electrical components—including generators, starter motors, and relays—depends on electromagnetism. A description of the operation of a relay follows later.

VEHICLE CIRCUITS AND COMPONENTS
Switch and Bulb Circuit

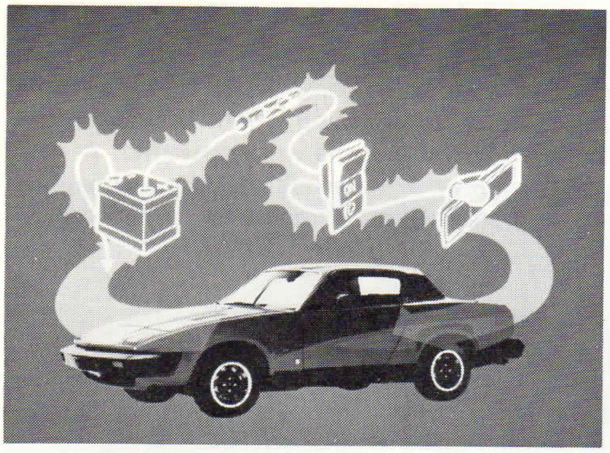


The essentials of this very simple circuit are a bulb, the battery, a switch, and the flow of current through them.

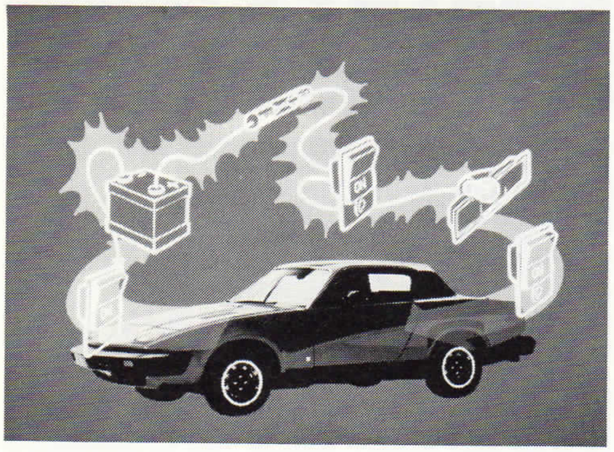
Current, of course, is supplied by the battery. The battery positive terminal is connected to one side of the switch. Between the battery and the switch, a fuse is added to the circuit to protect it from overloads. (Overloads occur when a component or wire is short-circuited and therefore draws excessive amounts of current.)

The other side of the switch is connected to one end of the filament in the bulb. The other end of the filament is connected to the body of the vehicle through the bulb holder. This is called the earth return connection.

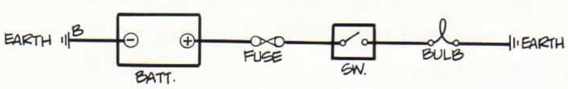
The negative side of the battery is also connected to earth—in this case, to the body of the car, via a heavy-gauge wire or strap. This is a distinctive characteristic of *vehicle* electrical systems: the metal body itself becomes a part of the circuit, returning the current flow to the battery.



When the switch is closed, or on, the circuit is complete. Current flows through the circuit, and lights the bulb.

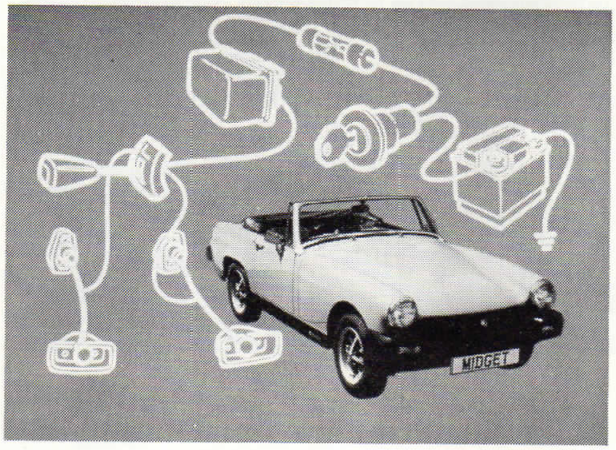


The switch could be located anywhere in the circuit, since its only function is to make or break the path from the battery positive terminal through the bulb and back to the battery negative terminal.



This is a wiring diagram of a simple switch and bulb circuit.

Direction-Indicator Circuit



Again current is supplied by the battery through the positive terminal connected to one side of the ignition switch. Actually, of course, the ignition switch feeds many circuits in addition to this one.

Again a fuse is placed between the ignition switch and the flasher unit to protect the circuit from overloads.

From the fuse, the conducting wire is connected to the flasher unit. The flasher is actually an electromagnetic switch that works automatically, switching the circuit on and off at set intervals.

From the output terminal on the flasher, a wire is connected to the direction-indicator switch. This switch is a double-throw switch—one side for the left lights, the other for the right lights—with the center position leaving the circuit open in both directions.

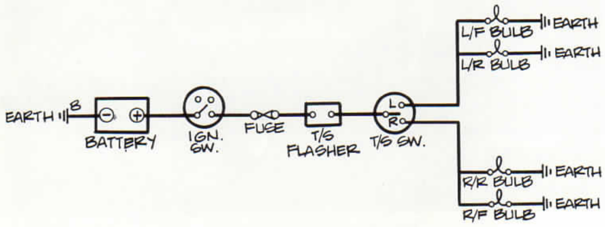
One end of the filament in each of the two left-side bulbs is connected to the appropriate side of the direction-indicator switch. The same is true for the right-side bulbs and the opposite side of the switch.

The other ends of all four filaments are connected to the vehicle through the bulb holders. These again are earth connections, which will complete the direction-indicator circuit via the body and the battery earth strap.

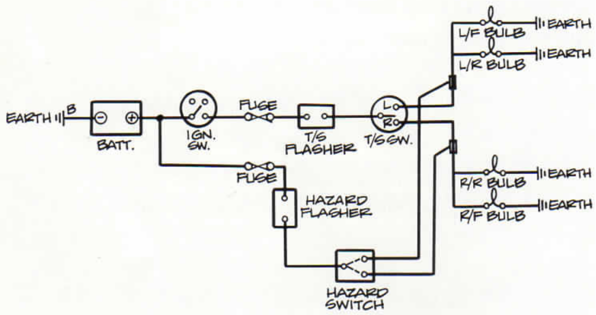
If the left direction-indicator is selected, both left lights will flash because the left circuit has been completed.

If the right direction-indicator is selected, both right lights will flash and the left lights will go out, because the right circuit is complete and the left circuit has been interrupted.

Of course, with the direction-indicator switch in the neutral position, both circuits are interrupted, and no current flows.

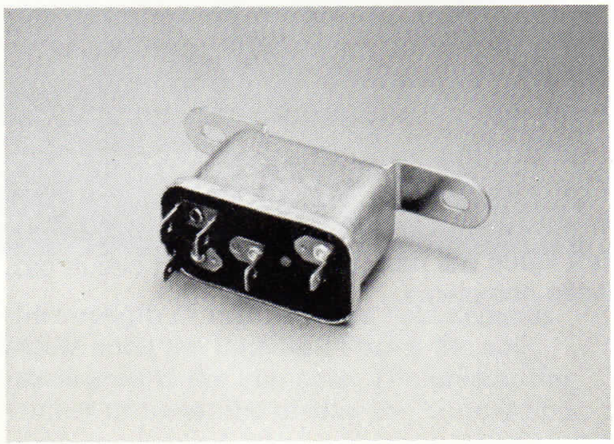


This is a wiring diagram of a direction-indicator circuit. Notice that the circuit as a whole is a mixture of series and parallel wiring. The components from the battery to the switch are connected in series, while each set of indicator bulbs is connected in parallel.

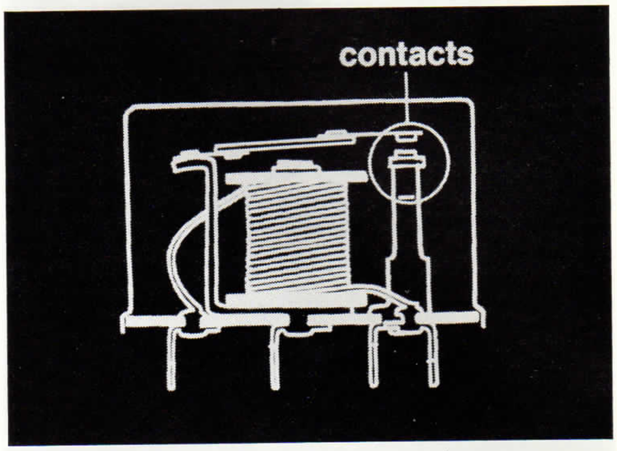


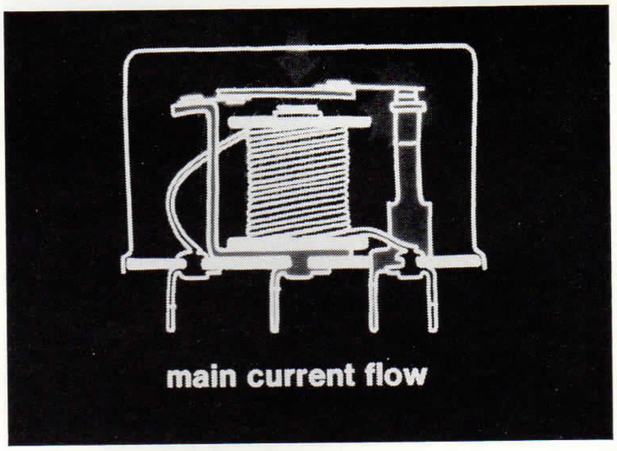
The indicator bulbs also serve as the four-way, flashing hazard/warning bulbs. This is usually done with a separate circuit connected into the direction-indicator circuit between the switch and the four bulbs.

Horn Circuit



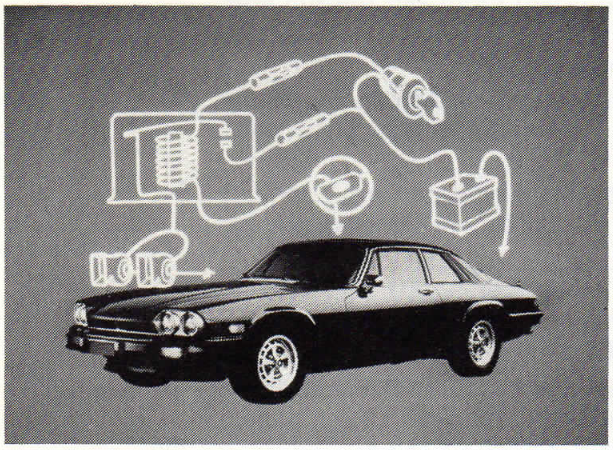
Because horns draw a lot of current, it's impractical to use the horn push switch on the steering column to complete the horn circuit. If we did, a lot of arcing would occur at the switch when the horns were operated. A remote heavy-duty switch called a relay is used to complete the circuit and operate the horns.





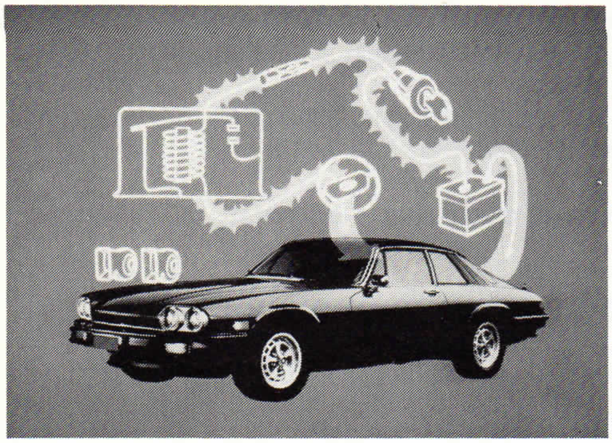
The contacts in the relay are controlled by an electromagnet. When current is passed through the coil via the horn switch circuit, the magnetized coil draws the upper contact bar downward toward it. This brings the contact at the end of the bar against the lower contact—and the main circuit which operates the horns is completed.

When current flow to the coil is stopped because the driver has released the horn push switch, a small spring returns the contacts to their open position.

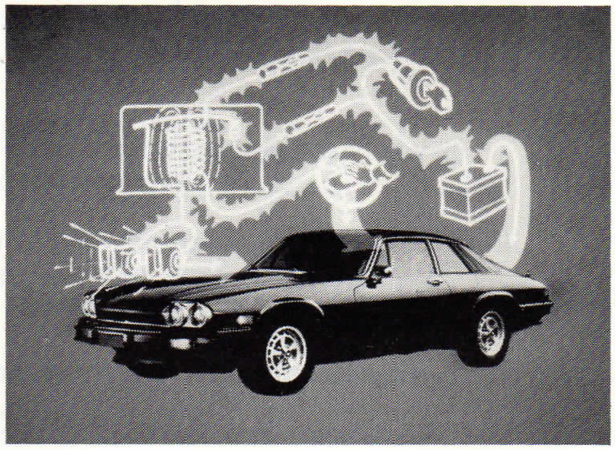


The battery supplies current to the switch circuit via the ignition switch and a fuse. From the fuse, a small-gauge wire is connected to the coil winding of the relay. From the other coil winding connection, the small-gauge wire goes to the horn switch and then to earth.

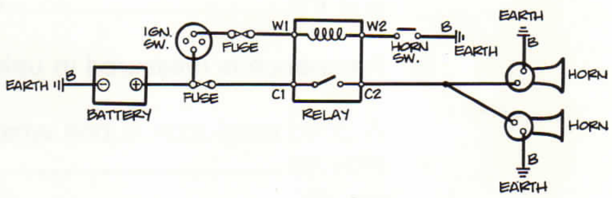
A heavy-gauge wire is connected from the battery through a fuse to one side of the contacts in the relay. From the other contact terminal, the heavy-gauge wire is connected to the horns and then to earth.



When the horn switch is pushed, the relay coil circuit is completed.



The relay contacts are drawn together by the magnetized coil, thereby completing the main circuit and operating the horns.



This is the wiring diagram of a horn circuit.

REVIEW QUIZZES

I. Terms and Fundamentals—Fill in the blanks

1. ________________ is the pressure or force which causes ________________ to flow.

2. ________________ is the flow of electrons which performs work.

3. Current is measured in units called ________________ .

4. Electrical systems use two methods of keeping electron pressure higher at one end of a conductor than the other. Those methods are ________________ ________________ and ________________.

5. The four main factors determining the resistance of any conductor are the ________________ , the ________________ , the ________________ , and the ________________ of the conductor.

6. Resistance is measured in units called ________________ .

7. A good conductor is one which possesses a relatively large number of freely moving ________________ .

8. ________________ , ________________ , and ________________ are three materials often used for electrical insulation.

9. Because the insulator of a ________________ ________________ must withstand thousands of volts, it's made of ceramic, one of the most effective insulating materials.

II. Circuits and Electromagnetism—Fill in the blanks

1. The essentials of a circuit are a ________________ supply and a complete path through which ________________ can flow.

2. A circuit in which components are connected to the battery in such a way that current has more than one path to follow is called a ________________ circuit.

3. In the ________________ type of circuit, the failure of one component means the failure of all.

4. In the ________________ type of circuit, the current in amperes is the same at all points in the circuit.

5. A voltmeter connected across a unit will measure the ________________ ________________ .

6. Excessive voltage drop is caused by the presence of unwanted ________________ in the circuit.

7. ________________ is always measured by attaching the ________________ directly into the circuit.

8. The three ways of stating Ohm's law are:
   ____
   ____
   ____

9. When a wire conductor is wound into a ________________ and electrical current is passed through it, a ________________ field is created.

10. A soft ________________ core positioned inside the coil will also become ________________ when current flows, resulting in a stronger ________________ field.

III. Vehicle Circuits and Components—Answer true or false

1. A fuse is placed in a circuit to protect it from overloads. T____ F____

2. A vehicle circuit is completed by a wire conductor leading from the final component back to the battery. T____ F____

3. In vehicle circuits, bulb holders are often earth return connections. T____ F____

4. A switch can be located at only one place in a circuit. T____ F____

5. The direction-indicator switch is a "double-throw" switch. T____ F____

6. A relay has one or more sets of contacts which are opened or closed by an electromagnet. T____ F____

7. The reason a relay is used in the horn circuit is that the horn circuit is unusually complicated. T____ F____

8. Relays are also used in windscreen wiper, power window, air conditioning, electronic ignition, electronic fuel injection, and charging circuits. T____ F____