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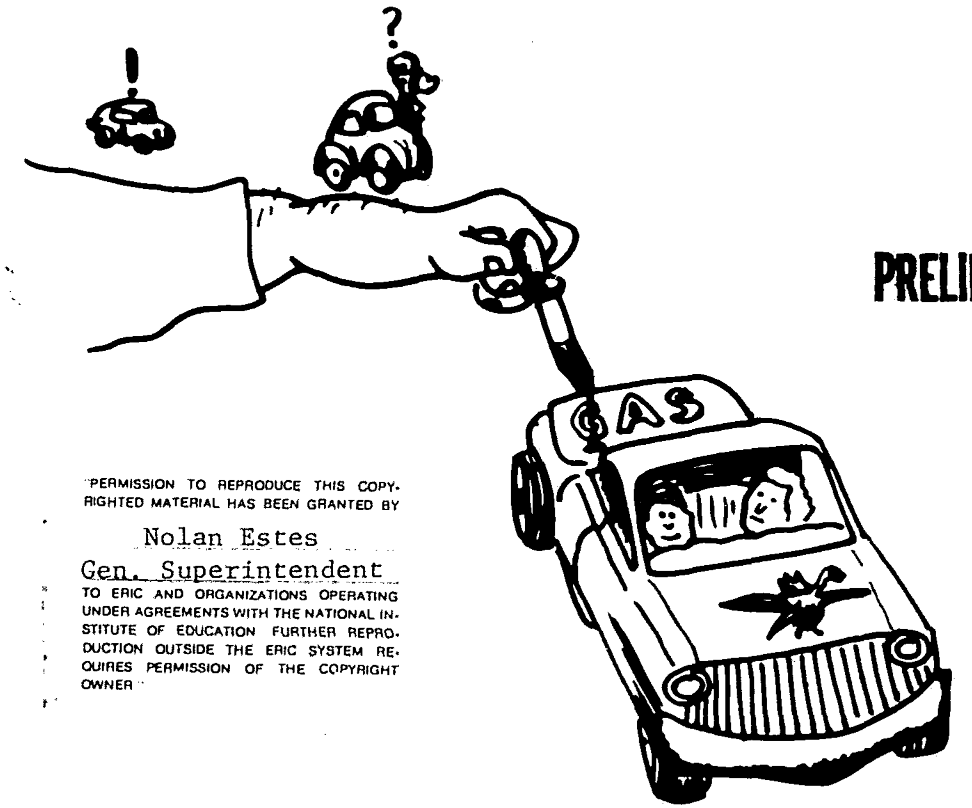
ABSTRACT

This minicourse was prepared for use with secondary physics students in the Dallas Independent School District and is one option in a physics program which provides for the selection of topics on the basis of student career needs and interests. This minicourse was aimed at providing the student with a basic understanding of the construction and operation of the ignition system of an automobile. The minicourse was designed for independent student use with close teacher supervision and was developed as an ESEA Title III project. A rationale, behavioral objectives, student activities, and resource packages are included. Student activities and resource packages involve studying the fundamentals of electricity and magnetism, investigating electromagnetism, constructing a battery, and examining the construction and operation of a generator, voltage regulator, ignition coil, distributor, condenser, and spark plug. (GS)

CAREER ORIENTED PRE-TECHNICAL PHYSICS

Automobile Ignition System Minicourse



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1974

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This Mini Course is a result of hard work, dedication, and a comprehensive program of testing and improvement by members of the staff, college professors, teachers, and others.

The Mini Course contains classroom activities designed for use in the regular teaching program in the Dallas Independent School District. Through Mini Course activities, students work independently with close teacher supervision and aid. This work is a fine example of the excellent efforts for which the Dallas Independent School District is known. May I commend all of those who had a part in designing, testing, and improving this Mini Course.

I commend it to your use.

Sincerely yours,

Nolan Estes

Nolan Estes
General Superintendent

mfs

CAREER ORIENTED PRE-TECHNICAL PHYSICS TITLE III ESEA PROJECT

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CAREER ORIENTED PRE-TECHNICAL PHYSICS

AUTOMOBILE IGNITION SYSTEM

MINICOURSE

RATIONALE (What this minicourse is about)

This minicourse is designed to develop a basic understanding of the construction and operation of the ignition system of an automobile. The operation of all components of an ignition system are based upon a few fundamentals of electricity and magnetism. Therefore, you will first study some technical physics of electricity and magnetism. This will make understanding the ignition system simple and easy.

After learning some fundamentals of electricity and magnetism, the ignition system will be studied in two basic groups: the charging group and the igniting group. The construction and function of the component parts within each group will be investigated. This investigation will not be rigorous and you will not be able to take over a mechanics job after completing the course. But you will end up with a better understanding of the ignition system of an automobile and its relationship to the automobile's efficient operation.

The energy crisis notwithstanding, the American is dominated in a very real sense by the automobile. The financial health of our nation is closely related to the condition of the automobile industry. There are more autos per capita in the United States than in any other nation in the world. Americans spend as much money on automobiles as they do on their homes! And auto repair constitutes one of the biggest business segments in our country.

Do you know that when most engine trouble occurs the first things checked for malfunction are the ignition and fuel systems? And we have all read the stories about shady repairmen who annually fleece hundreds of millions of dollars from motorists, because these motorists do not understand the basic operation of their automobiles. Far too often, the motorist bilked is a woman. Women are cheated more often because they are assumed to be ignorant of machines. Our culture used to discourage women's interests in things mechanical; little girls were encouraged to play with dolls only, and little boys were encouraged to play with machine toys. But today is part of a new beginning for womanhood in America. Do you know that many high schools, junior coleges, colleges, and universities now offer "powder puff" mechanics, automotive courses designed especially with women in mind? One covert (hidden) objective of this minicourse is to teach more about mechanics and physics to women.

What about automotive-related occupations? Most employers prefer to hire persons with at least a high school education, with an age of 18 to 25 years, and with some understanding of automobile construction and operation. And the better jobs go first to those with experience and to those with specialized training (technical and trade school training, apprenticeship, junior college certificate , etc.).

Jobs include the specialty areas of auto mechanics, sales, body repairs and painting; the specialty areas of diesel truck and heavy equipment mechanics; the specialty areas of aeronautical mechanics; and, of course, business for oneself.

In the early 1970's, there were an estimated three quarters of a million automobile mechanics in the United States. Their salaries averaged nearly $5 per hour, and a few skilled workers in specialty areas earned over $15,000 a year.

In addition to RATIONALE, this minicourse contains the following sections:

1) TERMINAL BEHAVIORAL OBJECTIVES (Specific things you are expected to learn from the minicourse)

2) ENABLING BEHAVIORAL OBJECTIVES (Learning "steps" which enable you to eventually reach the terminal behavioral objectives)

3) ACTIVITIES (Specific <u>things to do</u> to help you learn)

4) RESOURCE PACKAGES (Instructions for carrying out the learning <u>Activites</u>, such as procedures, references, laboratory materials, etc.)

5) EVALUATION (Tests to help you learn and to determine whether or not you satisfactorily reach the terminal behavioral objectives):

   a) Self-test(s) with answers, to help you learn more.

   b) Final test, to measure your overall achievement.

TERMINAL BEHAVIORAL OBJECTIVES

When you have completed this minicourse, you will demonstrate an understanding of the technical physics of an automobile ignition system by being able to:

1) write a description of electric current; identify some common electric circuit symbols; show correct placement of ammeters and voltmeters in simple ignition circuit diagrams; use Ohm's Law for simple circuits; distinguish between simple cases of series and parallel circuits; and describe the qualitative effects of current resistance and voltage in simple series and parallel circuits.

2) write a simple description of a physical model of a magnet, and of residual magnetism; draw and describe some properties of the fields associated with a bar magnet, with two opposite magnetic poles, and with two like magnetic poles; and build a simple electromagnet and list some factors that determine its field strength.

3) diagram and label the four (4) basic components of the charging group, and briefly list the function of each.

4) identify principal components of both an automobile lead storage cell battery and an automobile generator and write a simplified description of their operation; and diagram three (3) generator operating schemes for automobiles.

5) list the three (3) basic parts of an automobile regulator; write a brief description of the cutout relay operation and function; and differentiate between a voltage regulator and a current regulator.

6) diagram and label the basic components of the igniting group and briefly desctibe the function of each.

7) write a simple description of the operation and function of the ignition switch, the ballast resistor, the ignition coil, the distributor, the breaker points, the capacitor (condenser), the cam, the centrifugal and vacuum advance, and the spark plug.

ENABLING BEHAVIORAL OBJECTIVE #1:	ACTIVITY 1-1	RESOURCE PACKAGE 1-1
Describe electron flow in writing and list two (2) factors that affect this flow.	Read Resource Package 1.1.	"Fundamentals of Electricity"
ENABLING BEHAVIORAL OBJECTIVE #2:	**ACTIVITY 2-1**	**RESOURCE PACKAGE 2-1**
Match correctly eight (8) commonly used electrical terms with their definitions.	Read Resource Package 2.1.	"Common Electrical Terms"

Enabling Behavioral Objective	Activity	Resource Package
ENABLING BEHAVIORAL OBJECTIVE #3: Match twenty-two (22) electrical symbols with their names.	ACTIVITY 3-1: Study Resource Package 3-1. Complete Resource Package 3-2.1 and check your answers, using Resource Package 3-2.2.	RESOURCE PACKAGE 3-1: "Electrical Symbols" RESOURCE PACKAGE 3-2.1: "Electrical Symbols Exercise I" RESOURCE PACKAGE 3-2.2: "Answers I"
	ACTIVITY 3-2: Complete Resource Package 3-3.1 and check your answers, using Resource Package 3-3.2.	RESOURCE PACKAGE 3-3.1: "Electrical Symbols, Exercise II" RESOURCE PACKAGE 3-3.2: "Answers II"
ENABLING BEHAVIORAL OBJECTIVE #4: Write the names of the instruments used to measure current, potential difference, and resistance; and complete a simple circuit diagram showing their correct circuit placement.	ACTIVITY 4-1: Read Resource Package 4-1.	RESOURCE PACKAGE 4-1: "Electrical Measuring Instruments"
ENABLING BEHAVIORAL OBJECTIVE #5: Write solutions to the Ohm's Law equation for current, potential difference, and resistance.	ACTIVITY 5-1: Read Resource Package 5-1.	RESOURCE PACKAGE 5-1: "Ohm's Law"
	ACTIVITY 5-2: Complete Resource Package 5-2.	RESOURCE PACKAGE 5-2: "Using Ohm's Law"

	ACTIVITY 5-3	RESOURCE PACKAGE 5-3.1
	Complete Resource Package 5-3.1 and check using Resource Package 5-3.2.	"Review - Ohm's Law"
		RESOURCE PACKAGE 5-3.2
		"Answers - Review"
ENABLING BEHAVIORAL OBJECTIVE #6:	ACTIVITY 6-1	RESOURCE PACKAGE 6-1
Recognize how the ground symbol is used in the ignition system circuit; distinguish between series, parallel, and combination series-parallel circuits; and describe the effects of series and parallel circuits upon current, resistance, and potential difference.	Read Resource Package 6-1.	"Electrical Circuits"
	ACTIVITY 6-2	RESOURCE PACKAGE 6-2.1
	Complete Resource Package 6-2.1 and check using Resource Package 6-2.2.	"Circuits"
		RESOURCE PACKAGE 6-2.2
		"Answers"
	ACTIVITY 6-3	RESOURCE PACKAGE 6-3
	Complete Resource Package 6-3.	"Series Application"
	ACTIVITY 6-4	RESOURCE PACKAGE 6-4
	Complete Resource Package 6-4.	"Parallel Application"
ENABLING BEHAVIORAL OBJECTIVE #7:	ACTIVITY 7-1	RESOURCE PACKAGE 7-1.1
Test of progress.	Complete Resource Package 7-1.1 and check your answers using Resource Package 7-1.2.	"Self-test on Electricity"
		RESOURCE PACKAGE 7-1.2
		"Answers"

<u>ENABLING BEHAVIORAL OBJECTIVE #8:</u>	<u>ACTIVITY 8-1</u>	<u>RESOURCE PACKAGE 8-1</u>
Describe in writing a theory of magnetism and how materials become magnetized.	Read Resource Package 8-1 and complete Resource Package 8-2.	"Magnetism"
		<u>RESOURCE PACKAGE 8-2</u>
		"Definitions"
<u>ENABLING BEHAVIORAL OBJECTIVE #9:</u>	<u>ACTIVITY 9-1</u>	<u>RESOURCE PACKAGE 9-1</u>
Describe in writing what is meant by residual magnetism.	Read Resource Package 9-1.	"Residual Magnetism"
	<u>ACTIVITY 9-2</u>	<u>RESOURCE PACKAGE 9-2</u>
	Complete Resource Package 9-2.	"Investigating Residual Magnetism"
<u>ENABLING BEHAVIORAL OBJECTIVE #10:</u>	<u>ACTIVITY 10-1</u>	<u>RESOURCE PACKAGE 10-1</u>
Draw the magnetic fields produced by a bar magnet, by two opposite poles, and by two like poles.	Complete Resource Package 10-1.	"Mapping Magnetic Fields"
<u>ENABLING BEHAVIORAL OBJECTIVE #11:</u>	<u>ACTIVITY 11-1</u>	<u>RESOURCE PACKAGE 11-1</u>
List the factors that affect size, direction, and strength of the magnetic field due to a conductor.	Read Resource Package 11-1.	"Electromagnetic Fields"
	<u>ACTIVITY 11-2</u>	<u>RESOURCE PACKAGE 11-2</u>
	Complete Resource Package 11-2.	"Investigating Electromagnetism"
<u>ENABLING BEHAVIORAL OBJECTIVE #12:</u>	<u>ACTIVITY 12-1</u>	<u>RESOURCE PACKAGE 12-1</u>
Make an electromagnet and calculate its field strength.	Complete Resource Package 12-1.	"Electromagnet"

ENABLING BEHAVIORAL OBJECTIVE #13:	ACTIVITY 13-1	RESOURCE PACKAGE 13-1.1
Test your progress.	Take the Self-Test in Resource Package 13-1.1 and check your answers using Resource Package 13-1.2. Ask your instructor to explain whatever points may be confusing to you.	"Self-Test (Magnetism)" RESOURCE PACKAGE 13-1.2 "Answers"
ENABLING BEHAVIORAL OBJECTIVE #14:	ACTIVITY 14-1	RESOURCE PACKAGE 14-1
Draw and label a diagram showing the four (4) components of the charging group, and list the role each component plays in the charging group.	Read Resource Package 14-1.	"Charging Group"
	ACTIVITY 14-2	RESOURCE PACKAGE 14-2
	Locate the components of the charging group in an automobile made by Ford, General Motors, and Chrysler Corporation (plus any others which may be of special interest to you.)	Any charging group made by Ford, General Motors, and Chrysler Corporation.
ENABLING BEHAVIORAL OBJECTIVE #15:	ACTIVITY 15-1	RESOURCE PACKAGE 15-1
Describe in writing the construction of an automobile battery.	Read Resource Package 15-1.	"Battery Construction"
ENABLING BEHAVIORAL OBJECTIVE #16:	ACTIVITY 16-1	RESOURCE PACKAGE 16-1
Decribe the operation of an automobile battery in writing and by use of a diagram.	Read Resource Package 16-1.	"Battery Operation"
ENABLING BEHAVIORAL OBJECTIVE #17:	ACTIVITY 17-1	RESOURCE PACKAGE 17-1
Describe in writing the operation of an automobile generator.	Read Resource Package 17-1.	"Generator Operation"

	<u>ACTIVITY 17-2</u>	<u>RESOURCE PACKAGE 17-2</u>
	Complete Resource Package 17-2.	"Induced Voltage"
	<u>ACTIVITY 17-3</u>	<u>RESOURCE PACKAGE 17-3</u>
	Complete Resource Package 17-3	"The Generator"
<u>ENABLING BEHAVIORAL OBJECTIVE #18:</u>	<u>ACTIVITY 18-1</u>	<u>RESOURCE PACKAGE 18-1</u>
List the four (4) basic generator parts, label a generator diagram and write a brief description of the function of each component.	Study Resourse Package 18-1.	"Generator Parts"
<u>ENABLING BEHAVIORAL OBJECTIVE #19:</u>	<u>ACTIVITY 19-1</u>	<u>RESOURCE PACKAGE 19-1</u>
Diagrams three (3) generator operating schemes for an auto ignition system.	Study Resource Package 19-1.	"Generator Operating Schemes"
<u>ENABLING BEHAVIORAL OBJECTIVE #20:</u>	<u>ACTIVITY 20-1</u>	<u>RESOURCE PACKAGE 20-1</u>
List the three (3) basic parts of an automobile regulator.	Study Resource Package 20-1.	"The Regulator"
	<u>ACTIVITY 20-2</u>	
	Locate an automobile regulator and examine its three (3) basic parts.	

<u>ENABLING BEHAVIORAL OBJECTIVE #21</u>:	<u>ACTIVITY 21-1</u>	<u>RESOURCE PACKAGE 21-1</u>
Describe in writing the operation and function of the cutout relay.	Read Resource Package 21-1.	"Cutout Relay"
	<u>ACTIVITY 21-2</u>	<u>RESOURCE PACKAGE 21-2</u>
	Complete Resource Package 21-2.	"Relay I"
<u>ENABLING BEHAVIORAL OBJECTIVE #22</u>:	<u>ACTIVITY 22-2</u>	<u>RESOURCE PACKAGE 22-2</u>
By drawing arrows on a diagram of a voltage regulator, show the direction of current flow that will open and/or close the contact points.	Read Resource Package 22-2.	"Relay II"
<u>ENABLING BEHAVIORAL OBJECTIVE #23</u>:	<u>ACTIVITY 23-1</u>	<u>RESOURCE PACKAGE 23-1</u>
Recognize the difference between a voltage regulator and a current regulator.	Read Resource Package 23-1.	"Current Regulator"
<u>ENABLING BEHAVIORAL OBJECTIVE #24</u>:	<u>ACTIVITY 24-1</u>	<u>RESOURCE PACKAGE 24-1.1</u>
Test your progress	Take the Self-Test in Resource Package 24-1.1 and check your answers using Resource Package 24-1.2.	"Charging Group Self-Test" <u>RESOURCE PACKAGE 24-1.2</u> "Answers"
<u>ENABLING BEHAVIORAL OBJECTIVE #25</u>:	<u>ACTIVITY 25-1</u>	<u>RESOURCE PACKAGE 25-1</u>
Name the parts in the ingiting group of an automobile ignition system by labeling a diagram showing these parts.	Study Resource Package 25-1.	"Igniting Group"

Enabling Behavioral Objective	Activity	Resource Package
	ACTIVITY 25-2 Locate the components of the igniting group in an automobile made by Ford, General Motors, and Chrysler Corporation (plus any others which may be of special interest to you).	RESOURCE PACKAGE 25-2 Automobile made by Ford, General Motors, and Chrysler Corporation.
ENABLING BEHAVIORAL OBJECTIVE #26: Describe in writing the function of the ignition switch and the ballast resistor.	ACTIVITY 26-1 Read Resource Package 26-1.	RESOURCE PACKAGE 26-1 "Switch - Resistor"
ENABLING BEHAVIORAL OBJECTIVE #27: Label the parts of an ignition coil diagram.	ACTIVITY 27-1 Read Resource Package 27-1.	RESOURCE PACKAGE 27-1 "Ignition Coil"
ENABLING BEHAVIORAL OBJECTIVE #28: Describe the operation and function of an ignition coil in writing.	ACTIVITY 28-1 Read Resource Package 28-1.	RESOURCE PACKAGE 28-1 "Ignition Coil Operation"
	ACTIVITY 28-2 Complete Resource Package 28-2.	RESOURCE PACKAGE 28-2 "Induced Voltage"
ENABLING BEHAVIORAL OBJECTIVE #29: Write a brief and simple discussion of coil polarity.	ACTIVITY 29-1 Read Resource Package 29-1.	RESOURCE PACKAGE 29-1 "Coil Polarity"
ENABLING BEHAVIORAL OBJECTIVE #30: Name the nine (9) basic parts of a distributor assembly and locate them on a diagram.	ACTIVITY 30-1 Study Resource Package 30-1.	RESOURCE PACKAGE 30-1 "Distributor Assembly"

Enabling Behavioral Objective	Activity	Resource Package
ENABLING BEHAVIORAL OBJECTIVE#31: Describe the purpose, construction, and operation of breaker points.	ACTIVITY 31-1: Read Resource Package 31-1.	RESOURCE PACKAGE 31-1: "Breaker Points"
ENABLING BEHAVIORAL OBJECTIVE #32: Describe the function of proper cam angle.	ACTIVITY 32-1: Read Resource Package 32-1.	RESOURCE PACKAGE 32-1: "Cam Angle"
ENABLING BEHAVIORAL OBJECTIVE #33: Describe the construction and function of a capacitor (condenser).	ACTIVITY 33-1: Read Resource Package 33-1.	RESOURCE PACKAGE 33-1: "Condenser Construction"
	ACTIVITY 33-2: Complete Resource Package 33-2.	RESOURCE PACKAGE 33-2: "Condenser"
ENABLING BEHAVIORAL OBJECTIVE #34: In writing describe the operation of a condenser (capacitor) in the ignition group.	ACTIVITY 34-1: Read Resource Package 34-1.	RESOURCE PACKAGE 34-1: "Condenser Action"
ENABLING BEHAVIORAL OBJECTIVE #35: Distinguish between a centrifugal advance unit and a vacuum advance unit, when presented with diagrams or with the actual units.	ACTIVITY 35-1: Read Resource Package 35-1.	RESOURCE PACKAGE 35-1: "Distributor Subassemblies"
ENABLING BEHAVIORAL OBJECTIVE #36: List eight (8) parts of a spark plug and locate the eight parts on an actual spark plug or on a plug diagram.	ACTIVITY 36-1: Read Resource Package 36-1.	RESOURCE PACKAGE 36-1: "Spark Plug"

ENABLING BEHAVIORAL OBJECTIVE #37:	ACTIVITY 37-1	RESOURCE PACKAGE 37-1
Make an induction coil and, in writing, relate its operation to the operation of the igniting group.	Complete Resource Package 37-1.	"Induction Coil"
	ACTIVITY 38-1	RESOURCE PACKAGE 38-1.1
	Take Self-Test in Resource Package 38-1.1 and check your answers using Resource Package 38-1.2. Ask your teacher to explain any questions you have about the material you have studied.	"Self-Test"
		RESOURCE PACKAGE 38-1.2
		"Self-Test Answers"
TERMINAL EVALUATION	ACTIVITY 39-1	RESOURCE PACKAGE 39-1
	When you feel ready ask the instructor for the Final Evaluation.	"Final Evaluation"

RESOURCE PACKAGE 1-1

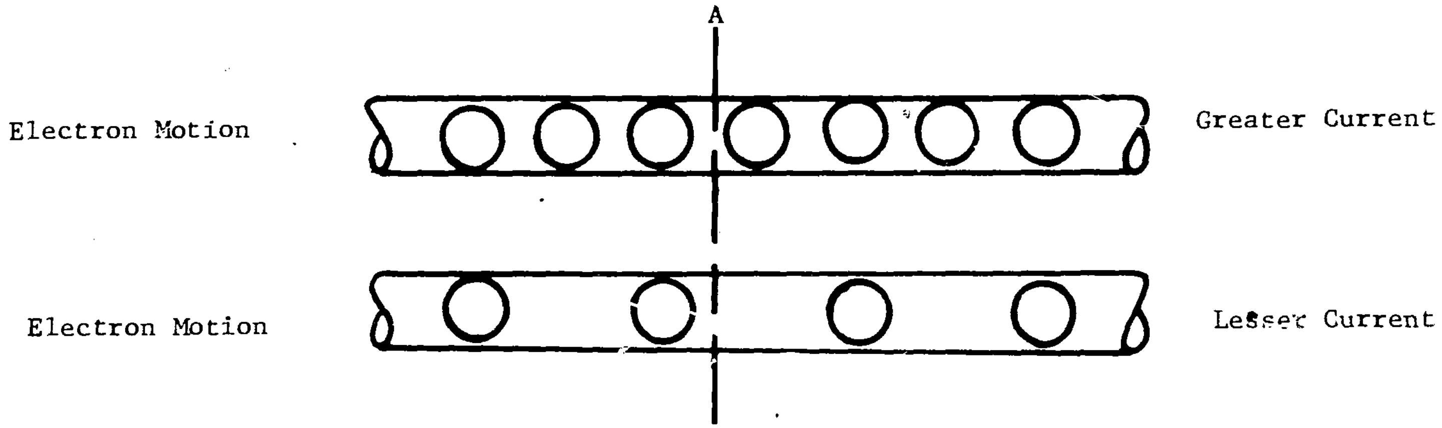
FUNDAMENTALS OF ELECTRICITY

A knowledge of the fundamentals of electricity is necessary for understanding the automobile ignition system.

The basis for understanding electricity is the electron theory. The electron theory assumes that the electron is the basic carrier of negative charge. It follows from this electron model that when electrons move along a conductor a current of negative charge can be said to be flowing. The theory assumes also that the proton is the basic carrier of positive electric charge. In solids, the protons reside in atomic nuclei and cannot move; therefore, in metallic conductors it is the so-called free electrons which can be made to flow and to constitute the stream of negative charge carriers we call a current.

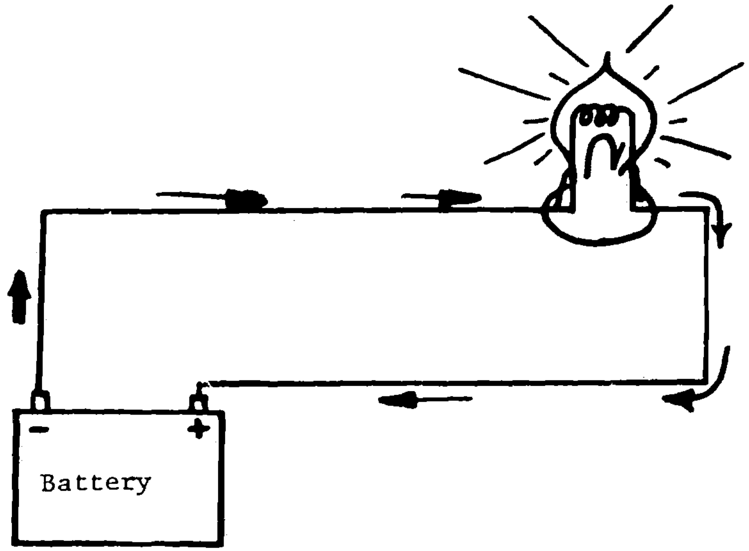
The amount of current in a conductor is determined by the number of electrons passing a given point in a prescribed interval of time. The unit of current is the ampere, and it will be defined later.

If you examine Fig. 1, you can see that the number of electrons flowing past line A in one second would be greater in the top conductor than in the bottom one. Therefore, the top conductor would have the larger current.



ELECTRIC CURRENTS
Fig. 1

Figure 2 shows a simple circuit using a battery as a source of electrons. The battery builds up an excess of electrons at the negative post (terminal) and a lack of electrons at the positive post. As soon as a wire is connected between both posts, electrons drift from the negative post through the lamp and on toward the positive post.

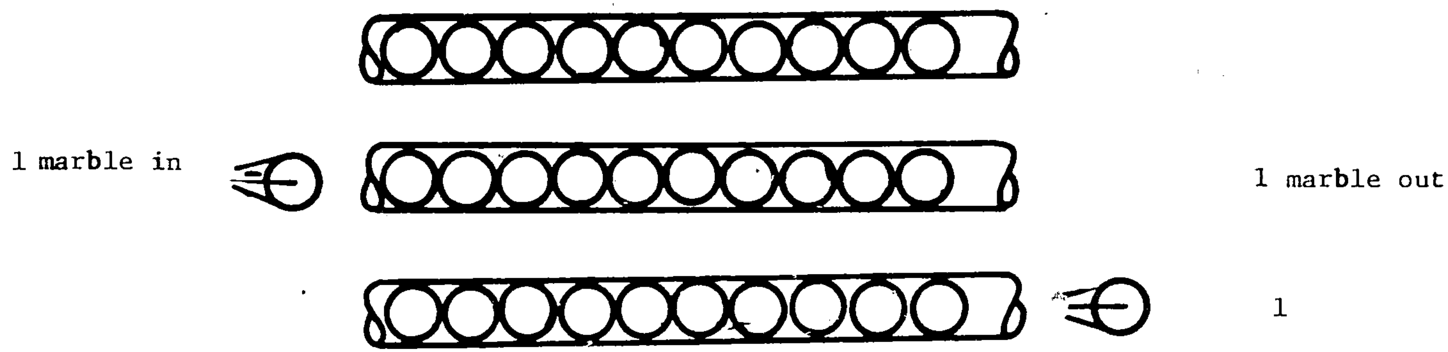


A SIMPLE CIRCUIT
FIG.2

As an electron leaves the negative post, it does not speed through the conductor but pushes against an adjacent electron. This adjacent electron bumps against its neighbor, which in turn bumps against its neighbor. Thus the electrons swarm along the wire in erratic zig-zag paths as they successively collide with one another; their collective movement down the wire is called electron <u>drift</u>. Contrary to common belief, electron drift is relatively slow and amounts to something like 3 ft per hour in an ordinary household circuit.

If we forget that the <u>actual</u> electron paths are more like bees swarming, we can illustrate current by use of a marble <u>analog</u> (comparison).

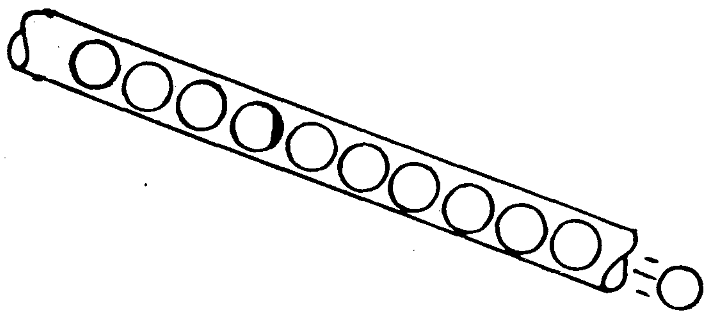
This analog is illustrated in Fig. 3, where marbles have been placed in a pipe to fill it from end to end. As one marble (electron) is pushed into the left end of the pipe (conductor) a marble must pop out the right end. When the first marble presses on the column of marbles, its movement is transmitted through the column. For each marble which enters the pipe, one must leave the pipe. This marble action represents a naive but sometimes useful way of thinking about electron drift (current).



MARBLE MODEL
Fig. 3

As has been said, current can be caused by having a surplus of electrons at one end of a conductor while the other end is lacking electrons (has a deficiency of electrons). The larger the surplus, the larger the force which causes the current. To maintain such a current it is necessary to maintain a difference of electron concentration or a difference of electron energy between the ends of a conductor. Energy difference is analagous to tilting the pipe of marbles in Fig. 3. In a titled pipe, the top marble is at a higher gravitational potential energy level than are the lower marbles; therefore, it can "run downhill" gravitationally forcing along the balls in front of it. See the diagram below.

Marble at Highest Gravitational Potential (Equivalent to battery terminal)



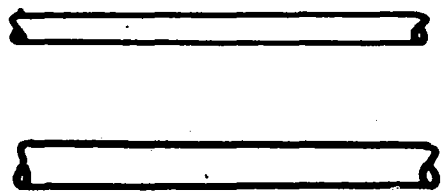
Marble at lowest Gravitational Potential (Equivalent to opposite terminal)

TILTED PIPE ANALOG

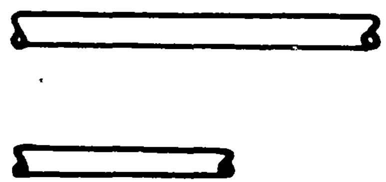
Batteries, alternators, and generators are merely devices which supply electrical potential energy to charge carriers. When so energized these charge carriers (electrons, for example) can "run down hill" electrically, just as the marbles in the tilted pipe analog. Electrical potential difference exists between the terminals of a current-inducing device such as the generator or battery. The charge carriers have greater energy at the terminal from which they drift, quite like the upper marble in the tilted pipe. The electrical potential difference between terminals is measured in volts. The higher the voltage, the greater the ability to cause charge carrier motion (current). In the ignition system of an automobile, this voltage is due to either a battery or alternator or generator. Cars commonly use either 6 or 12-volt ignition sytems.

As an electron drifts along a cinductor, it meets resistance. This resistance is caused by the electron "bumping into" (electrically interacting with) other electrons in the conductor. Such "collisions" cause a heating effect. As a metallic conductor heats, its resistance to electric current further increases. This can produce an important effect, since the conductor can become hotter and hotter until it melts. Electrical resistance is measured in ohms.

Current can be controlled by size factors of the conductor. If two conductors have the same length but different diameter, (one has a greater cross-sectional area), the conductor with the larger diameter (area) will offer less resistance to current. (See Fig. 4a)



Lower Conductor Offers
Less Resistance (greater area)
Fig. 4a



Lower Conductor Offers
Less Resistance (shorter)
Fig. 4b

CONDUCTOR RESISTANCES COMPARED
Fig. 4a & 4b

If two conductors have the same diameter but different length, the shorter conductor will offer less current resistance (See Fig. 4b).

Epilogue. Some tests use so-called conventional (historical) electrical current direction, which is defined as being the direction opposite to ELECTRON DRIFT DIRECTION.

RESOURCE PACKAGE 2-1

COMMON ELECTRICAL TERMS

Ampere. An ampere is a unit of electrical current.

Circuit. A circuit is a path along which charge carriers can move.

Conductor. A conductor is a material that can support electrical current efficiently. The ability to conduct depends upon such factors as conductor material, length, cross-sectional area, and temperature.

Current. A current is a drift of charge carriers. In metals, this is a drift of free electrons.

Insulator. An insulator is a material that cannot support electrical current efficiently. An insulator is sometimes called a dielectric.

Ohm. An ohm is a unit of electrical resistance.

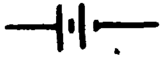
Semiconductor. A semiconductor is a material whose conducting properties lie between those of a conductor and those of an insulator.

Shunt. A shunt is a material of relatively low electrical resistance, used as an alternate or bypass route in an electrical circuit.

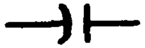
RESOURCE PACKAGE 3-1

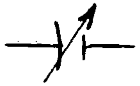
ELECTRICAL SYMBOLS

Below are listed some electrical symbols commonly used in auto ignition system diagrams.

Battery 

CAPACITORS:

Fixed 

 Variable

Fuse 

Ground 

GENERATORS:

DC Generator 

 AC Generator or Alternator

Motor 

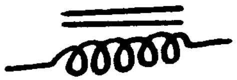
INDUCTION COILS:

Fixed 

 Variable

INDUCTORS:

Inductor, Air Core 

Inductor, Iron Core 

Lamp  or 

METERS:

Ammeter 

Galvanometer 

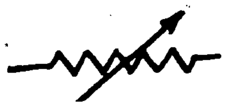
Ohmmeter 

Voltmeter 

RESISTORS:

Resistor, Fixed 

Resistor, Ballast 

Resistor, Variable 

Switch 

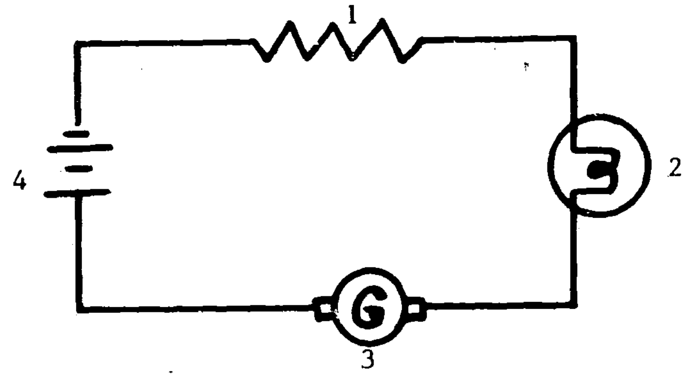
Transformer, (Iron-Core) 

RESOURCE PACKAGE 3-2.1

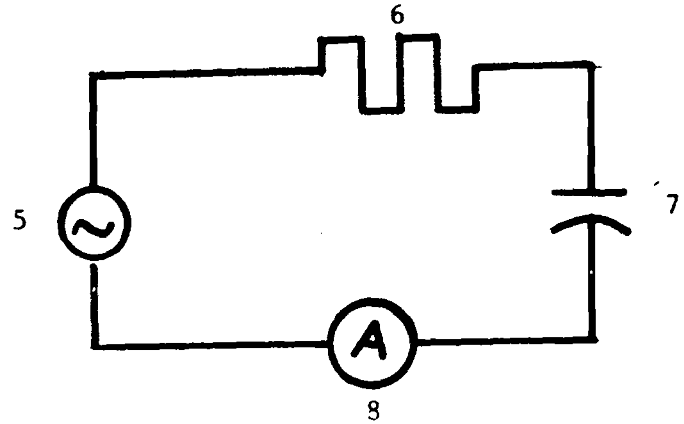
ELECTRICAL SYMBOLS, EXERCISE I

Number from 1 to 20 on a sheet of paper. Each number on your paper should correspond with a symbol in the four (4) circuits shown. Write the name of each symbol next to the number that corresponds to that symbol.

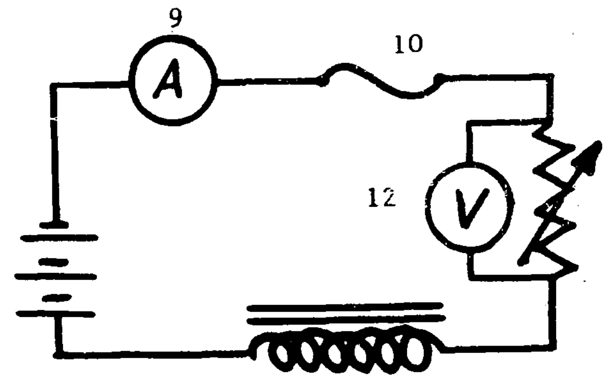
CIRCUIT #1



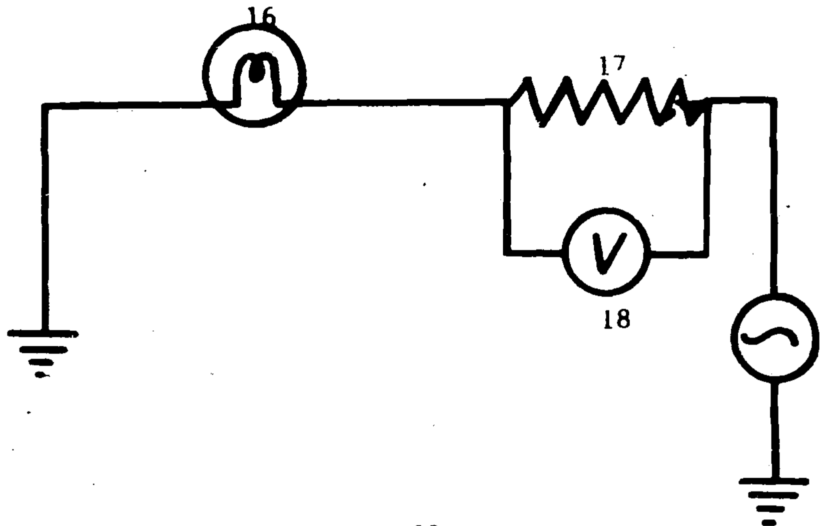
CIRCUIT #2



CIRCUIT #3



CIRCUIT #4



RESOURCE PACKAGE 3-2.2

ANSWERS I

The names to the electrical symbols in the diagrams are as follows:

CIRCUIT #1	1)	resistor (fixed)
	2)	lamp
	3)	DC generator
	4)	battery
CIRCUIT #2	5)	AC generator or alternator
	6)	resistor (ballast)
	7)	capacitor (fixed)
	8)	ammeter
CIRCUIT #3	9)	ammeter
	10)	fuse
	11)	resistor (variable)
	12)	voltmeter
	13)	inductor (iron-core)
	14)	battery
CIRCUIT #4	15)	ground
	16)	lamp
	17)	resistor (fixed)
	18)	voltmeter
	19)	AC generator or alternator
	20)	ground

If you did not answer at least eighteen (18) correctly, you should go back to RESOURCE PACKAGE 3-1 and study some more.

RESOURCE PACKAGE 3-3.1

ELECTRICAL SYMBOLS, EXERCISE II

Number from 1 to 10 on a sheet of paper. Draw the symbol that corresponds to the name that is given below.

1) Capacitor
2) Ground
3) Voltmeter
4) Switch
5) Fuse
6) Resistor (Ballast)
7) AC Generator
8) Transformer (Ignition Coil)
9) Battery
10) Lamp

RESOURCE PACKAGE 3-3.2

ANSWERS II

1) 

2) 

3) 

4) 

5) 

6) 

7) 

8) 

9) 

10) 

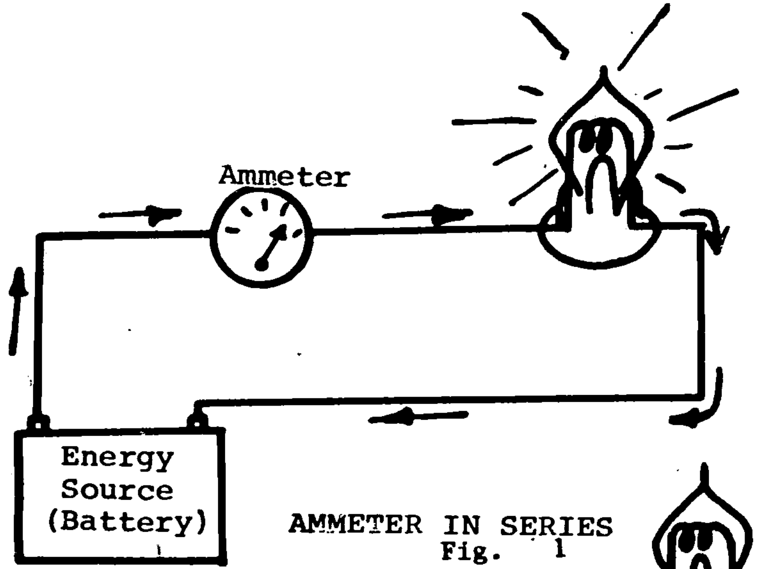
If you did not answer at least nine (9) correctly, you should go back to RESOURCE PACKAGE 3-1.

RESOURCE PACKAGE 4-1

ELECTRICAL MEASURING INSTRUMENTS

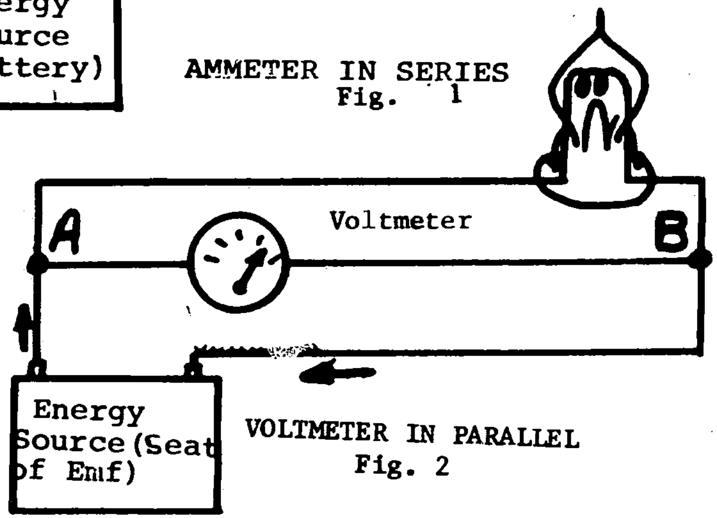
Instruments used for measuring amperage, voltage, and resistance are placed in a circuit as follows.

1) The ammeter is used to measure the current. The ammeter is a low resistance (shunt) device connected in series in the circuit (Fig. 1), so that it can measure the circuit current.



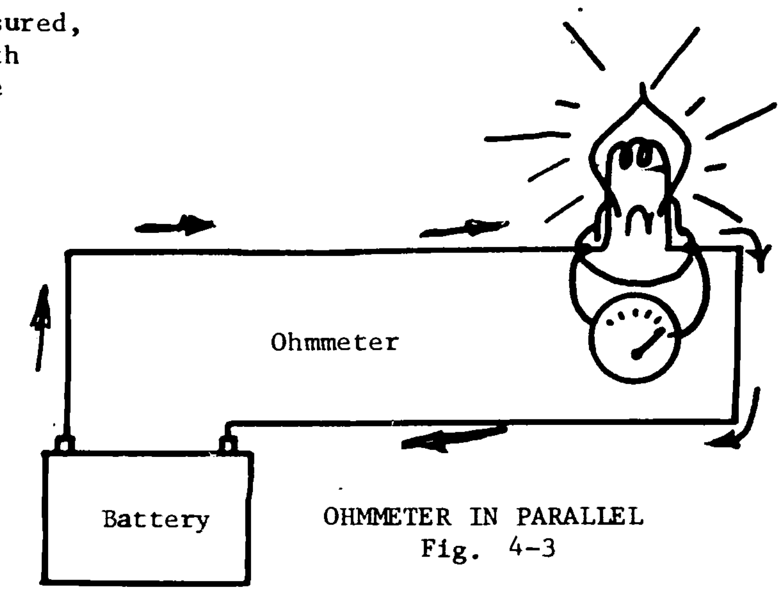
AMMETER IN SERIES
Fig. 1

2) The voltmeter is used to measure a potential difference between points of a circuit. The voltmeter is a high resistance device connected in parallel "across" the circuit (Fig. 2), so that it can measure the drop in potential difference between the two circuit points, A and B.



VOLTMETER IN PARALLEL
Fig. 2

3) The ohmmeter is used to measure the resistance of a circuit element. The ohmmeter is connected in parallel "across" the resistor to be measured, and in such a way that there is only one path for the current between the terminals of the ohmmeter.



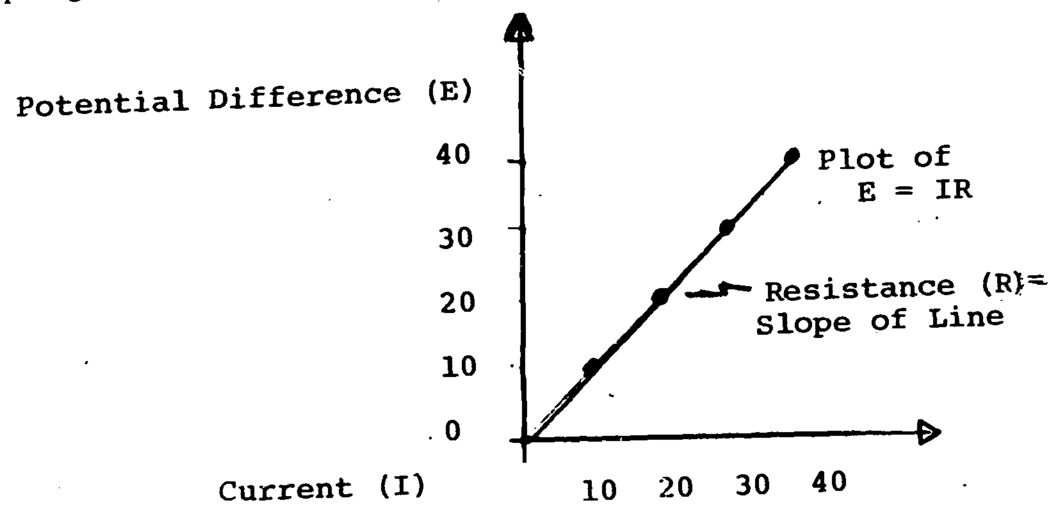
OHMMETER IN PARALLEL
Fig. 4-3

RESOURCE PACKAGE 5-1

OHM'S LAW

Potential difference, current, and resistance can have a very simple relationship when DC circuit resistors are of the common metallic types. This is because the electrical resistance of such resistors remains constant over a wide range of potential differences and currents. Such resistors are said to be <u>linear</u> or <u>ohmic</u> resistors.

A graph of increasing potential difference (volts) vs the accompanying increase of current (amperes) reveals the straight line (linear) nature of ohmic circuits. Notice in the diagram below that plotting voltage-amperage values from the chart results in a straight-line (linear) graph.



Volts	Amps
0	0
10	10
20	20
30	30
40	40

GRAPH OF POTENTIAL DIFFERENCE VS CURRENT

The simple mathematical equation which represents this electrical relationship is E = I R, and this equation is sometimes called "Ohm's Law."

The equation E = I R can be used to define the volt, the ampere, and the ohm as follows:

a) E = I R

volt = ampere (ohm)

= the potential difference needed to cause a one amp current in a resistor of one ohm.

b) E = I R

$I = \frac{E}{R}$

amp = volt/ohm

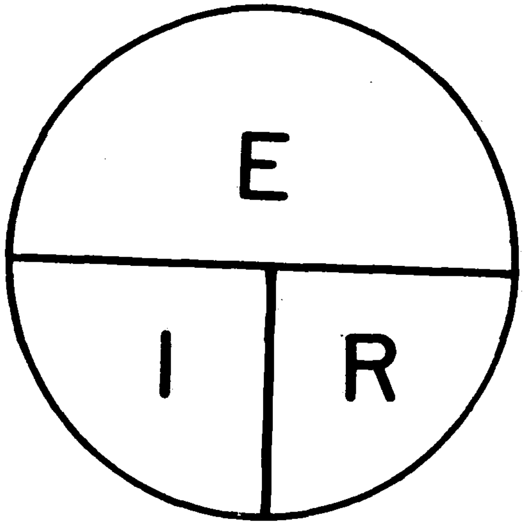
= the current which results when one volt potential difference overcomes a resistance of one ohm.

c) E = I R

R = E/I

= the resistance required if one volt potential difference results in a current of one amp.

To solve the algebraic equation E = I R for I or R is not hard to learn to do. Only a division process is involved! However, some people find the "Ohm's Law Circle" easier to apply. This circle is shown below.



The trick is to cover up the unknown symbol E, I, or R, and to read the correct combination that should be used in the solution equation. See if you can find the three forms of the Ohm's Law Equation using this method. Practice with it until this method becomes easy.

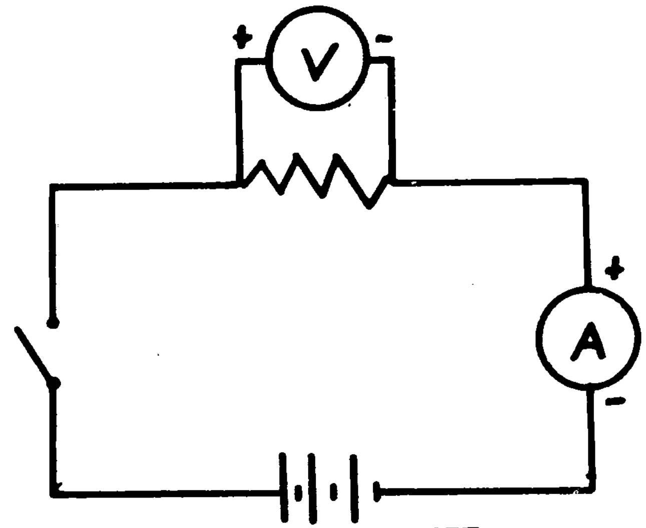
RESOURCE PACKAGE 5-2

USING OHM'S LAW

You will need these items:

- DC source (dry cells or power supply; $1\frac{1}{2}$ - 8 volts)
- voltmeter (0-15 volts)
- ammeter (0 - $1\frac{1}{2}$ and 0 - 15 amperes)
- knife switch
- circuit wires
- ohmic resistors (5, 10, and 15-ohm)

Study the scales on the meters. Check with the instructor to make certain that you can read them properly. Connect the DC source, the switch (open position), the ammeter, and a 5-ohm resistor (R_1) in series. Place the voltmeter across the resistor in parallel (Fig. 1).



OHM'S LAW CIRCUIT
Fig. 1

HAVE YOUR INSTRUCTOR CHECK YOUR CIRCUIT BEFORE CONTINUING (To make sure you are on the right track, and to avoid possible damage to the meters). Close the switch and read the meters. OPEN THE SWITCH AS SOON AS THE READINGS ARE COMPLETED (To avoid excessive drain on the power supply). Record the readings in a table similar to Table 5-1.

Calculate the value of the resistor in ohms and record this in the table. Use the equation $R = \frac{E}{I} = \frac{Volts}{Amps}$

Change the voltage to a higher value and again read the meters. Record the readings and calculate the resistance of R_1 a second time.

Start with a low voltage and take ten (10) sets of voltage and amperage readings for the 10-ohm resistor, R_2. Calculate the resistance for each set of readings and record them in the table.

Repeat the 10-ohm resistor procedure for a 15-ohm resistor.

Make graphs of E vs I for all measurements of the 10 and 15-ohm resistors. Put the graphs on one page of graph paper.

When you have completed your investigation, discuss the results with your instructor. Ask yourself, Can I determine what will happen to the current across an ohmic resistor if the voltage is increased? What will happen to the current across a linear resistor if the resistance is increased?

TABLE 5-1

	VALUE OF RESISTOR (ohms)	VOLTAGE (E) (volts)	CURRENT (I) (amperes)	RESISTANCE (R) (ohms)
R_1				
R_1				
R_2				
R_3				
R_3				

RESOURCE PACKAGE 5-3.1

REVIEW - OHM'S LAW

Write on a sheet of paper the equations one would use to find the three quantities listed below, in terms of the symbols I, R, and E.

1) Amps

2) Volts

3) Ohms

RESOURCE PACKAGE 5-3.2

ANSWERS - REVIEW

1) $I = \frac{R}{E}$

2) $E = I \times R$

3) $R = \frac{E}{I}$

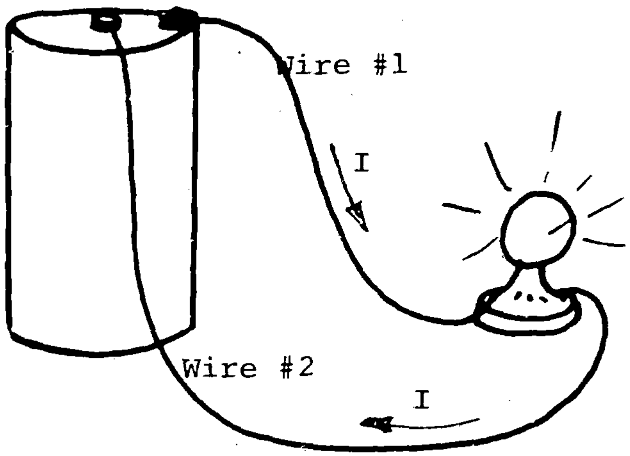
If you have not answered the three questions correctly, re-study RESOURCE PACKAGE 5-1.

RESOURCE PACKAGE 6-1

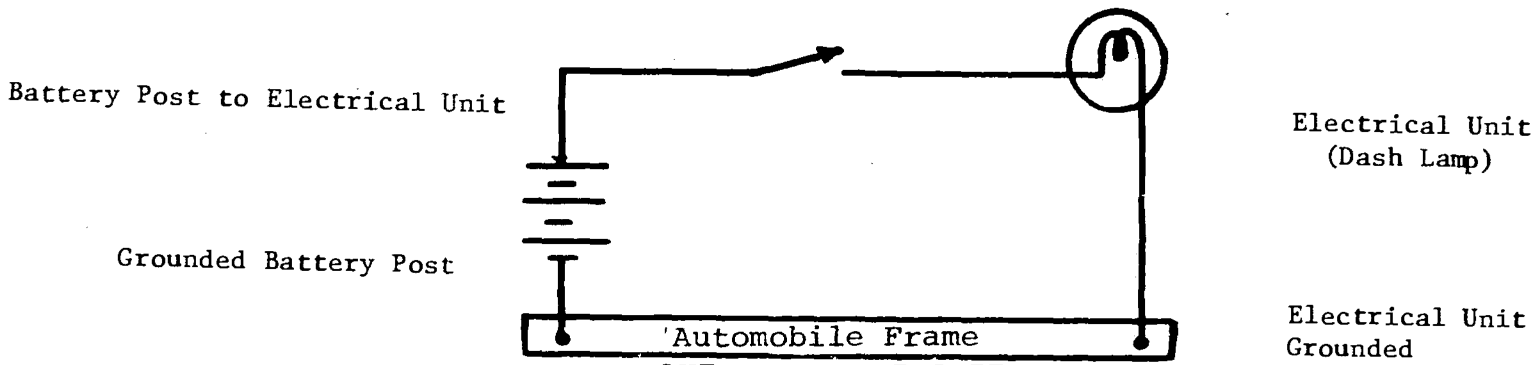
ELECTRICAL CIRCUITS

Grounded circuits require an electrical path away from the energy source (called a seat of em) and back to the source (Fig. 1). Because the body, engine, etc. of an automobile are made of conducting materials such as iron and steel, it is not necessary to have a two-wire circuit. The conducting structure of the car can act as one wire. One battery post is connected (grounded) to the conducting framework of the vehicle. The other post is connected to the various electrical units with insulated wire. By connecting the electrical units to the framework, the circuit is then completed. (Fig. 2).

Seat of Emf (Battery)



AN ELECTRICAL CIRCUIT
Fig. 1



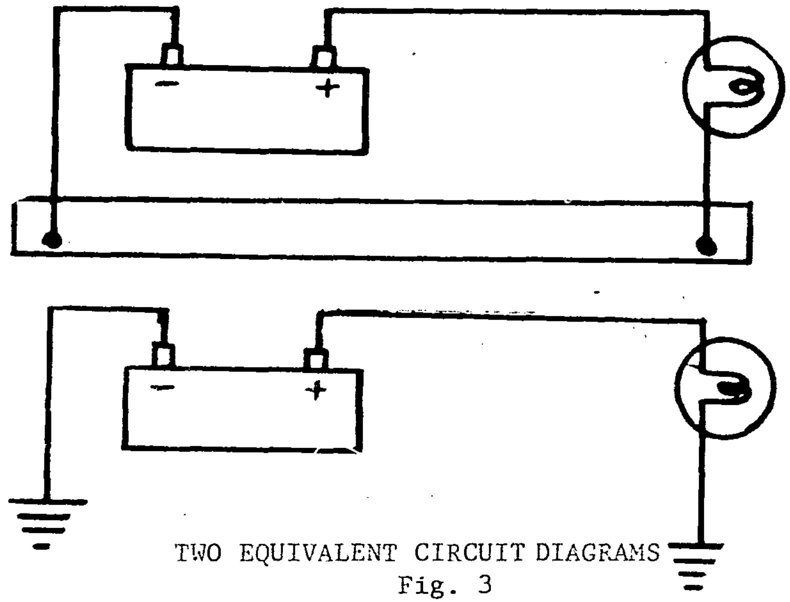
AUTOMOBILE CIRCUIT

Fig. 2

American cars have a grounded negative post. This is important to remember when working on foreign cars, or when installing foreign-made automobiles, because foreign cars have grounded positive posts.

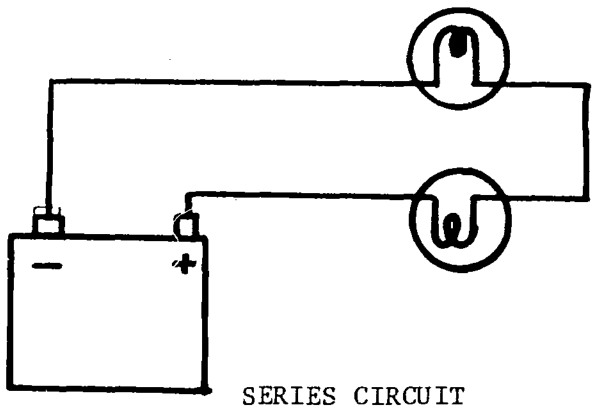
Corvettes and a few other cars have fiberglass bodies. Here, again, special care must be taken with electrical units because fiberglass is an insulator and cannot act as one of the wires, as does a conducting metal frame.

Wiring diagrams usually indicate where the circuit is connected to the steel structure of the automobile. This eleminates the need to draw the complete circuit. For example, the upper circuit diagram in Fig. 3 includes the car's body in the circuit. But the lower diagram is the same circuit using two ground symbols to complete the circuit.



TWO EQUIVALENT CIRCUIT DIAGRAMS
Fig. 3

A <u>series circuit</u> is a circuit having only one electrical path. (Fig. 4) Any number of lamps, resistors or other such devices can be used as units of a series circuit. The more resistors added to a series circuit, the higher will be the total circuit resistance.

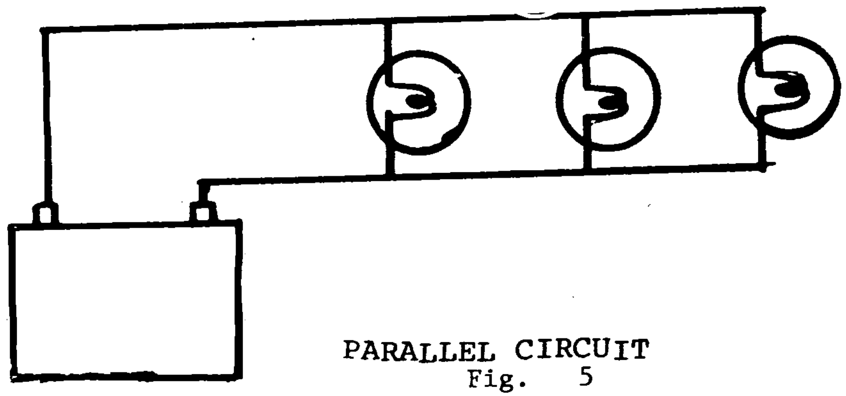


SERIES CIRCUIT
Fig. 4

Since there is only one path for the current, all the current must pass through each portion of the circuit. Obviously, if a broken or open circuit occurs, current cannot persist and the current drops to zero.

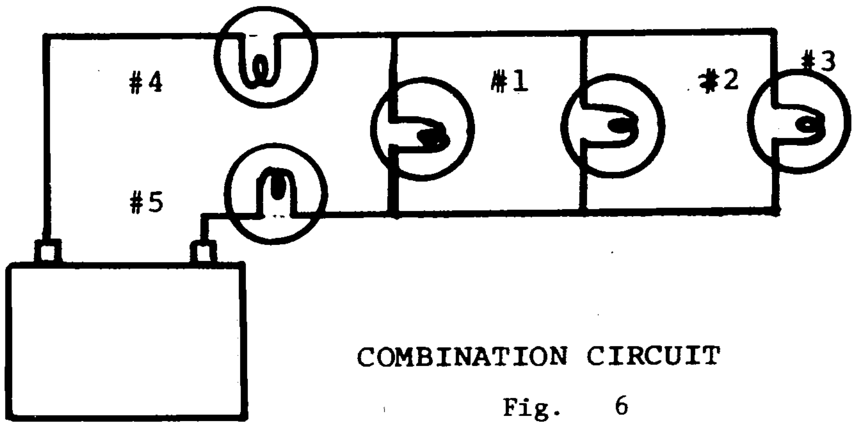
Current in a series circuit can be controlled by the circuit resistance and the circuit voltage. Current will be the same in all places in the circuit; however, the voltage will be different from point to point. The higher electrical energy of a charge carrier at the battery point will drop to a lower level as the charge carrier expends energy moving through the circuit resistors. This energy loss, or voltage drop, always accompanies charge carriers moving through a resistor. In a series circuit, where the units are connected one after the other, the total voltage drop will always equal the sum of the individual voltage drops across the individual resistor units.

A parallel circuit has more than one path for current (Fig. 5). All resistor units connected in parallel across a voltage source have the same voltage applied to them. Since the current has alternate paths (unlike a series circuit) it divides among the various branches of the circuit. Because the resistance of the individual circuit units may not be the same, the current through each branch will vary according to the resistance of the branch unit. The total circuit current will always equal the sum of the current in the branches. The total circuit resistance will always be less than that of the smallest resistor in the circuit. If a break occurs in a parallel circuit, the circuit is not rendered inoperative because there are alternate paths for the current to follow.



PARALLEL CIRCUIT
Fig. 5

You may remember that certain strings of Christmas tree lights are rendered inoperative when a single bulb burns out (breaks or opens the circuit). Other more expensive Christmas lights continue to operate even when one or more bulbs burn out. Can you account for this (Hint: one circuit is of series design; the other is of parallel design)?



COMBINATION CIRCUIT

Fig. 6

There are many applications in the electrical system of the automobile that depend upon a combination series-paralled circuit. Such a combination is shown in Fig. 6 .

To determine the total resistance (R_T) of this circuit, one must first determine the equivalent resistance of the paralled branches housing resistors #1, #2, and #3, and then add this equivalent resistance (R_E) to that supplied by resistors #4 and #5. Circuit current can then be determined from the equation $I = \frac{E}{R_T}$.

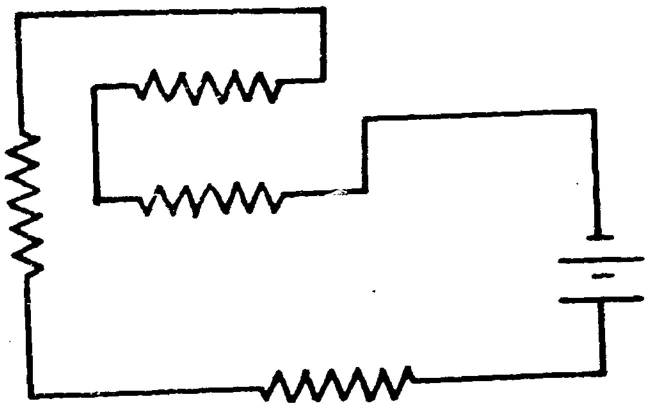
The voltage drop around the circuit will be the drop across the paralled circuit plus the drops across the individual series resistors. This can be determined from $E_T = I\ R_T$

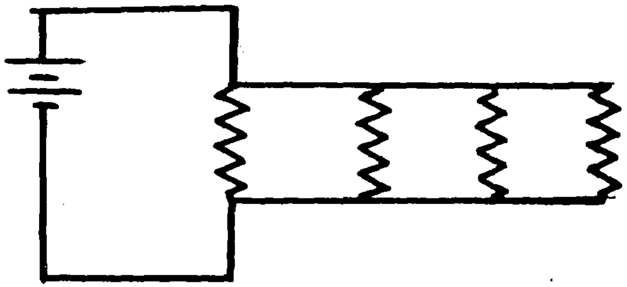
RESOURCE PACKAGE 6-2.1

CIRCUITS

. Look at each circuit and write the name of the type of circuit on a separate sheet of paper (Each circuit has only one name.).

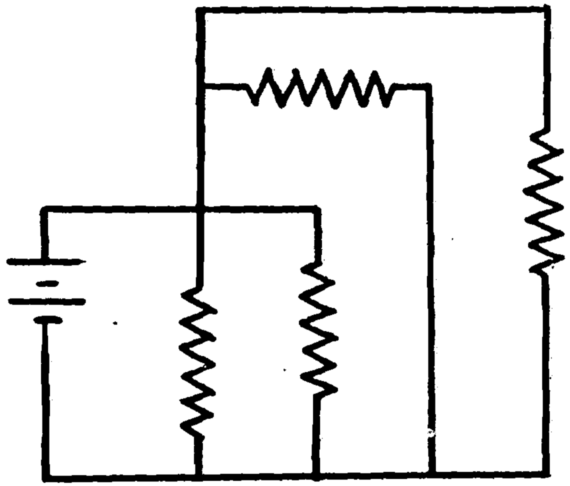
CIRCUIT #1



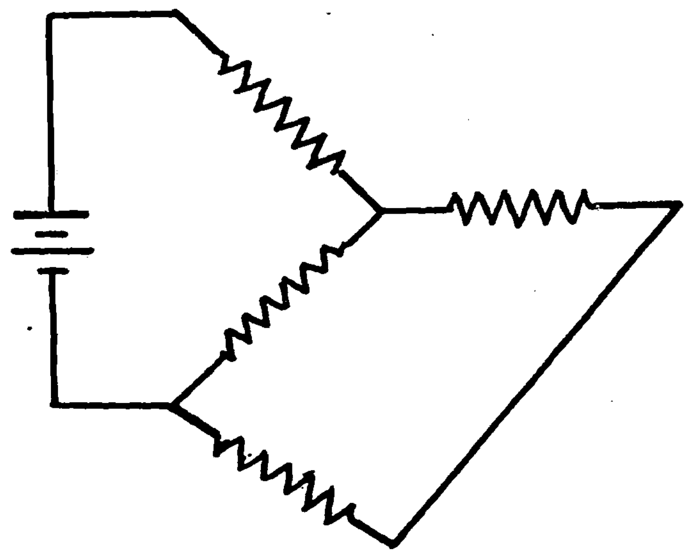


CIRCUIT #2

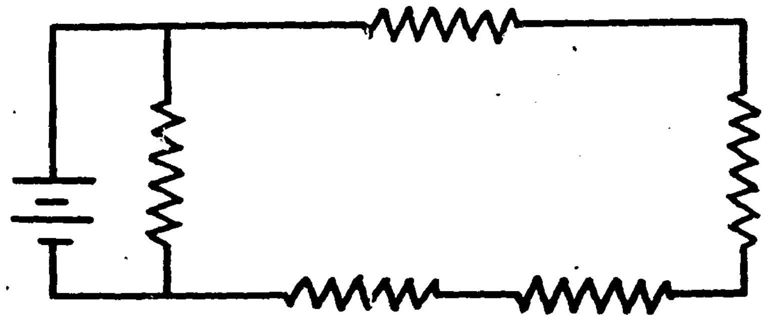
CIRCUIT #3



CIRCUIT #4



CIRCUIT #5



RESOURCE PACKAGE 6-2.2

ANSWERS

The names of the circuits found in Resource Package 6-2.1 are:

1) series

2) parallel

3) parallel

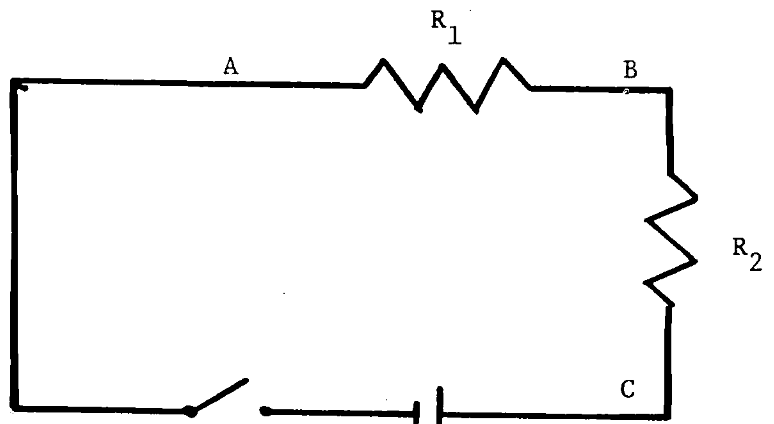
4) series-parallel, or combination

5) series-parallel, or combination

RESOURCE PACKAGE 6-3

SERIES APPLICATION

A series connection is the connection of two or more electrical units in a line, such that there are no alternate current paths. Thus, R_1 and R_2 are connected in series in the diagram below.

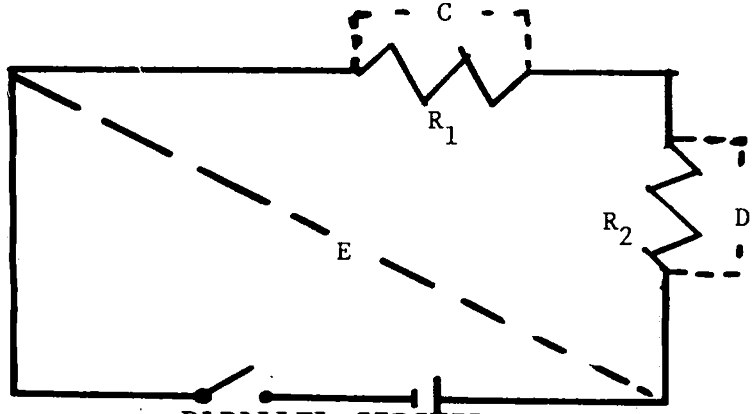


SERIES CIRCUIT

Obtain the following equipment: 2 known resistors, DC ammeter (0-1 and 0-10 amp range), DC voltmeter (0-15 volt range), SPST (Single pole, single throw switch), DC source (3-6 volt range), some copper wire.

<u>Measuring</u>. Point A in the diagram is a position where an ammeter can measure the current between R_1 and R_2. Location C will be suitable for measuring the current between R_2 and the energy source.

Connect the circuit as diagrammed, with an ammeter at location A. Make sure all connections are positive (+) to negative (-). Have your instructor check the circuit connections; close the switch and record the readings of the ammeter. <u>Open the switch as soon as the ammeter reading has been made</u>. Disconnect the ammeter. Repeat the above procedures for locations B and C. Record your ammeter readings for each location. What relation do you see when you examine your ammeter readings?



PARALLEL CIRCUIT

<u>Measuring Potential Differences</u>. Points C, D, and E are locations for the determination of the potential difference (voltage drops) across R_1, R_2, and both R_1 and R_2, respectively. Connect the apparatus and the voltmeter as indicated for location C. This will yield the voltage drop across R_1. Close the switch and record the reading of the voltmeter. Open the switch and disconnect the voltmeter. Connect the voltmeter for measuring the potential difference across R_2. Record the voltmeter reading and disconnect the voltmeter.

Determine the potential difference across both R_1 and R_2 (Use position E.). Record your reading. What relationships do your data show between the total potential difference across R_1 and R_2, and the potential difference across the individual resistor units of the circuit? Turn in your notes and data for evaluation. <u>From your data</u>, calculate the combined resistance of R_1 and R_2 (their equivalent resistance). Then compute their equivalent resistance by using the total difference of potential across them (point E to point F voltage reading).

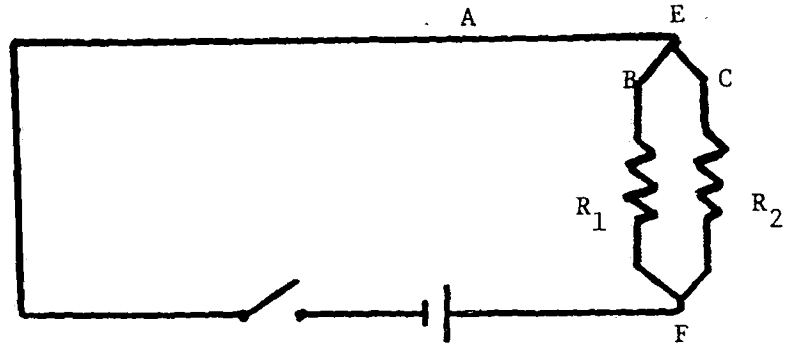
	CURRENT (Amps)	POTENTIAL DIFFERENCE (Volts)	RESISTANCE (Ohms)
R_1			
R_2			
$R_1 + R_2$			

Submit your notes and calculations for evaluation.

RESOURCE PACKAGE 6-4

PARALLEL APPLICATION

Another name for a parallel circuit is a branch circuit. The diagram below shows a resistor R_1 and a resistor R_2 connected in parallel.



BRANCH CIRCUIT

You will need the same equipment used in RESOURCE PACKAGE 6-3. Positions A, B, and C indicate the locations an ammeter could be placed to measure the current to the two resistor units, the current to R_1 alone, and the current to R_2 alone, respectively. Connect the appartus as shown, with the ammeter at location A. Make sure that all the connections are positive (+) to negative (-). Close the switch and record the reading of the ammeter in a table such as the one on the following page. In all trials open the switch as soon as the ammeter reading has been made. Disconnect the ammeter.

What current have you measured?

Use the same procedure for locations B and C. Record your ammeter reading for each location. Do the three current readings show any relationship? Now, connect the voltmeter at points E and F. This location will give you the potential drop across both resistors R_1 and R_2. Close the switch and record the reading of the voltmeter. By the use of the Ohm's Law Equation, calculate the combined resistance of R_1 and R_2. Compare this value with the value found using the equation for the equivalent resistance of resistors in parallel:

$$\frac{1}{R_E} = \frac{1}{R_1} + \frac{1}{R_2}$$

Remember, after you solve this equation, your fractional answer must be inverted (turned upside down) to yield the equivalent resistance! If you are confused by this, ask your instructor for assistance.

Your data should be recorded in a table similar to the one given below:

	CURRENT (Amps)	POTENTIAL DIFFERENCE (Volts)	RESISTANCE (Ohms)
R_1			
R_2			
$R_1 + R_2$			

Submit your notes and calculatons for evaluation.

RESOURCE PACKAGE 7-1.1

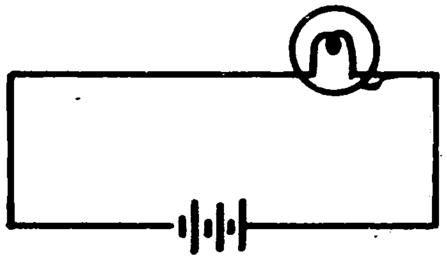
SELF-TEST ON ELECTRICITY

Complete this self-test on a separate sheet of paper.

1) List two (2) factors that determine electron drift in a conductor.

2) Name three instruments that are used to measure voltage, amperage, and resistance.

3) Draw the diagram below on your answer sheet. Then draw in the three instruments of question 2, above, in the proper location to measure the voltage drop across the light and the resistance of the light.



4) Match the name on the left with the phrase or symbol on the right.

a) Circuit	1) Drift of free electrons
	2) Electric current path
b) Current	3) Measure of electrical potential difference
	4) Measure of electric current
c) Ohm	5) Alternate electric current path
	6) Unit of electrical resistance
d) Shunt	

e) Fuse

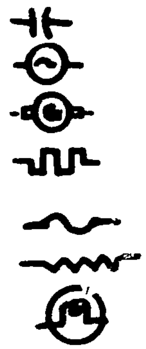
f) Capacitor

g) Lamp

h) Resistor (Ballast)

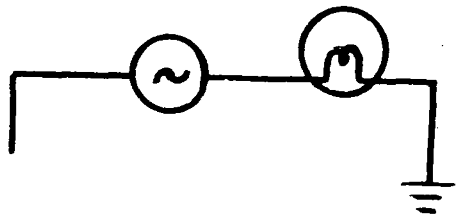
i) Generator (DC)

(7)
(8)
(9)
(10)
(11)
(12)
(13)



5) Write OHM'S LAW in a <u>statement</u> form and in an <u>equation</u> form.

6) If this is supposed to be a circuit diagram, what is incorrect about it?



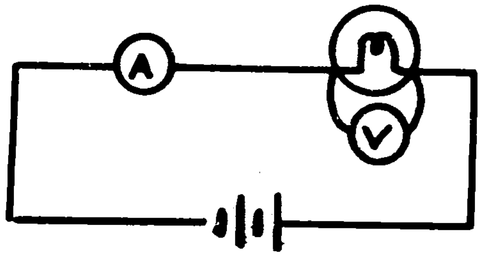
RESOURCE 7-1.2

ANSWERS

1) The voltage potential difference across the conductor.

The resistance offered by the conductor.

2) (a) Ammeter, (b) Voltmeter, (c) Ohmmeter

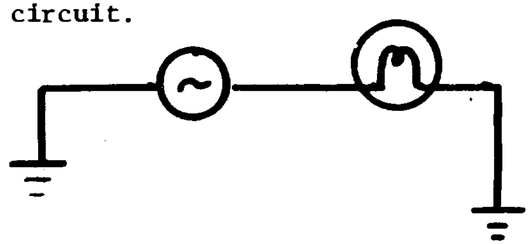
3) 

4) a-2; b-1; c-6; d-5; e-11; f-7; g-13; h-10; i-9

5) In an ohmic resistor, current and resistance are directly proportional.

E = I x R

6) A ground symbol is needed to complete the circuit.



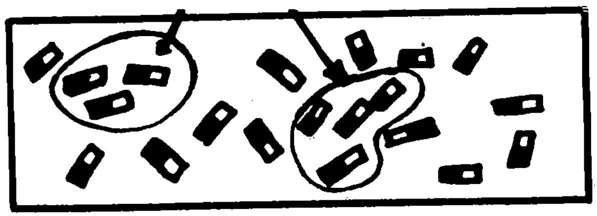
If you did not answer all six (6) questions correctly, you should review the relevant parts of this section.

RESOURCE PACKAGE 8-1

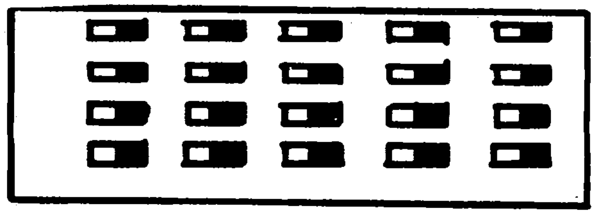
MAGNETISM

Approximately 70% of an automobile's electrical devices make use of magnetic effects. Therefore, it is important to understand some basic principles of magnetism. An accepted theory of magnetism uses the following model. A ferro magnetic material consists of many, many tiny magnets oriented in a non-aligned manner. The tiny magnets result chiefly from the electron configuration (arrangement) in individual atoms, in molecules, or in groups of atoms forming tiny crystals. Small clumps in the magnetic material have these tiny magnets aligned in the same direction; these are called domains. In non-magnetized material these domains are oriented in all directions, so that they tend to cancel out each other's magnetic effect. (Fig. 1) If a sufficient number of magnet domains are lined up in the same direction, the material is said to be magnetized (Fig. 2)

MAGNETIC DOMAINS



UNMAGNETIZED
Fig. 1



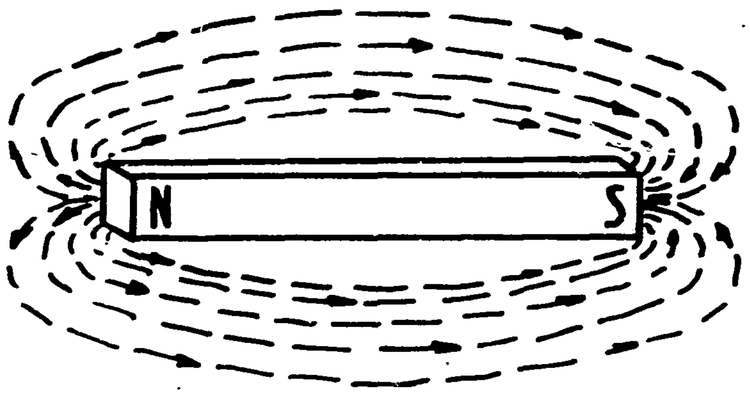
MAGNETIZED
Fig. 2

Domain alignment can by accomplished in several ways. A simple way is to stroke the non-magnetized material with a strong magnet, being careful to always stroke in the same direction. Another way is to place the non-magnetized material in a magnetic field and heat it until the melting material releases its fixed domains.

They then rotate and line up with the external magnet field. When the material cools, the domains will be locked in alignment. A third way is to place the material in a strong electromagnetic field (magnetic field produced by an electric current in a coil of wire) and literally pull the domains into alignment. The more the individual domains are aligned, the stronger will be the magnetic effect of the material.

Can you think of three possible ways to destroy or weaken a material's magnetism? How about breaking it into halves, fourths, etc.?

The magnetic effect of a magnet occurs not only in the magnet material, but also in the space surrounding the material. The space in which magnetic effects are present is called a magnetic field. The strength of the magnetic field is represented by the number of lines of magnetic force in the space. Flux is the name for the density of lines of force in a given volume. Lines of force have direction. They are said to leave the north (N) pole of a magnet, to travel out from the magnet, to reenter the south (S) magnetic pole, and then to pass on from the south pole to the north pole through the body of the magnet (Fig. 3).



MAGNETIC FIELD
Fig. 3

Geophysicists and geologists have learned a great deal about the earth's history from studies of magnetic rocks. The earth itself behaves quite like a huge bar magnet. Certain magmas (hot volcanic materials) contain magnetic particles which align themselves with the earth's magnetic field before the magma cools and hardens. Such magnetic evidence has been used to verify continental drift, reversal of the earth's north-south poles, etc. (Did you know that the north and south poles have flip-flopped and exchanged places numerous times?)

Epilogue. This discussion of magnetic theory was principally concerned with the behavior of ferromagnetic materials (iron, steel, etc.), because these materials are used in conventional ignition systems of automobiles.

There are other classes of magnetic materials. And an accepted model which explains their magnetic behavior includes growth (enlargement) of domains, rather than domain alignment.

RESOURCE PACKAGE 8-2

DEFINITIONS

Use a reference book to find the definition of the following words. The definitions should pertain to magnetism.

Domain

Electromagnet

Weber

Induced Magnetism

Field

Flux

Lines of Force

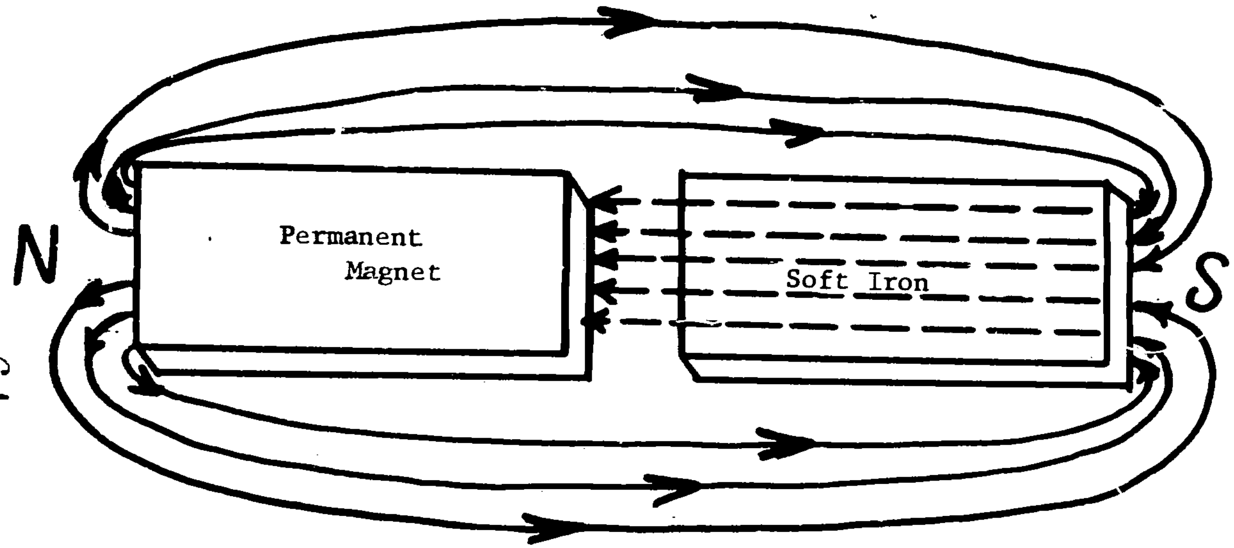
Pole

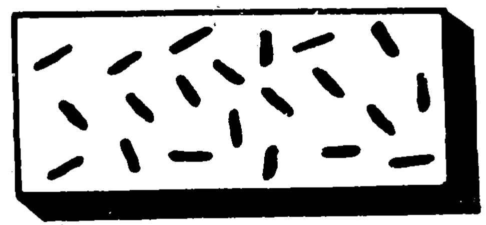
Reluctance

RESOURCE PACKAGE 9-1

RESIDUAL MAGNETISM

Soft iron (Fig. 1) will become magnetized when placed in a magnetic field (Fig. 2) and will lose most of its magnetism when removed from this field (Fig. 3).



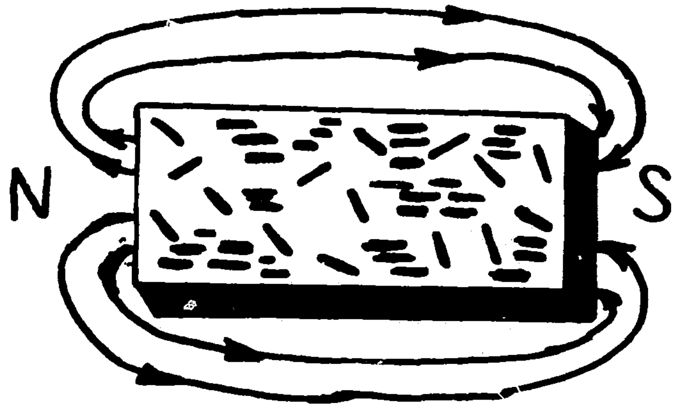


UNMAGNETIZED IRON
(Random Domains)
Fig. 1

SOFT IRON IN A MAGNETIC FIELD
Fig. 2

When the soft iron is removed, only a few of the domains will remain in magnetic alignment; however, these few domains do produce a magnetic field. This phenomenon (happening) is called <u>residual</u> <u>magnetism</u>.

Residual magnetism makes it possible for the DC generator to start its generating cycle. It is a form of <u>self-excitation</u> without which the DC generator would not start once it had been stopped.



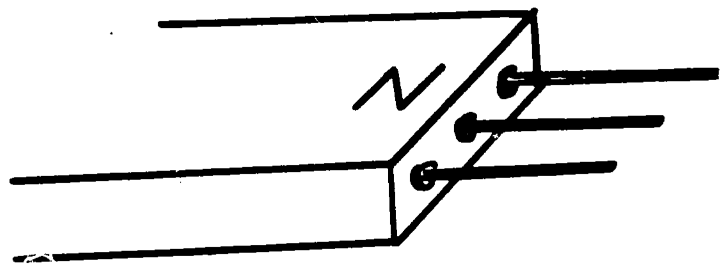
RESIDUAL MAGNETISM
(Less-Random Domains)
Fig. 3

RESOURCE PACKAGE 9-2

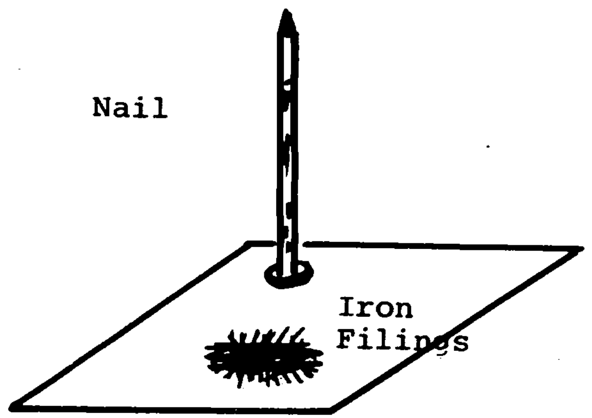
INVESTIGATING RESIDUAL MAGNETISM

You will need: three small nails
bar magnet
iron filings

Place the three nails on the north (N) pole of the magnet (Fig. 4). After five (5) minutes have passed, remove one nail and place the nail head near a pile of iron filings (Fig. 5). Observe the quantity of iron filings attracted to the nail head.



MAGNETIZING NAILS
Fig. 4



TESTING RESIDUAL MAGNETISM
Fig. 5

When another five minutes have passed, use the second nail and repeat the procedure used for the first nail. Make the same observation. After another five (5) minutes, repeat the procedure and observation using the third nail. Make a written note of observed relationships between the length of time the nail remains on the magnet and the quantity of iron filings attracted to the nail head. This quantity is an indirect measure of the amount of residual magnetism! Using one of the partially magnetized nails, determine which end of the nail has north (N) polarity. Turn in your notes for evaluation.

RESOURCE PACKAGE 10-1

MAPPING MAGNETIC FIELDS

Iron filings become magnetized in a magnetic field. This causes each filing to behave like a tiny compass and to align itself with the magnetic field. Where the field is strongest, the field lines will be more dense; accordingly, iron filings will also be more dense (crowded) where the field is strongest. When iron filings are sprinkled around a magnet, the positions they take as they align themselves with the field forms a definite pattern. Such a pattern is called a <u>field map</u>; the process is known as mapping the magnetic field. Now try the following:

1) Lay a bar magnet on a table. Put a stiff, thin cardboard or a glass plate over the magnet. From a height of about 10 inches, sprinkle iron filings on the surface of the glass or cardboard. From time to time, gently tap the surface. Notice the pattern that forms. Now repeat the above activity using a stronger magnet. Can you detect a difference in the patterns formed? Record any such differences, and make a sketch of one of these patterns.

2) Lay two bar magnets end to end, with their <u>opposite</u> poles facing each other. The poles should be about an inch apart. Again cover the magnets and sprinkle the iron filings over the surface which covers the space between the poles. Tap the surface lightly and examine the pattern formed. Make

a simple sketch of the pattern.

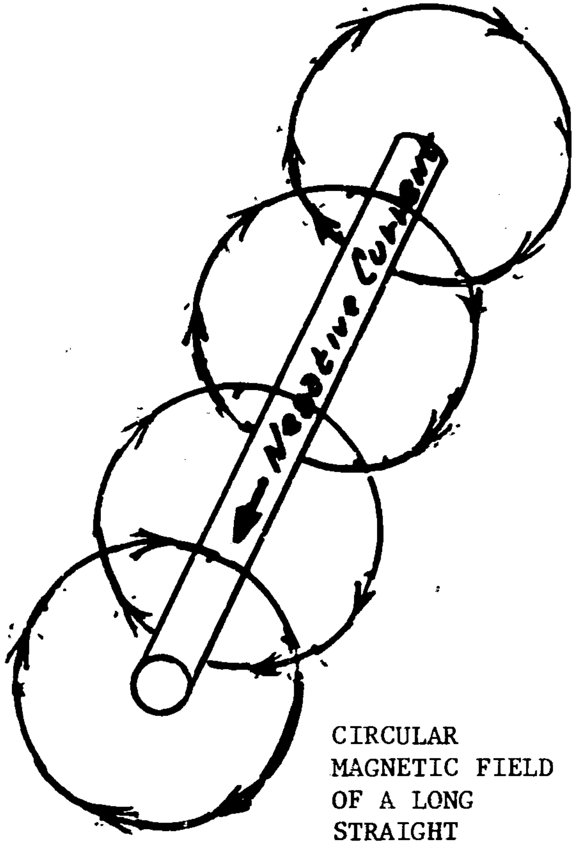
3) Place the two bar magnets end to end about an inch apart, with their <u>like</u> poles facing each other. Cover the magnets and sprinkle iron filings over the surface which covers the ends of the magnets. Tap the surface lightly as you sprinkle. Examine the pattern formed, and make a simple sketch of it.

Turn in your sketches and notes for evaluation. Have you ever pondered how much artistic beauty and how many symmetries are to be found in nature? Are you impressed by the beauty and the symmetries of magnetic fields?

RESOURCE PACKAGE 11-1

ELECTROMAGNETIC FIELDS

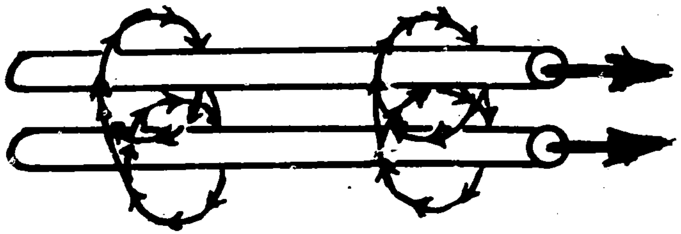
There is a close relationship between electricity and magnetism. In fact, magnetism results from electric currents. In permanent magnets the domains themselves constitute tiny currents. So one finds that magnet lines of force are produced around permanent magnets, and also around conductors carrying electrical currents. When electrical current is passing along a conductor, there will always be a magnetic field surrounding the conductor (Fig. 1). The strength of this magnetic field depends upon the amount of current. The greater the current, the greater the field strength.



CIRCULAR MAGNETIC FIELD OF A LONG STRAIGHT CONDUCTOR

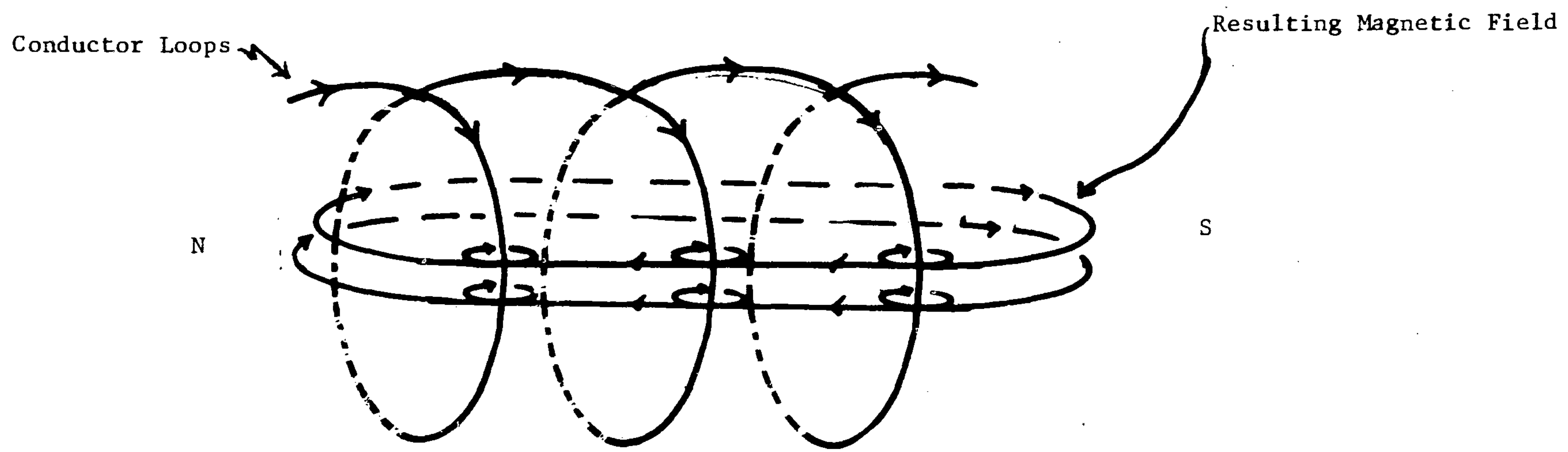
Fig. 1

If two long, straight conductors are arranged side by side (Fig. 2) and if current is passing through both conductors in the same direction, the two conductors will be attracted to each other.



LONG, STRAIGHT, PARALLEL CONDUCTORS
Fig. 2

On the other hand, if the current is in opposite directions, the two conductors will repel one another. This interaction between parallel conductors is employed in the operation of the starter motor on an automobile.



MAGNETIC FIELD OF A COIL
Fig. 3

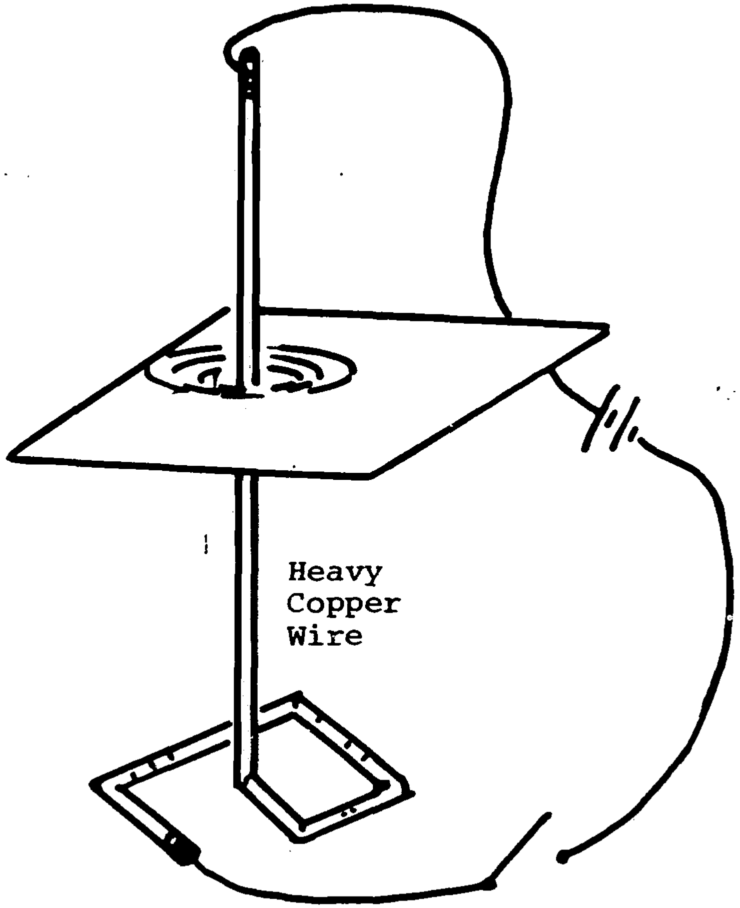
If a conductor is looped to form a coil (a series of such loops is sometimes called a helix) the current will be in the same direction in each turn (Fig. 3). The magnetic field produced by each turn combines with the field produced by adjacent turns, and results in a magnetic field quite like that which would result if a bar magnet were resting lengthwise inside the coil. The polarity of the field depends upon the current direction, and the field map resembles that of a bar magnet. The magnetic field strength depends upon the number of wire loops, the amount of current, the medium surrounding the device, and the material comprising the coil core. (In this case, the core is air, but different core materials can increase or decrease the field strength. If a soft iron core were used, for example, the field would be increased appreciably.)

RESOURCE PACKAGE 11-2

INVESTIGATING ELECTROMAGNETISM

You will need: about 40 cm of heavy copper wire
power source
single pole switch
sheet of plastic or cardboard

To determine the pattern of the magnetic field produced by a long straight conductor, place a heavy copper wire in series with a switch and an energy source (Fig. 1). The copper wire is bent to support itself vertically and then inserted through a hole in a sheet of plastic or cardboard, which is supported in a horizontal position. With the switch closed, sprinkle iron filings on the sheet. Tap the sheet lightly and observe the pattern formed by the iron filings. Sketch this pattern on a sheet of paper.

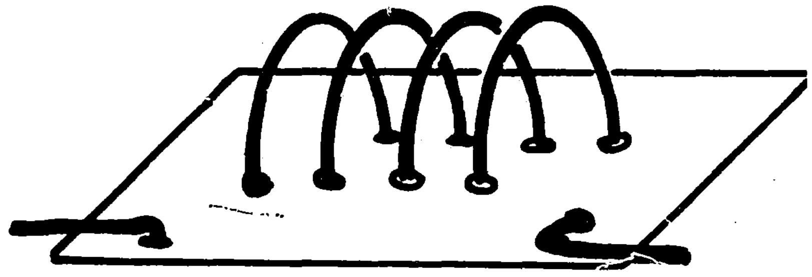


LONG STRAIGHT CONDUCTOR
Fig. 1

Open the switch. Spread the filings evenly over the sheet. Reverse the battery polarity and see if there is any change in the general pattern of the field.

To determine the pattern of the magnetic field produced by a coiled conductor, copper wire is threaded through a section of sheet as shown in Fig. 2.

The rest of the circuit is the same as for the first part of this investigation. Before closing the switch, sprinkle iron filings evenly over the sheet. Close the switch and tap the sheet lightly. Make a sketch of the field pattern. Is there any similarity in this pattern and that formed by a bar magnet?



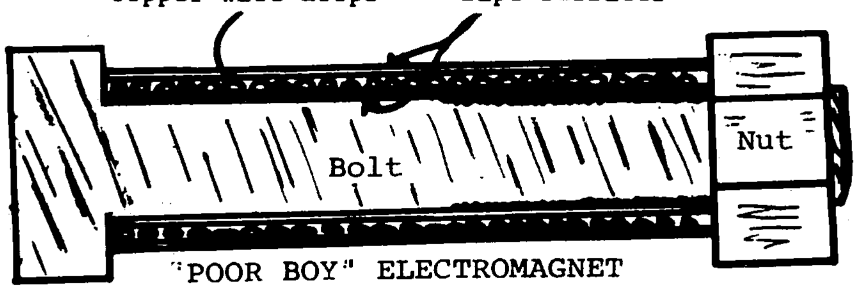
COILED CONDUCTOR
Fig. 2

RESOURCE PACKAGE 12-1

ELECTROMAGNET

An electromagnet consists essentially of a coil of conducting wire with a core. To make the electromagnet in this Resource Package you will need:

- some circuit wire
- one good-sized bolt, with nut
- #18 magnet wire
- masking tape
- DC power supply (0-15 volt)
- ammeter (0-25 amps)
- some steel washers (any size)



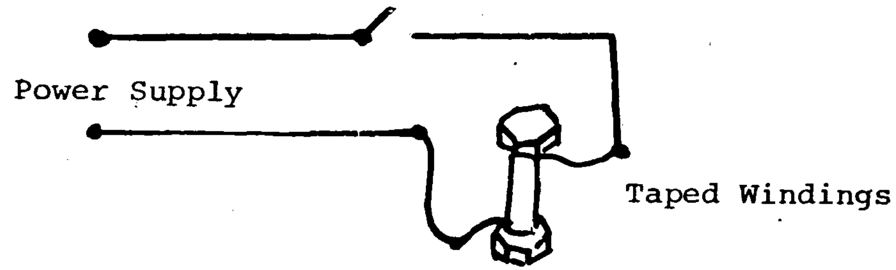
"POOR BOY" ELECTROMAGNET

To construct the core, place the nut on the bolt and secure it. Next, wrap two layers of masking tape the entire length of the bolt, as shown above. You have now completed the core.

To construct the windings, carefully wind one layer of #18 magnet wire around the core. Leave about six inches of wire sticking out each end of the core as terminals.

Keep the windings close together and fairly tight. After completing several turns, place tape on them. The tape will hold this several-turn section of wire stationary and will keep the wire from pulling away as you wind the core. Count and record the number of turns when the single layer of windings is complete. Lastly, wrap the windings with tape to protect them and to hold them together.

Scrape the terminal ends of the wire clean and connect them to the power supply and switch, as shown in the diagram below. Make a table like the one on the next page.



"POOR BOY" ELECTROMAGNET

With the switch open, adjust the power supply to 3 volts. Close the switch and check to see if the electromagnet is working. OPEN THE SWITCH EACH TIME THE MAGNET IS NOT IN USE. With the switch closed, what is the maximum number of washers the magnet picks up? Now, increase the power supply to 6 volts. Does the number of washers you can pick up with the magnet increase? Record the number of washers for each setting. Read and record the ammeter values for the 3 and 6-volt power supply settings.

The strength of an electromagnet is measured in ampere-turns (written IN, where I is current in amperes and N is the number of turns). Thus, a coil with 200 turns and two amperes of current would have a strength of 400 IN, as follows:

CURRENT X NUMBER OF TURNS = AMPERE TURNS

= (I) (N)

= IN

= (2 AMPERES) (200 TURNS)

= 400 IN

Calculate and record the strength of the electromanget at 3 and 6 volts.

	Number of turns (N)	Current (I)	Strength (IN)	Number of Washers
3 volts				
6 volts				

KEEP YOUR ELECTROMAGNET. IT WILL BE USED LATER.

RESOURCE PACKAGE 13-1.1

SELF-TEST (MAGNETISM)

Respond to the following questions <u>on a separate sheet of paper</u>.

1) Describe a theory of how materials become magnetized.

2) What is a residual magnetic field?

3) Define the following terms: a) magnetic flux

b) magnetic domain

c) reluctance

4) Make a drawing showing the magnetic field for two like poles of a bar magnet placed in inch or so apart and facing one another.

5) List at least two (2) factors that affect the strength of the field produced by an electromagnetic.

6) A 5-inch electromagnet is made with 150 turns of #18 magnet wire. If 6 amperes of current is passed through the turns, what is the ampere-turn strength of the electromagnet?

RESOURCE PACKAGE 13-1.2

ANSWERS

1) As magnetic domains are aligned, the material becomes magnetized.

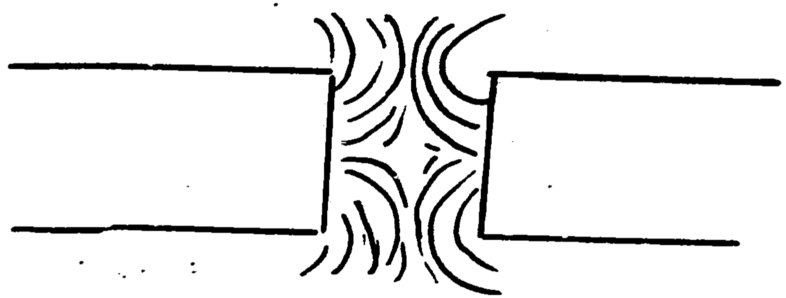
2) Magnetism remaining in a material after an external magnetic field has been removed.

3) a) The lines of force in a defined region of a magnetic field.

b) A neighborhood of atoms or molecules whose alignment is such that their magnetic fields reinforce one another.

c) Resistance to magnetic fields.

4)



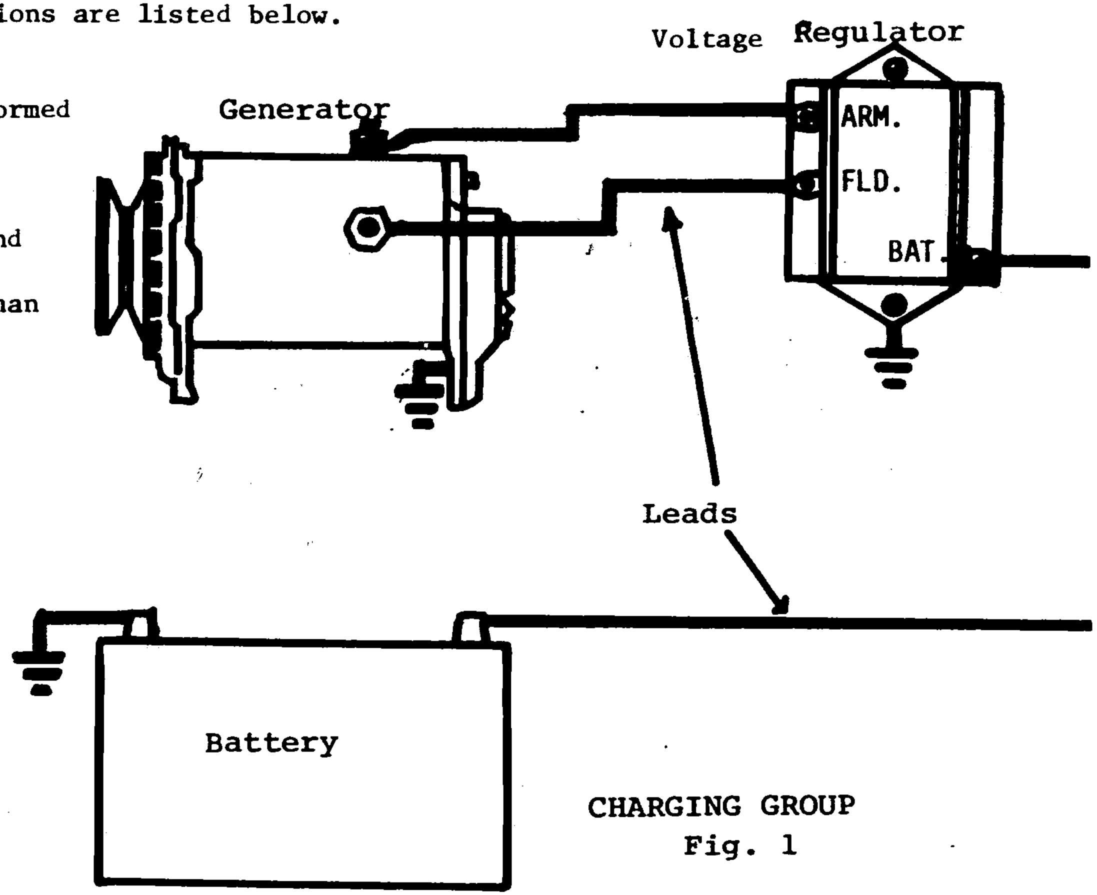
5) The current, the number of turns, the core medium, the core diameter, etc.

6) 6 amperes x 150 turns = 800 ampere-turns.

RESOURCE PACKAGE 14-1

CHARGING GROUP

The charging group in the ignition system consists of these four important components: battery, generator, voltage regulator, and leads. Their functions are listed below.



CHARGING GROUP
Fig. 1

Battery. The two important functions performed by the battery are to supply electrical energy while the car is being started and whenever the generator output is less than the needs of the system.

Generator. The generator converts mechanical energy to electrical energy.

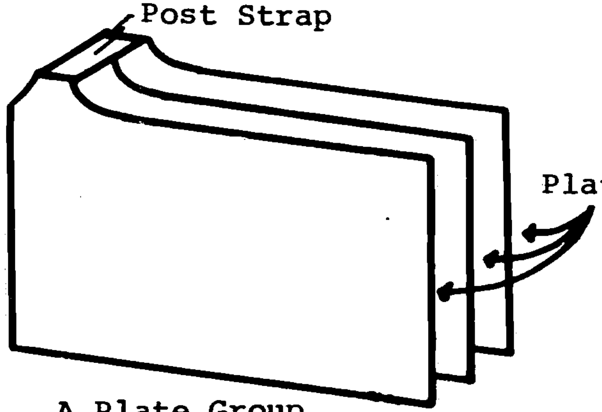
Voltage Regulator. The voltage regulator automatically controls the generator output to meet varying electrical energy requirements.

Leads. The leads complete the electrical circuit between the various electrical components and the vehicle itself.

RESOURCE PACKAGE 15-1

BATTERY CONSTRUCTION

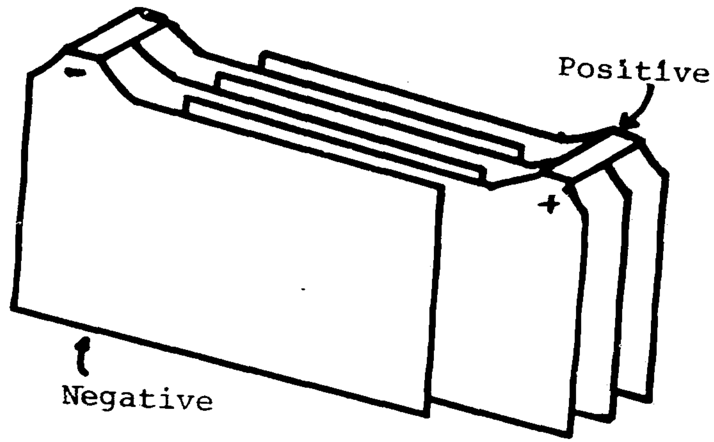
An automobile battery is commonly constructed of three elements (6 volts) or six elements (12 volts). An element is made of two groups of plates; a positive group made of lead peroxide and a negative group made of sponge lead. The plates of a group are aligned side by side, with a space between each plate, and are welded to a post strap (Fig. 1). Both groups are then alternately sandwiched together (positive, negative, positive, etc.) to form elements (Fig. 2). Insulating separators of microporous rubber, cellulose fiber, or some other type of non-conducting material are placed between each adjacent plate. The separators prevent the plates from touching one other and shorting out; however, separator openings allow the electrolyte* to move about freely (Fig. 3).



A Plate Group
Fig. 1

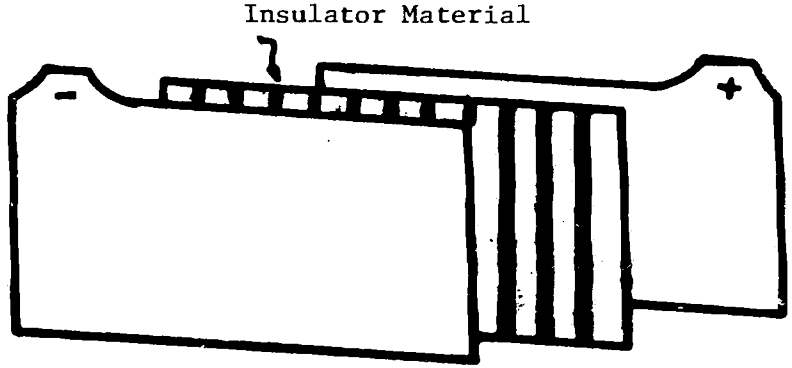
*The electrolyte is a battery fluid. It is described in a later paragraph of this Resource Package.

The elements are assembled in a hard rubber or plastic battery box or case. The case has partitions which divide the case into compartments or cells, one for each element. (Fig. 4)

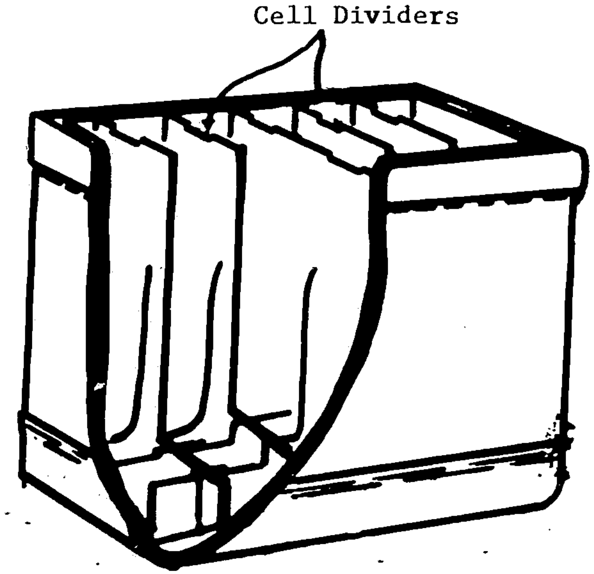


AN ELEMENT
Fig. 2

When assembled, each cell is connected to its neighbor by a lead strap.

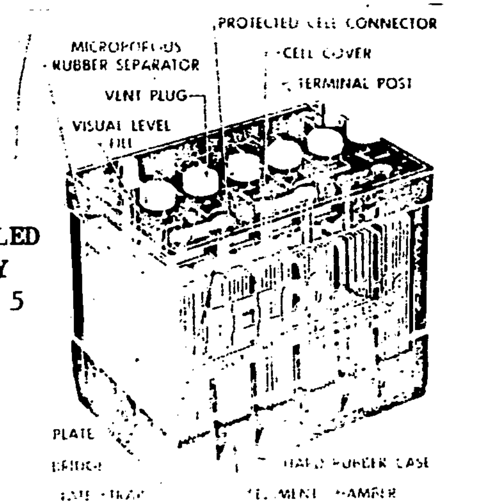


A SEPARATOR BETWEEN PLATES
Fig. 3



CELLS
Fig. 4

Figure 5 shows the assembled battery. Notice that the elements are kept away from the floor of the container. This allows room for the material that the plates shed to deposit itself on the floor of the battery case; if this sediment touches across battery plates, it causes a short circuit and the plates becomes inoperative.



ASSEMBLED
BATTERY
Fig. 5

The battery is filled to a level just above the top of the plates with an electrolyte. An electrolyte is a solution which conducts electricity. The usual battery electrolyte is a solution made of sulfuric acid (H_2SO_4) and distilled water (H_2O). The water makes up about 64% (by weight) of the electrolyte. The positive post is marked with a POS or "+", and is somewhat larger than the negative post, marked NEG or "-".

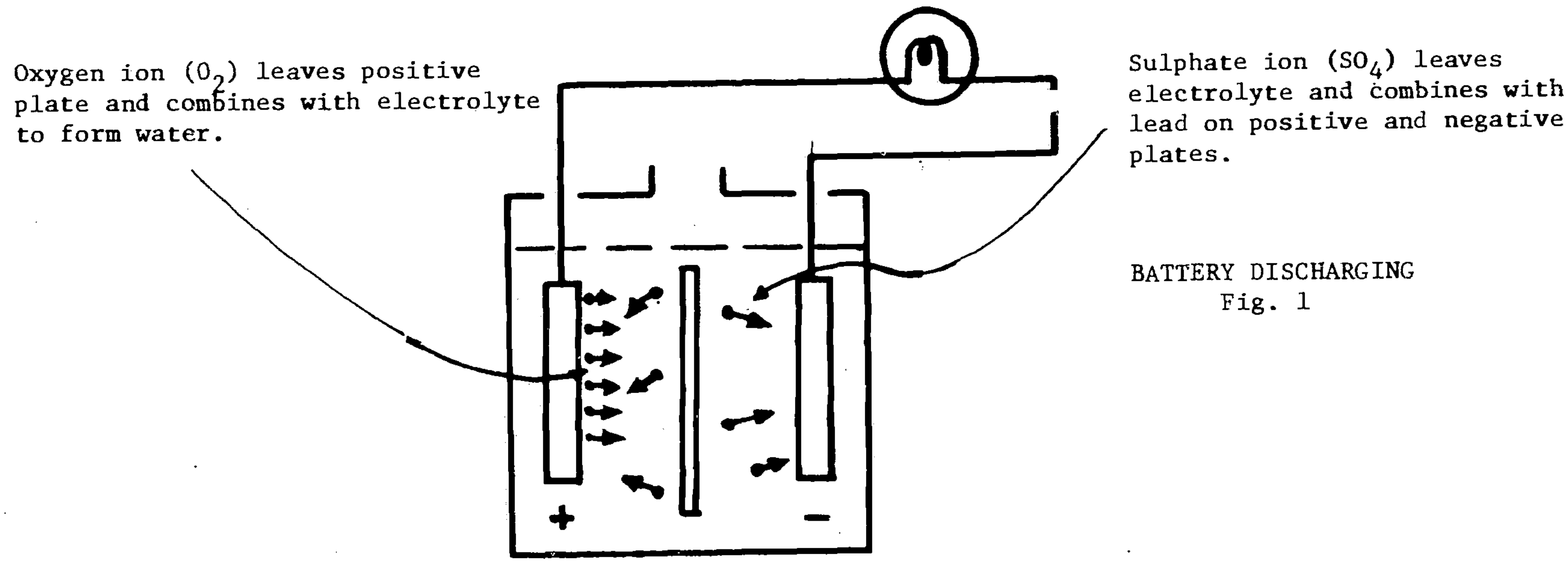
RESOURCE PACKAGE 16-1

BATTERY OPERATION

The battery does not "store" electricity. When a battery is charged, electrical energy is converted into chemical energy; it is the chemical energy which is stored in the battery. Then during discharge of the battery, chemical activity of the electrolyte and the plates results in a transfer of chemical energy to electrical energy of the charge carriers.

When a battery is placed in a closed circuit, surplus electrons at the negative post drift along the circuit toward the positive post. This drift of electron charge carriers constitutes the electrical current. To drive the charge carriers the battery must first convert chemical potential energy into electrical potential energy, which is then transformed into the mechanical kinetic energies of the drifting circuit electrons.

Within the battery an internal current results from the movement of molecular SO_4 and O_2 charge carriers, which move between the plates. The SO_4 and O_2 molecules are called ions, because they are charge carriers formed from what were initially electrically-neutral molecules. The sulphate (SO_4) in the electrolyte combines with the lead plate material, forming lead sulfate. As the current producing chemical activity continues, the electrolyte becomes weaker and weaker and eventually the battery discharges completely. (Fig. 1).



BATTERY DISCHARGING
Fig. 1

Each cell of an automobile storage battery is a source of 2 volts potential difference for the electron charge carriers in the electrical circuit. A 6-volt rated battery has three such cells connected in series. How many cells do you think a 12-volt rated battery has?

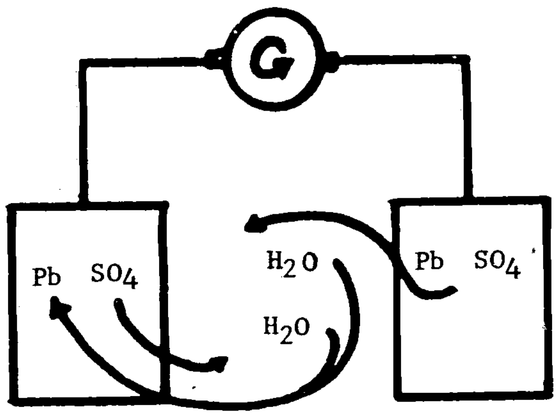
The current output of storage batteries depends principally upon the condition of the electrolyte (acid to water ratio), the number of battery plates, and the surface area of the battery plates. The total number of charge carriers which a battery can energize is measured in terms of ampere-hours. Prices of storage batteries usually depend upon their so-called ampere-hour capacity. For example, a 120 ampere-hour battery will energize a number of electron charge carriers equivalent to 10 amperes to a 6 or 12-volt potential difference for a period of 10 hours. How long would a 6-volt rated, 100 amp-hr battery supply a current to a 5-amp stereo unit?

To find out how long a charged battery will operate under a given load, use the formula:

$$A_H = I\ T$$

Where, I is the current in amperes, T is the time in hours, and A_H is the ampere-hour capacity rating of the battery.

<u>Charging</u> the battery can be done by passing DC through the battery in a reversed direction. Charging reverses the chemical action of discharging (Fig. 2). The sulfate ion (SO_4) now <u>leaves</u> the plates and returns to he electrolyte in the form of sulfuric acid (H_2SO_4), and the plates revert to lead peroxide (Pb SO_4) and sponge lead (Pb).



CHARGING A BATTERY
Fig. 2

Some simple rules of storage battery care follow:

1) Only distilled water should be added to the electrolyte of a battery, and a battery should be checked regularly to insure that the electrolyte covers the cell separators by about $\frac{1}{2}$-inch.

2) A completely discharged battery should be charged immediately. A fast charge (large reversed current for a short time) should be avoided; a slow charge is better because the battery will not overheat during charging.

3) Large starting currents should not be used over long time intervals. Short intervals of large currents do not harm the battery.

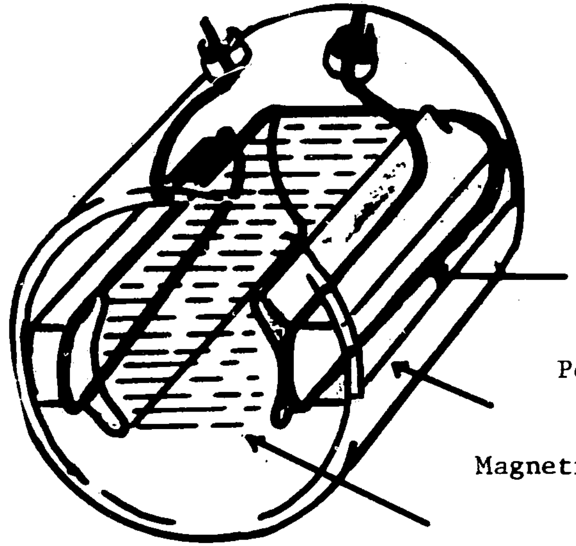
Visit a service station owner and ask to see his battery service operation. Explain that this is an activity required of your class.

Turn in a brief written summary of this experience to your instructor.

RESOURCE PACKAGE 17-1

GENERATOR OPERATION

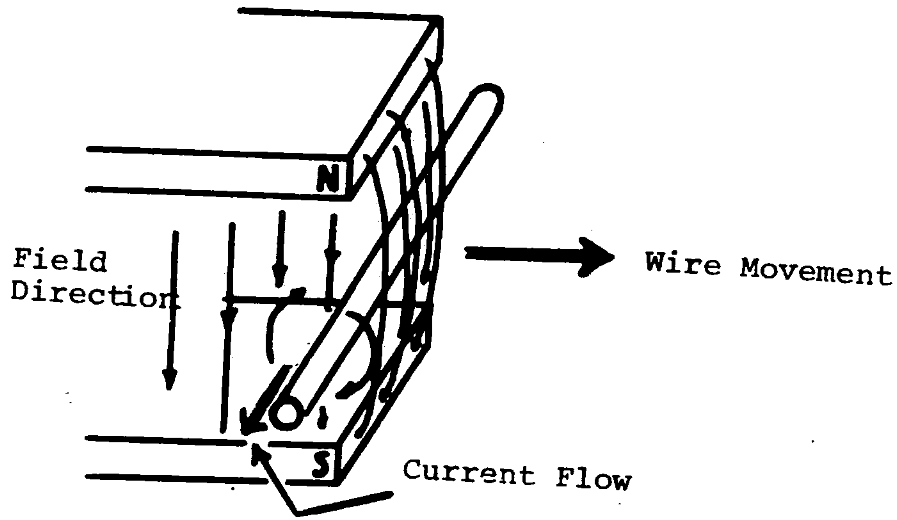
The automobile generator induces (causes) electrical current when its windings are rotated through a magnetic field. This magnetic field is induced by electrical currents in the field coil windings, which are wrapped around the pole shoes (Pole shoes are the metal cores of the generator's electromagnets).



THE GENERATOR
Fig. 1

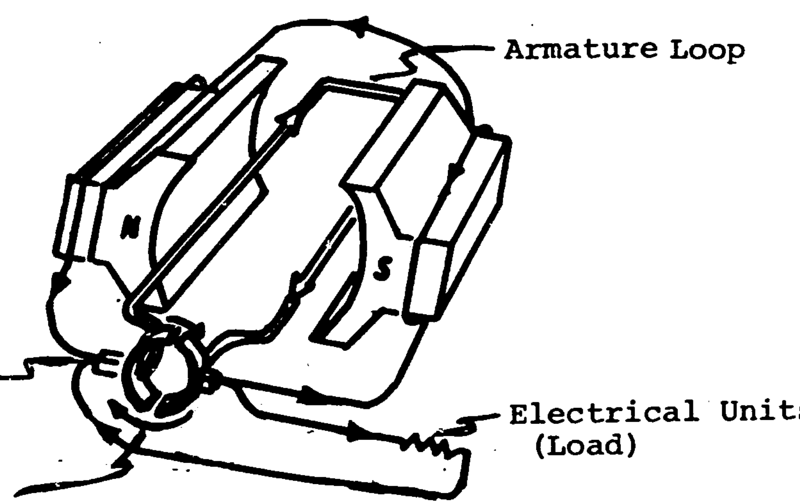
When a conductor is moved through a magnetic field, it cuts magnetic lines of force and a difference of potential is induced in the conductor. This induced voltage caused a current, if the conductor complete circuit. The direction of the induced current is governed by the relative position of the moving conductor and the magnetic field.

Their are various rules which can be used to determine the direction of induced current in the conductor (See Fig. 2). You are advised to study these rules in the refereneces and in your textbook. You can also consult your instructor.



INDUCED CURRENT
Fig. 2

Figure 3 illustrates the basic elements of a generator cirucit. The <u>armature</u> windings are illustrated as a single rectangular loop of wire. Each end of this armature loop is connected to one of the <u>commutator segments</u>. The function of the commutator is to <u>rectify</u> (change) the alternating current generated by the revolving armature into direct current to the load.



GENERATOR COMPONENTS
Fig. 3

As the armature (wire loop) is rotated in the magnetic field, the potential difference induced in it causes a current in the generator circuit. The external circuit is from the insulated brush to the load and back to the generator ground brush. A portion of the generator current is directed through the field coils, to strengthen and to sustain the magnetic field through which the armature moves.

The faster the armature is turned, the more frequently the lines of force are cut and an increased generator output results. This increased output also results in increased current through the field coil, which causes a greater magnetic field. This increase in field strength also increases generator output. To control generator output when the automobile engine is running at high speeds, a voltage regulator is used. The voltage regulator will be considered further in later Resource Packages.

RESOURCE PACKAGE 17-2

INDUCED VOLTAGE

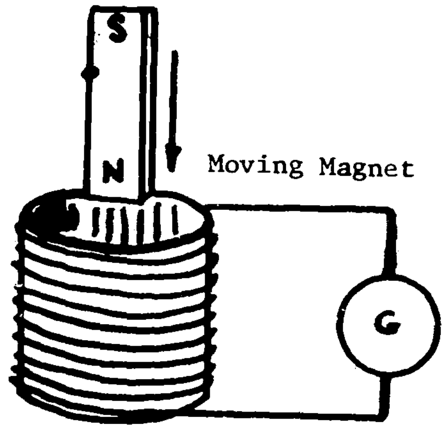
You will need the following materials for this investigation:

- 2 solenoids (50 and 100 turns of No. 22 insulated copper wire)
- galvanometer
- 2 bar magnets
- some copper circuit leads

Connect the 100-turn coil to the galvanometer* as shown in Figure 1. If the galvanometer does not indicate polarity, ask the instructor which <u>binding post</u> (terminal) the current enters to produce a right deflection of the needle. Record answers to questions in this Resource Package, and submit them for evaluation.

Thrust the N pole of the magnet downward into the coil. From the deflection of the galvanometer, determine the direction of current in the coil.

* A galvanometer is a device which can measure small currents.



INDUCED CURRENT
Fig. 1

Is the current flowing clockwise or counter-clockwise around the upper face of the coil?

Pull the magnet out and again note the deflection.

Repeat this with S pole.

Does the magnet direction of motion have any effect on the direction of the current? Does the galvanometer indicate a current when the coil and magnet are stationary?

Repeat the previous procedure, but use different speeds of insertion and withdrawal of the magnet. Does rate of speed affect the galvanometer reading?

Hold two bar magnets together, with their like poles side by side. Thrust the combined N poles into the coil. How does this affect the deflection of the galvanometer needle?

Using the 50-turn coil, repeat the procedures above and observe the galvanometer needle deflections. Is there a difference in the magnitude (size) of the needle deflections, as compared to the 100-turn coil?

RESOURCE PACKAGE 17-3

THE GENERATOR

For this investigation, you will need the following:

St. Louis Motor (simplified motor-generator)
galvanometer
some circuit wire

Examine the device (Fig. 1). Identify the armature, field magnets, commutator slip rings, and brushes.

Connect the terminals of the slip rings (the uncut brass rings) to a galvanometer. By hand, turn the armature slowly and watch the glavanometer. Record answers to these questions:

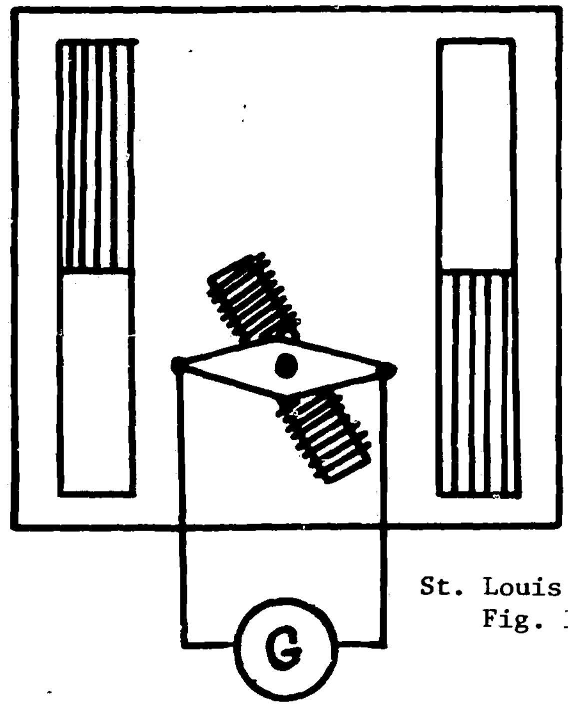
1) Does the galvanometer detect a changing current? How do you know this? What two aspects of the current change?

2) Relative to the magnetic field, in what position is the armature when the change of induced emf (and consequent circuit current) occur?

3) How many changes occur during one complete turn of the armature?

4) What type of induced emf (potential difference) are you observing, alternating or direct? If the galvanometer were removed, would a current exist?...would an induced emf exist?

5) Is the magnitude of the induced emf the same for all positions of the armature?



St. Louis Motor
Fig. 1

6) Relative to the magnetic field in what position is the armature when the emf is a maximum? Is this the same position as for maximum current?

Reverse the direction of rotation of the armature. Answer the following in terms of the observed effects.

7) Has this changed the direction of the induced emf?

8) What effects does turning the armature faster have on the emf?

9) How does reducing the magnet field strength affect the emf? (Field strength can be reduced by moving the magnetic poles farther apart.)

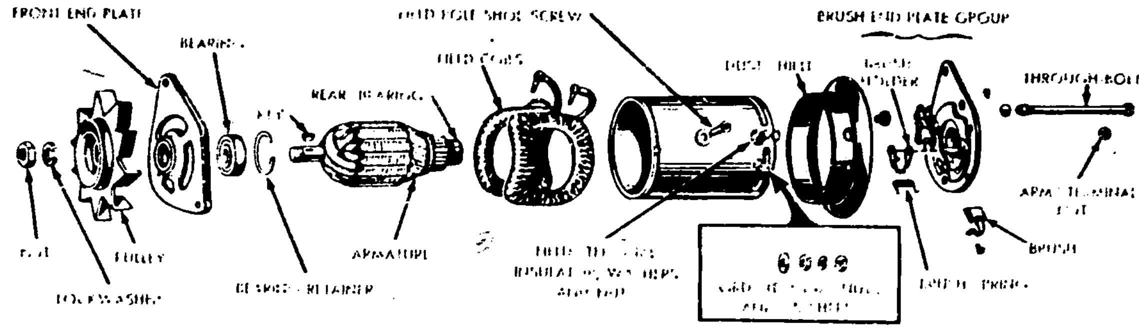
10) What type of emf results when the slip rings are replaced by the commutator? (You can replace these easily.)

11) When the armature is turned in the opposite direction, how does this affect the emf?

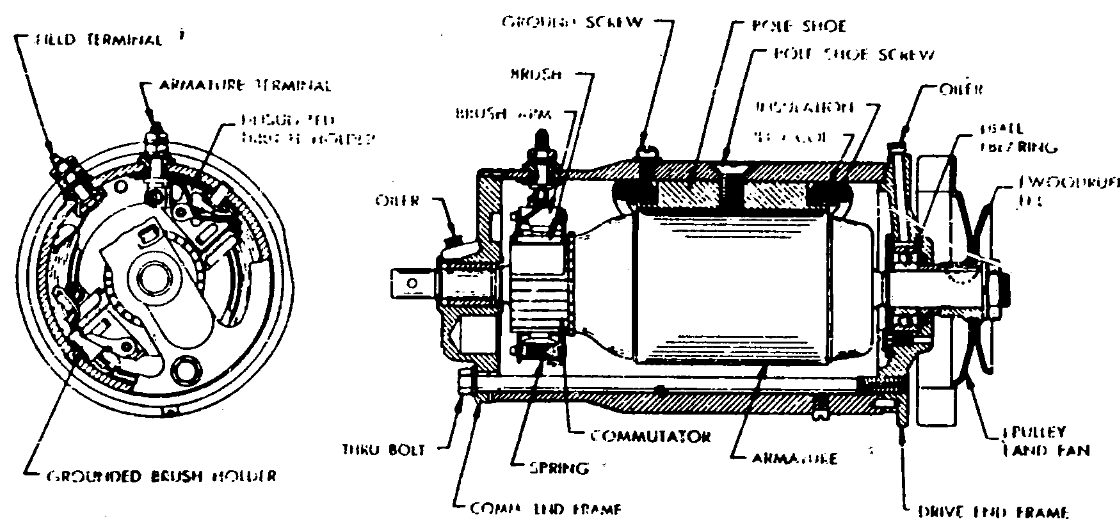
RESOURCE PACKAGE 18-1

GENERATOR PARTS

Exploded View



Cross-Sectional View



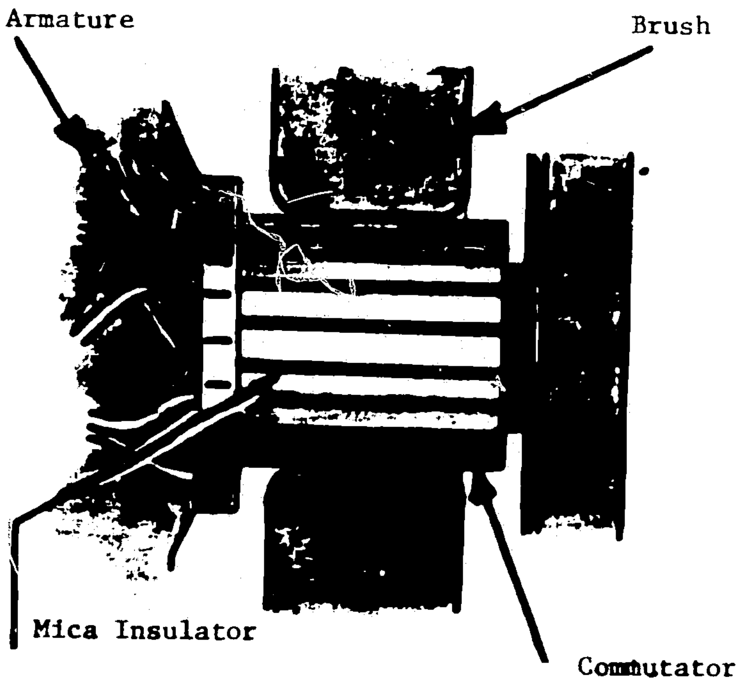
THE GENERATOR
Fig. 1

Figure 1 shows the exploded and cross-sectional views of a typical generator. The basic operating parts are the pole shoes, armature, commutator and brushes. A generator uses two pole shoes instead of permanent magnets. Many turns of wire are wound around the pole shoes. As current passes through the windings, the pole shoes become electromagnets. The greater the current, the stronger the electromagnetic field. Such windings are often called field coils or field windings. The field windings are connected in series, and are so wound that one pole shoe has north polarity and the other has south polarity.

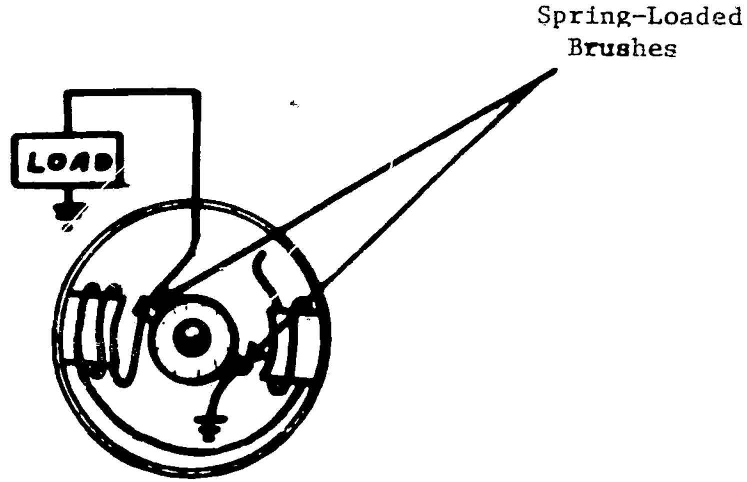
The loops that are to rotate in the magnetic field are wound on a laminated holder called an armature. The armature is supported in bearings set in the end plates. Generally a ball bearing is used at the pulley (front) end plate and a bronze brushing at the other. The armature is turned by a pulley, which is usually driven by a V-belt from the engine crank pulley.

The segments (winding sections) of the commutator are fastened to the armature, and the ends are insulated from the armature and from each other. Figure 2 shows the mica insulators which separate the ends of the windings.

Two carbon brushes are attached to the brush (rear) end plate. One brush is held within an insulated holder and is in contact with the armature windings. This insulated brush is connected to the armature (ARM) terminal of the generator by a short wire. The other brush holder is grounded to the automobile frame, which completes the circuit. Spring pressure on both brushes holds them in firm contact with the commutator at all times (Fig. 3)



BRUSHES AND COMMUTATOR
Fig. 2

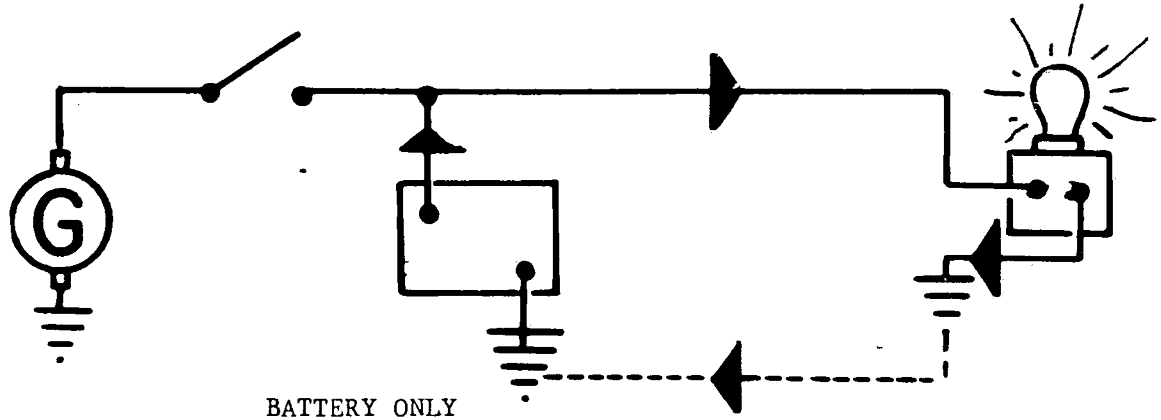


BRUSHES
Fig. 3

RESOURCE PACKAGE 19-1

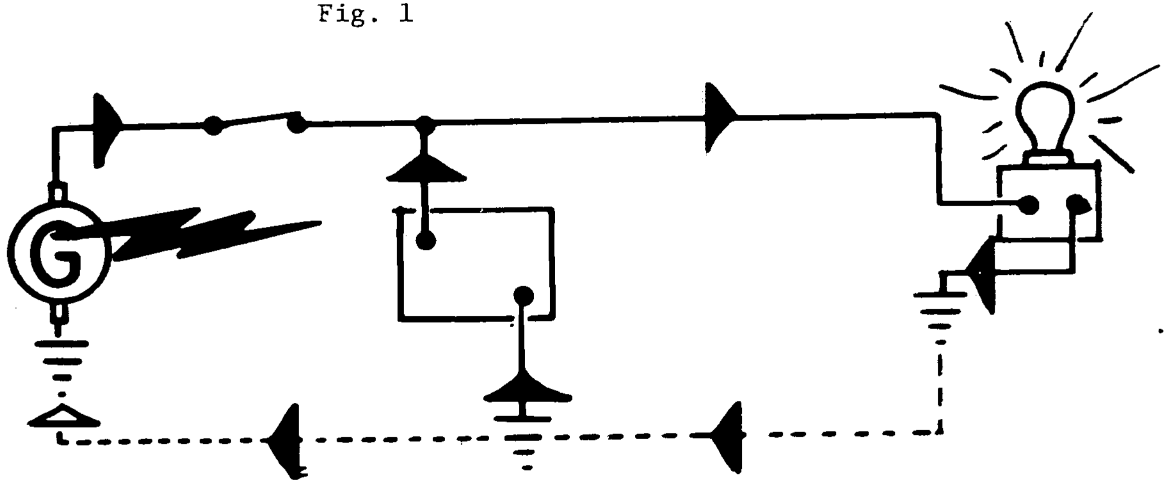
GENERATOR OPERATING SCHEMES

The generator does not function at low speeds or at rest. At such times, all electrical energy is supplied by the battery (Fig. 1)



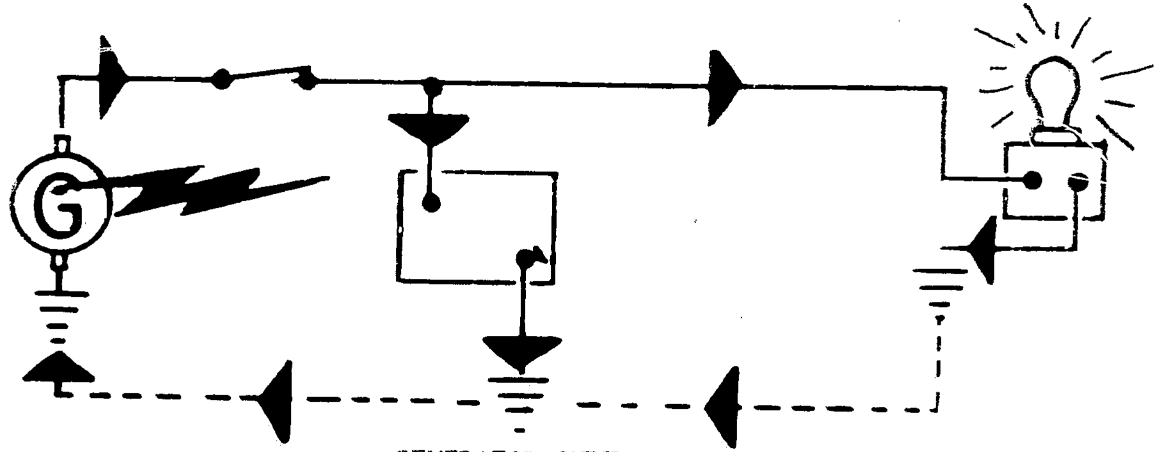
BATTERY ONLY
Fig. 1

With the generator operating, the battery supplements the generator only whenever the electrical load exceeds the generator output. (Fig. 2)



BATTERY AND GENERATOR OPERATING
Fig. 2

When the electrical load is less than the generator output, the generator supplies all the energy for the load and also recharges the battery (Fig. 3)

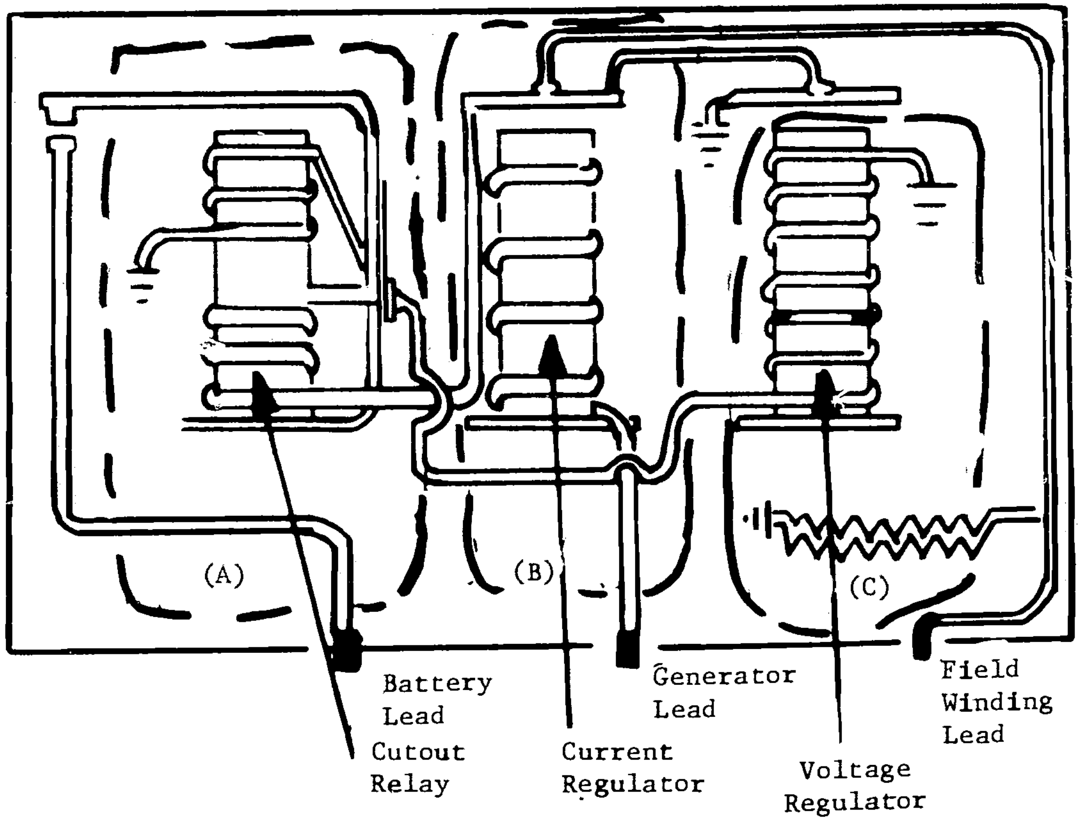


GENERATOR ONLY
Fig. 3

THE REGULATOR

Because excessive generator output can damage the wiring, the battery, the bulbs, and other electrocal units, it is necessary to control the generator's emf and current. This is done by incorporating a voltage and current regulator into the charging group of the ignition system.

The commonly used regulator has three separate controlling units. One unit (Fig. 1,C) controls the emf (voltage regulator); another unit (Fig. 1.B) controls the current (current regulator); and the third (Fig. 1,A) connects and disconnects the generator from the battery circuit (cutout relay.)

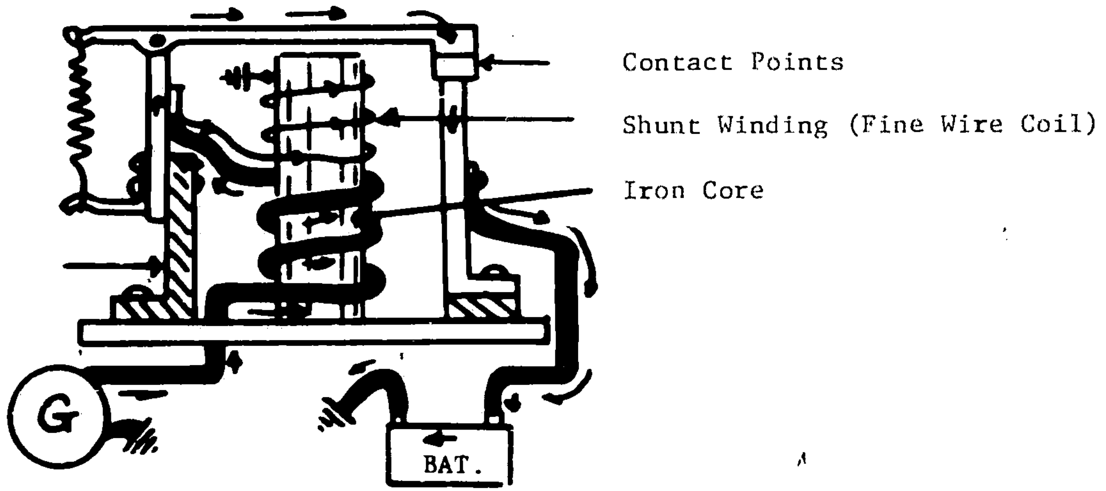


REGULATOR UNIT
Fig. 1

RESOURCE PACKAGE 21-1

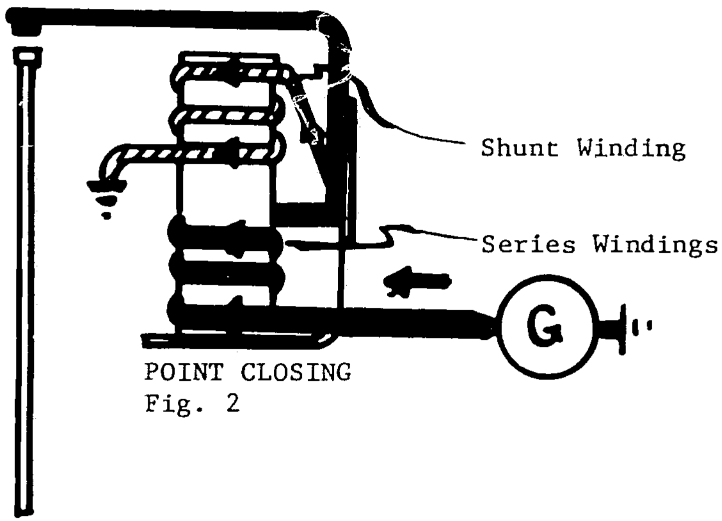
CUTOUT RELAY

The cutout relay (Fig. 1) is an electromagnetic device used to open and to close the charging circuit between the battery and the generator. This circuit is closed only when the battery needs charging (when the cutout relay response to the generator voltage is greater than to the battery voltage).

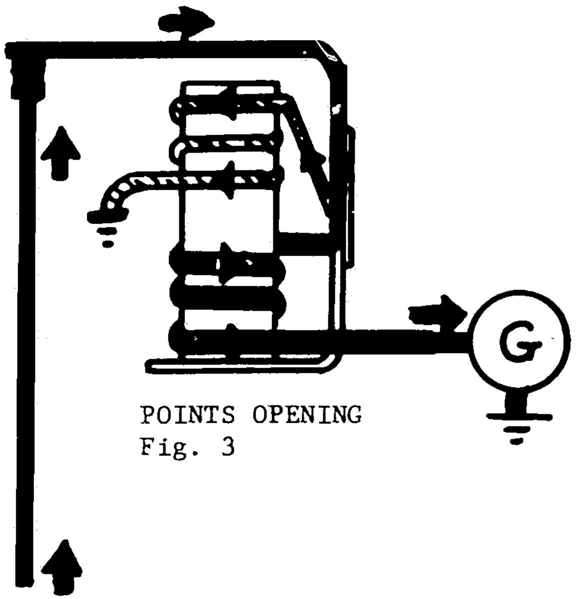


CUTOUT RELAY
Fig. 1

The cutout relay has a fine wire coil acting as a shunt from the generator output lead to the ground. This shunt coil is "voltage sensitive" because its current depends upon the generator emf. Therefore, when the generator voltage response is sufficient for the cutout relay electromagnet to overcome the pre-set spring tension, the contact points are closed and generator current charges the battery.



POINT CLOSING
Fig. 2



POINTS OPENING
Fig. 3

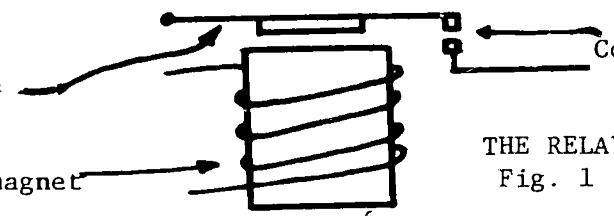
When the generator is charging the battery, current is in the same direction in both the <u>series</u> and <u>shunt</u> windings of the relay. The magnetic fields induced by both windings combine to hold the cutout points closed.

When the battery is not charging, the current is reversed in the series winding (because the shunt winding responds to a higher battery voltage). Since the current in the series and the shunt windings are now in opposite directions, the induced magnetic fields tend to cancel each other, the relay core becomes demagnetized, and the spring opens the contact points so that the battery cannot charge.

RESOURCE PACKAGE 21-2

RELAY I

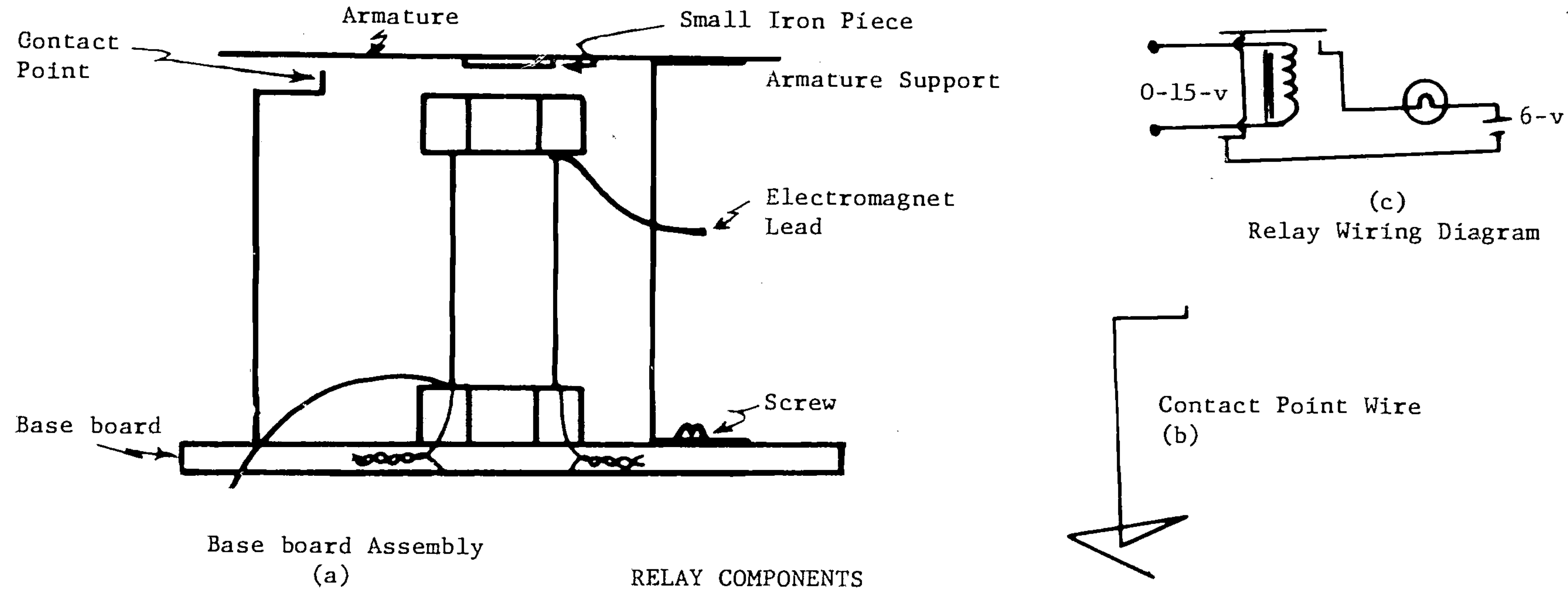
An automobile ignition system relay has three basic parts: armature, contact points, and electromagnet.



THE RELAY
Fig. 1

In this exercise you will make a relay similar to that used in the car regulator. You will need the following: electromagnet made in Resource Package 12-1; a board about 12 inches long (baseboard); a sheet of brass about 3/4 x 6-1/2 inches (armature support); a brass strap about 1/4 x 6 inches (armature); 1/8 inch diameter copper wire, 10 inches long (contact point wire); 6-volt DC power supply; 0 - 15 volt DC power supply; ammeter (0-25 amps); some circuit wire; some small wood screws.

Secure the electromagnet to the base board with tape or with wire, as shown in Fig. 2 (a). Punch a screw hole in one end of the 3/4 x 6-½ inch brass sheet; then make a 90^{o} angle at both ends to form the support of the armature. The bend should be made about 1-¼ inch from each end. Screw the armature support to the base board; set it about 1-½ inch from the electromagnet. Next tape the ¼ x 6 inch brass strap (armature) to the armature support. Tape a small piece of iron firmly to the armature above the electromagnet. Last, bend the copper contact point wire in the configuration shown in Fig. 2 (b).



RELAY COMPONENTS
Fig. 2

The circuit is wired according to Fig. 2 (c).

When the apparatus is completed, close the switch and carefully adjust the voltage until the light glows.

What effect does the gap setting between the core and the armature have upon the operation of the relay?

What effect does the distance between the armature and contact wire have upon the operation of the relay?

Measure and record the distance between the armature and the core, and between the armature and the contact point. Make a data table like the one shown below. Calculate and record the minimum strength of the magnet needed to close the contact point. Make this calculation for two different contact point settings. Use the equation from Resource Package 12-1.

Trial	Gap Distance	Contact Distance (mm)	Magnet Strength (IN)
#1			
#2			

Do your data indicate a relationship between gap distance and magnet strength? . . . . between contact distance and magnet strength?

KEEP THIS SETUP FOR FUTURE USE

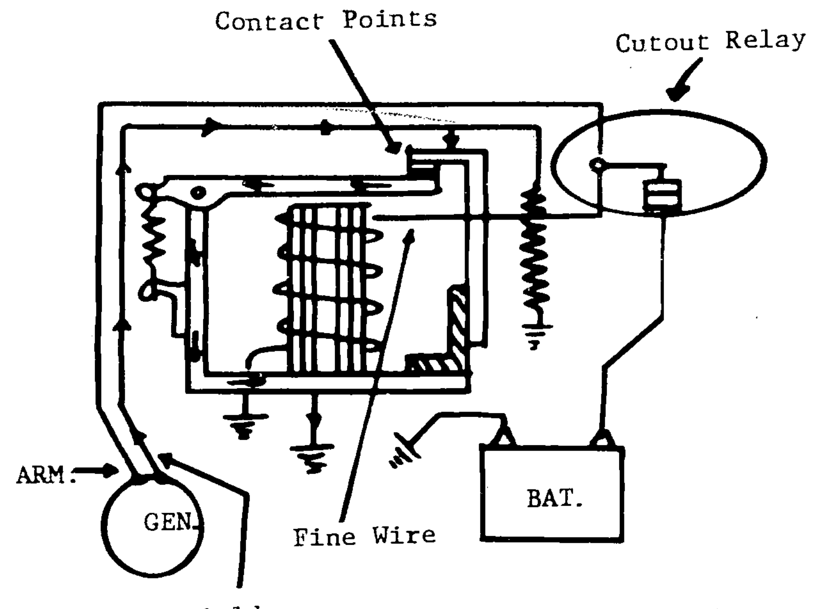
RESOURCE PACKAGE 22-1

VOLTAGE REGULATOR

The voltage regulator is used to prevent the generator from developing too high an emf; it essentially limits the charging voltage to a value which is safe for the electrical components of the ignition system.

The voltage regulator contact points are installed in series with the generator field windings, so that all of the generator field coil current must pass through the points of the voltage regulator and then to ground. As long as the voltage regulator points are closed, the field current and the generator output will attain a maximum value for any given generator speed.

The fine wire coil of the voltage regulator relay is connected across the generator output circuit, enabling it to sense the output voltage. When the voltage output of the generator reaches a safe maximum limit, the induced magnetic field of the voltage-sensitive regulator coil becomes



VOLTAGE REGULATOR
Fig. 1

strong enough to overcome the pre-set spring tension and to open the contact points. With the points open, the generator field coil circuit is routed through a resistor; this lowers the field coil current thereby decreasing the generator output. The regulator system is inter-dependent.* The decreased voltage output of the generator reduces the current and consequent magnetic strength in the voltage regulator coil; the spring closes the contact points and thereby completes the field coil circuit to ground, which allows the generator output to rise.

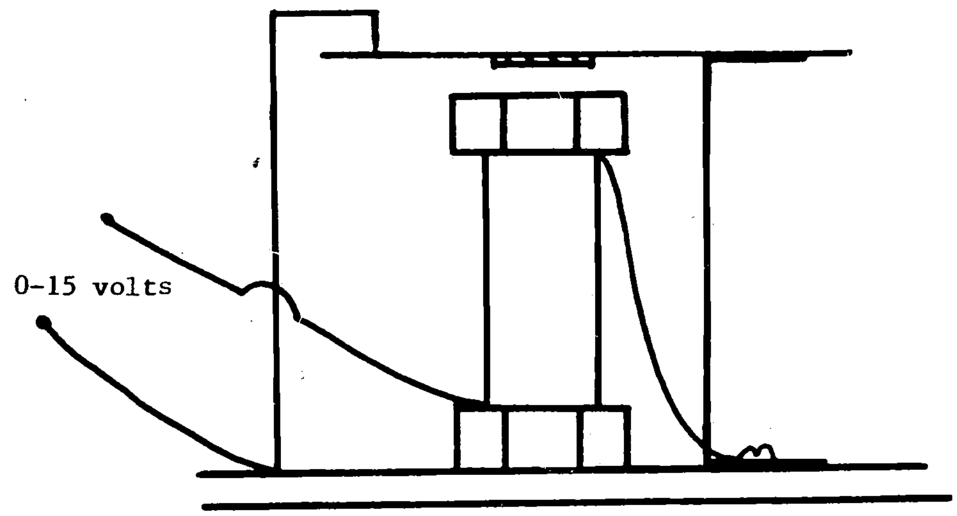
During operation, the points vibrate at a frequency of from 50 to 250 cycles per second, depending upon the specific output voltage setting.

* This kind of system is known in technical physics as a <u>feed-back</u> or <u>cybernetic</u> system.

RESOURCE PACKAGE 22-2

RELAY II

Use the same setup as in Resource Package 21-1, with the minor changes shown in the diagram below.



ANOTHER RELAY

Assemble the apparatus as shown. The relay should be in series between the power supply and the load. Close the switch and adjust the current until the armature vibrates. What is causing the relay to vibrate?

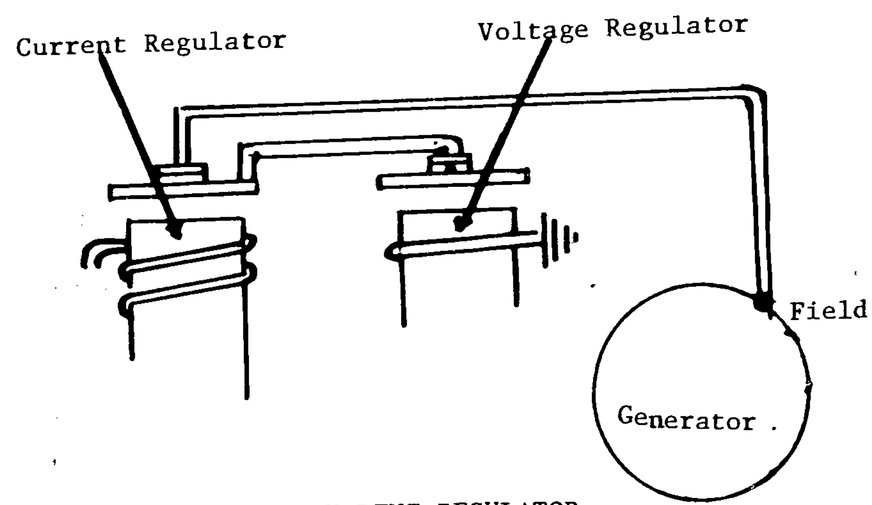
Find the maximum and the minimum current needed to vibrate the armature. In your reading, did you find a mathematical <u>curve</u> that illustrates the current change in this circuit?...

RESOURCE PACKAGE 23-1

CURRENT REGULATOR

Even though the generator voltage is controlled, when the battery is at low charge or when a heavy load is on the system it is possible for the generator current to rise too high. High currents could overheat the generator and melt the windings. Therefore, the current as well as the voltage must be monitored.

As the generator reaches the safe value for which the current regulator has been pre-set, the regulator contact points begin to vibrate. This vibration alternately opens and closes the contact points, which inserts and removes a resistance in the generator field circuit. The change in resistance controls the voltage and thereby limits the current output of the generator.



CURRENT REGULATOR
Fig. 1

The generator field coils are in series with the current regulator points and the voltage regulator points (Fig. 1). The current regulator windings are made of heavy wire, and carry the entire output of the generator. When the current output reaches the maximum output of the generator, the magnetic field due to the heavy windings of the current regulator becomes strong enough to overcome the pre-set spring tension and to open the contact points to break the generator field coil circuit. The field coil current then passes through a resistor to ground, reducing the output of the generator. At the same time, the current through the regulator windings drops, reducing the magnetic field and allowing the points to close and to complete the generator field coil-to-ground circuit. Generator output then rises; and the induced magnetic field in the relay again opens the points, inserting the resistance once more into the field circuit. This feed-back action continues as long as current regulation is required.

The current regulator and the voltage regulator do not operate at the same time. If the electric load requirements are heavy and the battery is low, the overall ignition system voltage will not be sufficient to operate the voltage regulator. Instead, the generator output will increase until it reaches the value for which the current regulator was pre-set, at which value the current regulator will operate to protect the generator from overload.

If the electrical load is reduced, or if the battery condition rises to normal charge-wise, the system voltage will increase to a value sufficient to cause the voltage regulator to operate. When this happens, the generator output is reduced to below the value required to operate the current regulator. The current regulator will stop operating, and all generator control will be handled by the voltage regulator.

RESOURCE PACKAGE 24-1.1

CHARGING GROUP SELF-TEST

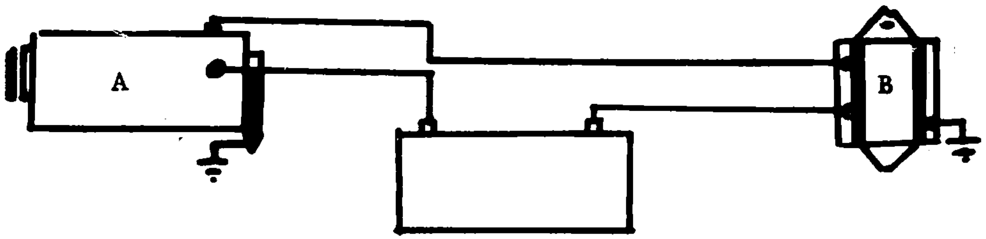
Complete the following quiestions on a separate sheet of paper.

1. Consult the diagram below.

   a) Is the diagram wired correctly?

   b) What is the name of the part lettered A?

   c) What is the function of the part lettered B?



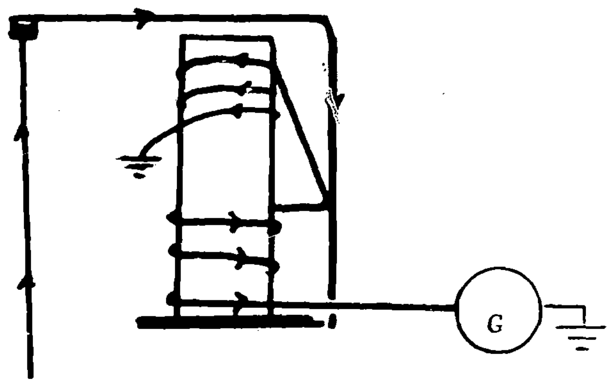
2. Describe the construction and operation of an automobile battery.

3. Describe the operation of an automobile generator.

4. Name the four basic parts of an automobile generator.

5. Name the three parts of an automobile regulator.

6. Look at the diagram. What part of the automobile regulator does this diagram represent? Do the arrows show correct current directions. Why? Why not?



RESOURCE PACKAGE 24-1.2

ANSWERS

1. a) No

   b) Generator

   c) Controls the generator output.

2. A battery is constructed of three or six elements assembled in a hard rubber or plastic case. The elements are formed by sandwiching two different groups of plates together so that a negative plate adjoins a positive plate. Insulating separators prevent the plates from touching. The positive plates are lead peroxide; the negative plates are spongy lead.

   The battery transforms chemical energy to electrical energy. In the process, the ions SO_4 and O_2 move to and from the plates. The oxygen ion leaves the positive plate and combines with the electrolyte to form water, while the sulfate ion leaves the electrolyte to combine with the lead on both plates.

3. The generator develops an emf by moving wire conductors through a magnetic field. The current induced moves from the insulated brush through the electrical load and back to the generator ground brush. A portion of the generator output current is directed through the generator's field coils to develop a magnetic field.

4. Armature, commutator, brushes, pole shoes.

5. Cutout relay, voltage regulator, current regulator.

6. Cutout relay. Yes.

If you have not correctly completed all six (6) questions, you should review.

RESOURCE PACKAGE 25-1

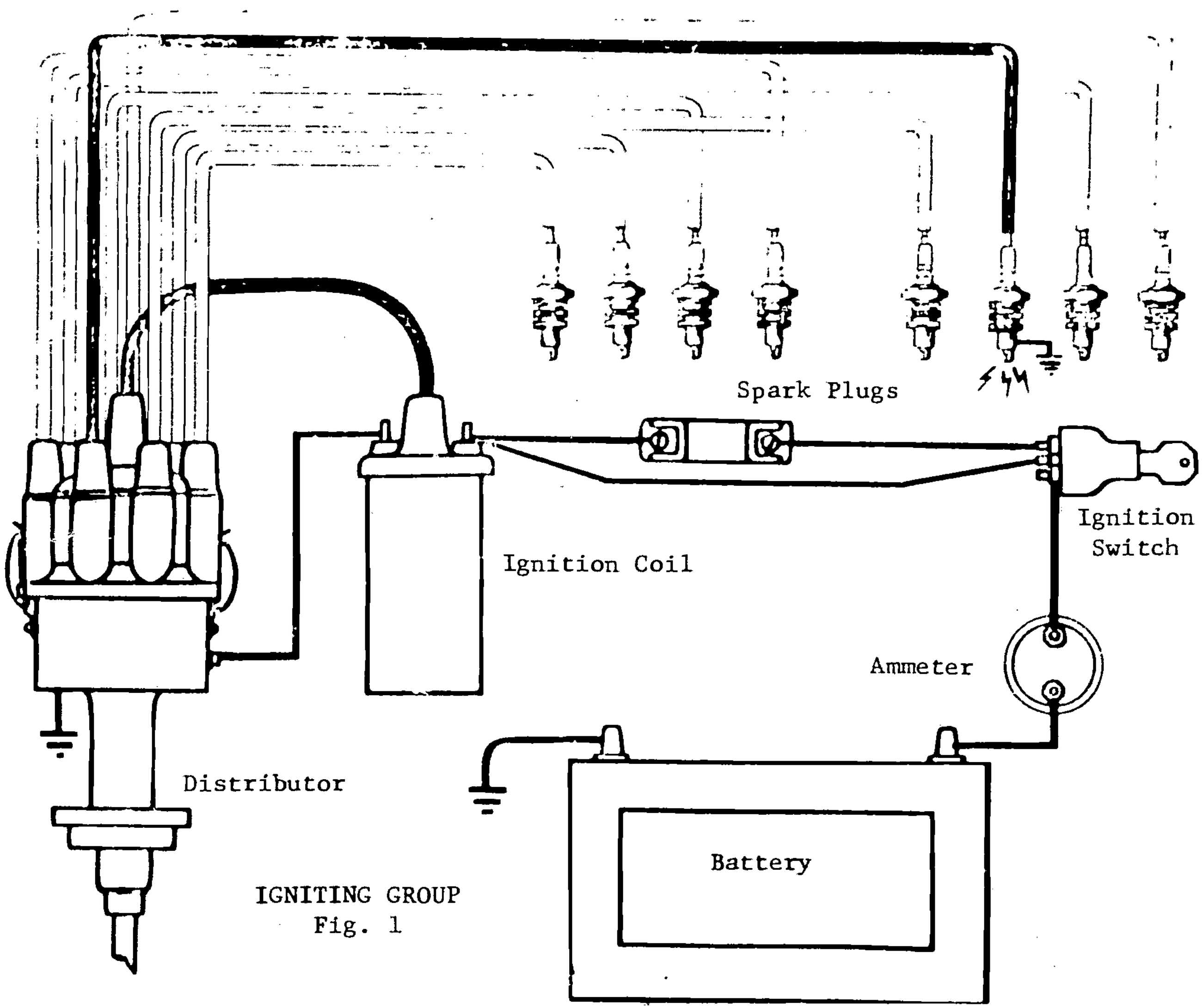
IGNITING GROUP

The function of the igniting group (Fig. 1) is to deliver a high-voltage electrical pulse to the spark plugs, precisely timed to ignite the air-fuel mixture compressed in the cylinders.

The igniting group consists of the following components:

- battery
- ignition switch
- ballast resistor
- ignition coil
- distributor assembly
- high tension* leads
- spark plugs

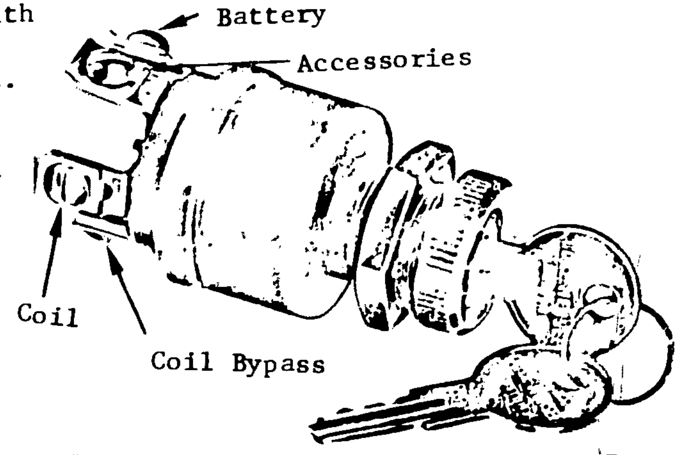
*high tension is another phrase for high voltage.



IGNITING GROUP
Fig. 1

SWITCH-RESISTOR

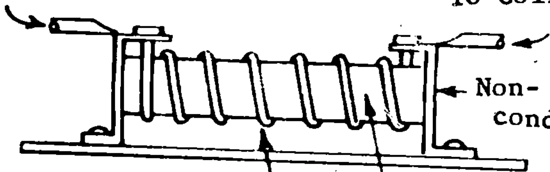
The ignition switch (Fig. 1) is simply an ON-OFF switch in series with the battery, the ignition coil, and the rest of the ignition circuit.



IGNITION SWITCH
Fig. 1

When the ignition switch is closed, current passes through the coil-distributor (primary) circuit and returns by way of the car frame or engine block to the battery. The ignition switch also serves as a bypass switch during engine starting.

The ballast resistor (Fig. 2) in the ignition primary circuit is designed to permit an optimal (best) current for all driving conditions. However, during engine starting the ballast resistor is bypassed to permit maximum voltage and maximum current through the ignition coil. The high tension or secondary leads "conduct" the high voltage from the ignition coil to the distributor, and then from the distributor to the spark plugs.



BALLAST RESISTOR
Fig. 2

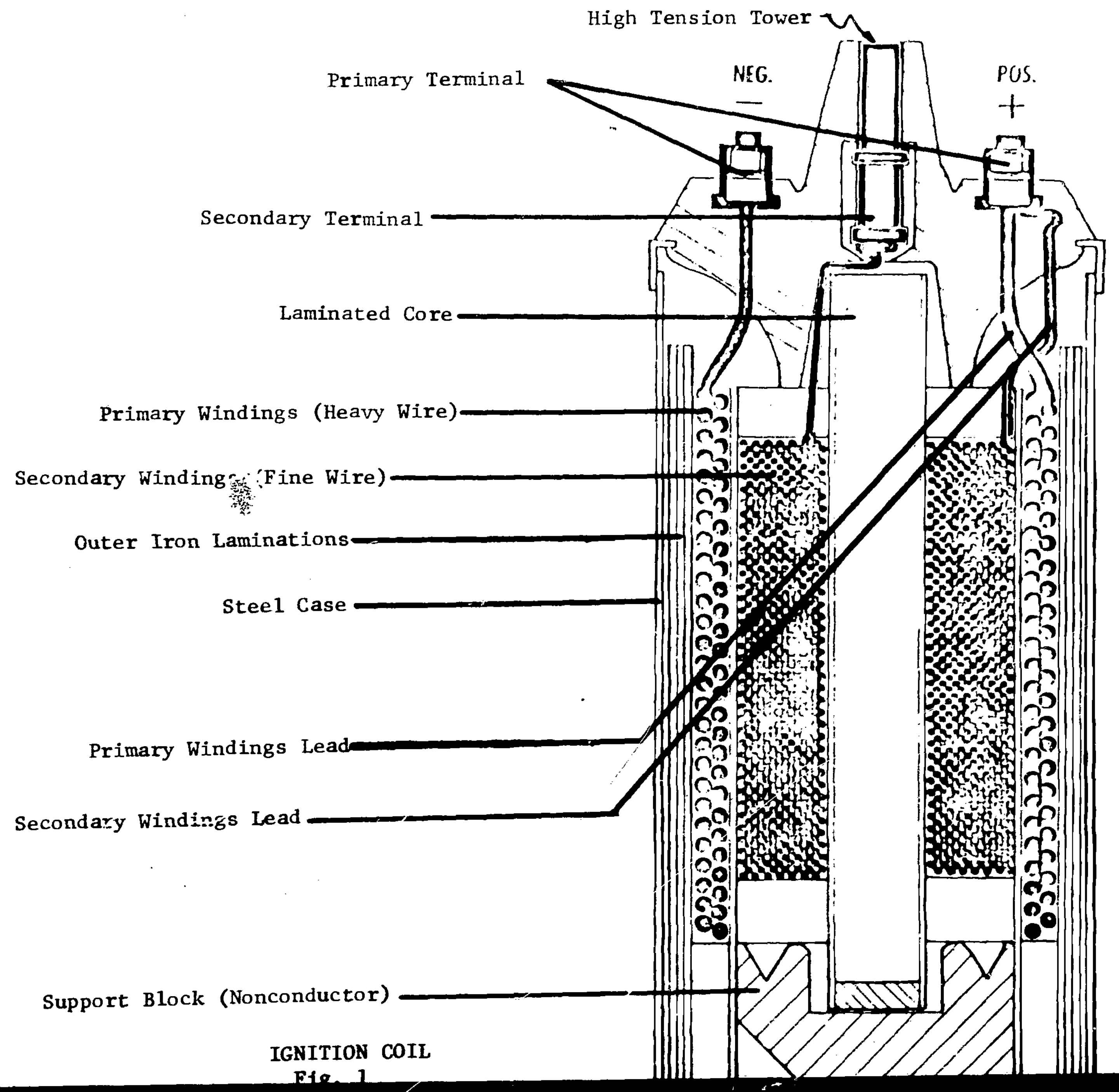
RESOURCE PACKAGE 27-1

IGNITION COIL

An ignition coil (Fig. 1) is composed essentially of a core and two windings (primary and secondary), enclosed in a metal case. The core of the coil usually consists of thin soft iron strips or laminations. The iron core's function is to increase the efficiency and output of the coil. It does this by providing faster and stronger magnetic fields than would an air core, and it does so with a lesser enengy requirement.

The two windings are identified as a primary winding and a secondary winding. The primary winding consists of approximately 250 turns of relatively heavy wire, which is insulated with a special varnish. The secondary winding is wound inside the primary winding and consists of approximately 20,000 turns of very fine varnished wire. The many layers of the secondary winding are insulated from each other by high dielectric (insulating) paper. One end of the secondary winding is connected to the high tension tower (high voltage terminal) while the other end is connected to one of the primary terminals inside the coil.

Ignition coils are often filled with oil or special compounds to provide additional insulation and to help dissipate the heat due to current resistance in the windings.

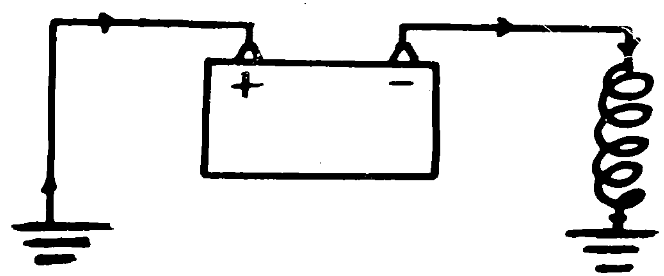


IGNITION COIL
Fig. 1

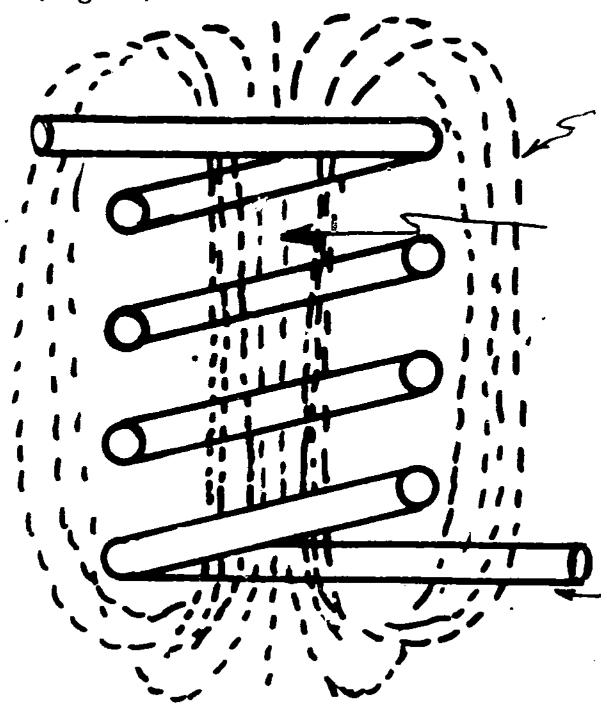
RESOURCE PACKAGE 28-1

IGNITION COIL OPERATION

When the ignition switch is turned on, the current path is to the primary winding of the coil, to the ground, and then back to the battery via the frame. (Fig. 1)



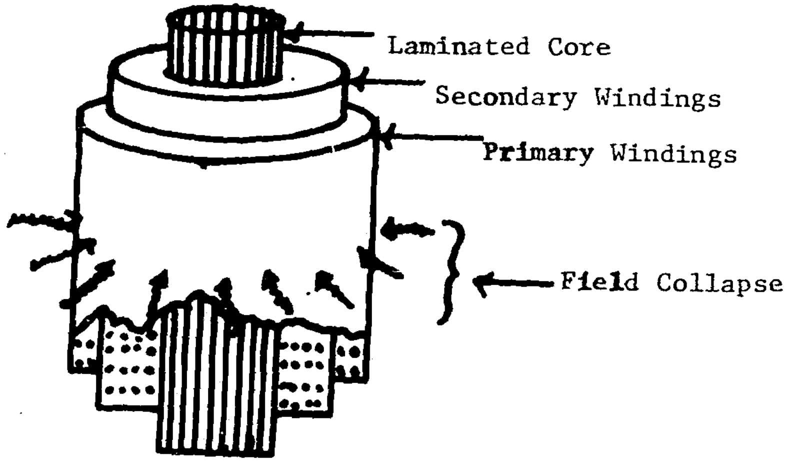
PRIMARY CIRCUIT
Fig. 1



MAGNETIC FIELD OF PRIMARY
Fig. 2

As current flows through the primary windings, a magnetic field is induced around them and is concentrated in the core region (Fig. 2). Because there are several hundred turns of wire in the primary windings, the magnetic field is strong. This magnetic field also passes through the secondary windings, which are housed inside the primary windings (See Resource Package 27-1).

If the current through the primary windings is interrupted, the induced magnetic field will collapse quickly. During build-up and during collapse, the induced magnetic field (concentrated in the region housing the secondary windings) cuts through the thousands of turns of secondary wire and induces a tiny emf in each turn. Since the turns are in series, the emf per turn is multiplied by the number of turns. An ordinary ignition coil's voltage is in excess of 20,000 volts.



PRIMARY AND SECONDARY WINDINGS
Fig. 3

Of course, as the magnetic field passes through the primary turns an emf will also be induced in them. But since these turns are far fewer in number , the voltage multiplication will be considerably less (somewhat over 200 volts).

RESOURCE PACKAGE 28-2

INDUCED VOLTAGE

You will need the following:

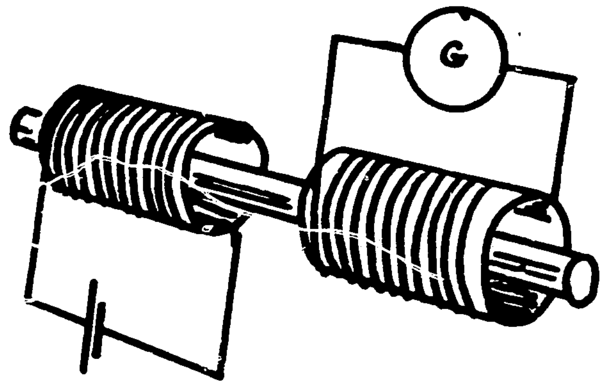
1) 2 solenoids (50 & 100 turns of #22 copper wire)

2) galvanometer

3) soft-iron rod

4) 1.5 volt DC power source

5) some circuit wire



INDUCED VOLTAGE
Fig. 1

Place the two solenoids (coils) on a long soft-iron rod as shown in Fig. 1. Connect the 100-turn secondary coil to the glavanometer, and connect the 50-turn primary coil to the DC source. Leave one terminal of the cell loose (disconnected) until you are ready to make observations. Close the circuit by touching the loose lead end to the source terminal. Observe the galvanometer deflection as the circuit is thus closed and opened.

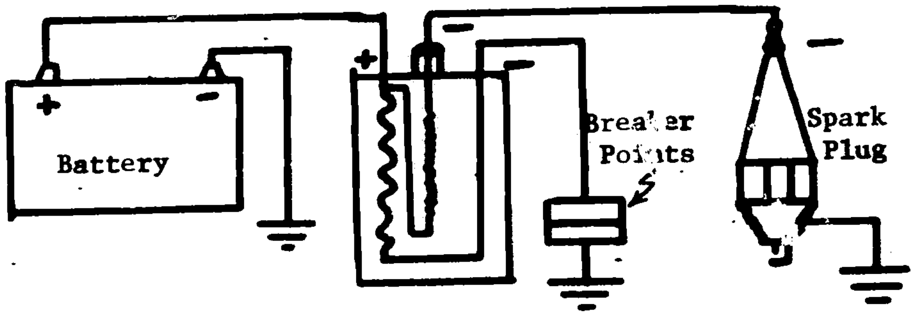
When is an emf induced in a secondary coil? Why is the emf induced when the primary circuit is opened? Compare the direction of the induced emf when the circuit is closed to the direction when the circuit is opened. Reverse the direction of current in the primary coil and observe the effect on the galvanometer. Record these observations.

Leave the coils side by side, and remove the iron core. Using the same DC source, note the galvanometer deflection as you "make" and "break" the circuit. Compare these deflections with those when the iron core was present.

RESOURCE PACKAGE 29-1

COIL POLARITY

Most coils have the primary terminals marked with (+) or (-) (Fig. 1). The coil must be installed in the primary circuit according to the way the car is grounded. If the battery has its negative terminal grounded (as do Amer. n-made automobiles) the negative terminal of the coil must be connected to the distributor. If the battery positive terminal is grounded (as in many foreign-made automobiles) the positive side of the coil must be connected to the distributor lead. This careful coil-to-distributor circuit wiring must be made to insure proper polarity at the spark plug. This is because electron charge carrier drift is made easier if the drift current is from a hotter surface to a cooler one. Because the center electrode of the plug is always the hotter of the two plug electrodes, a negative polarity at the inner electrode will insure a current direction away from this center electrode. The result will be a lower voltage requirement, a lighter coil "load," and a "hotter" plug discharge.



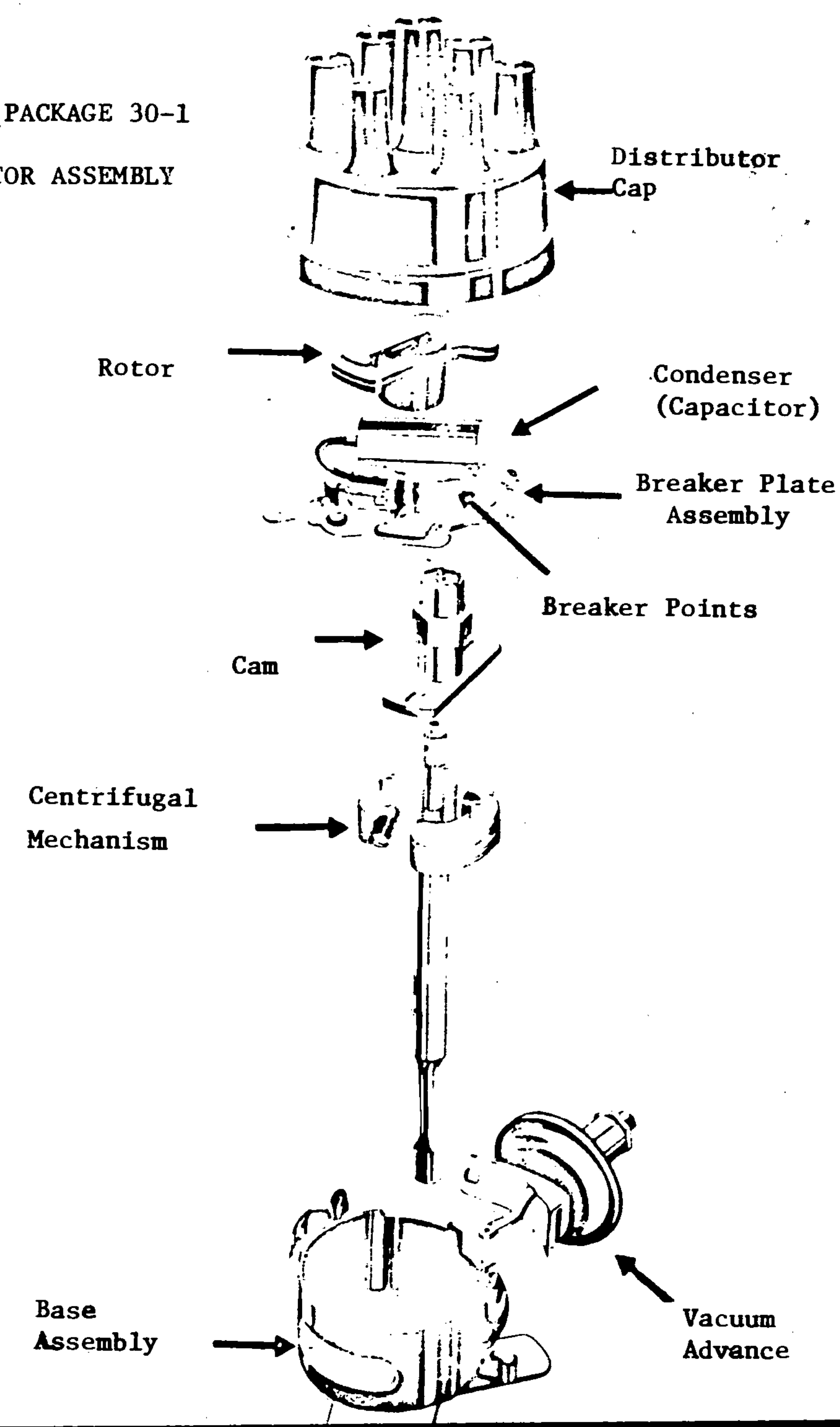
COIL POLARITY
Fig. 1

The coil will build up a potential difference just sufficient to cause a current discharge (fire) across the plug electrode gap. Even though the coil output can exceed 20,000 volts, it generally requires only 2,000 to 10,000 volts potential difference before a discharge occurs across the electrode gap.

RESOURCE PACKAGE 30-1

DISTRIBUTOR ASSEMBLY

Fig. 1 shows the basic parts of the districutor. The distributor plays a vital role in the igniting group. Its function is to direct the high coil energy to the proper spark plug at the optinum instant for peak engine performance.



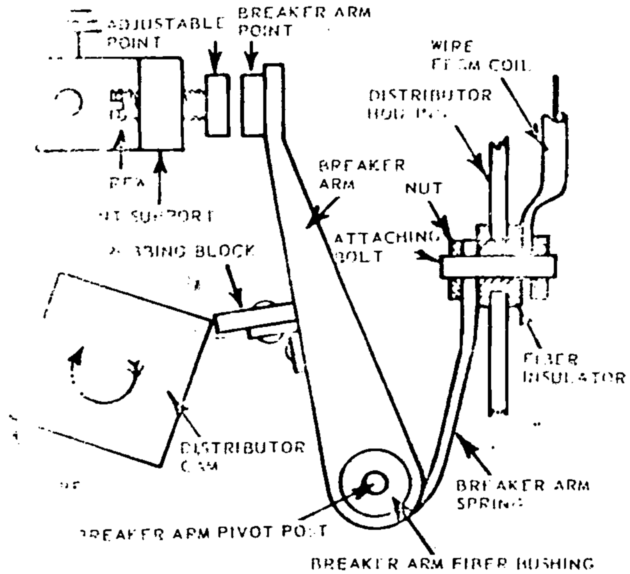
RESOURCE PACKAGE 31-1

BREAKER POINTS

For efficient coil operation, the current through the primary windings must be interrupted (broken) quickly and "cleanly" (no electrical <u>flash-over</u> or <u>arcing</u> at the point of disconnection).

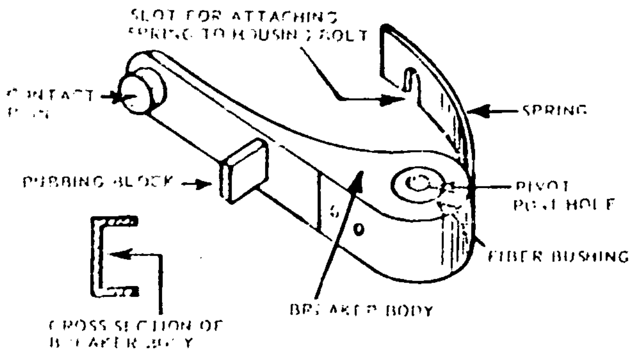
The unit that is used to connect (make) and disconnect (break) the current in the primary circuit contains a set of <u>breaker points</u>. These points open and close to make and break the circuit.

The breaker points are constructed as two separate pieces. <u>One point</u> is grounded through the distributor <u>breaker plate</u>, which is fixed in place. (This point never moves, except during installation and point gap adjustment). <u>The second point</u> is fastened to the breaker arm, which is pivoted on a steel post and moves when in operation. A <u>fiber brushing</u> is used as a bearing on the <u>pivot post</u>. A thin steel spring is used to



BREAKER POINTS
Fig. 1

press the movable breaker arm against the stationary breaker plate, causing the two contact points to remain pressed firmly together unless separated by <u>cam</u> action. The movable arm is lifted by a <u>cam</u> <u>lobe</u> during operation, and this action breaks the points. The cam lobe is turned at one-half the engine rate; i.e., if the engine is idling at 800 rpm, the cam lobe is turning at 400 rpm.



BREAKER ARM
Fig. 2

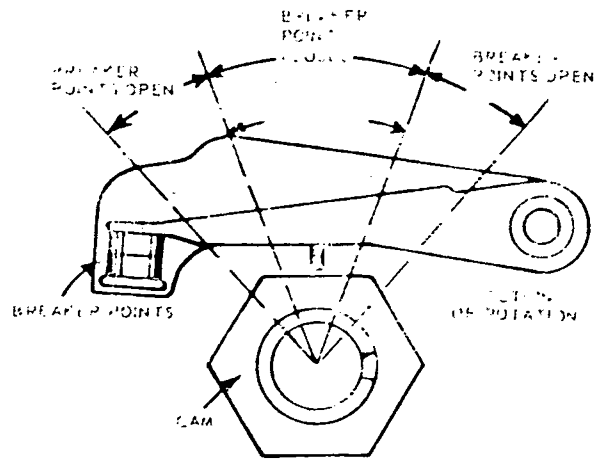
The breaker arm contacts the cam by means of the fiber <u>rubbing</u> <u>block</u>. This rubbing block is fastened to the breaker arm and rubs against the cam, to cause opening and releasing of the spring-loaded points. The movable breaker arm is insulated so that the primary circuit will not be energized unless the points are touching.

The breaker point must be carefully aligned so that the two points make good contact. This means that the contact surfaces of the points must be smooth (non-pitted) and free of oil or other contaminates. The points must open a precise amount; this <u>gap</u> must agree with the auto manufacturer's specification, since a slight variation in gap can upset cam angle and consequent ignition timing. The contact points are made of tungsten steel. Tungsten is resistant to burning and to electrical arcing.

RESOURCE PACKAGE 32-1

CAM ANGLE

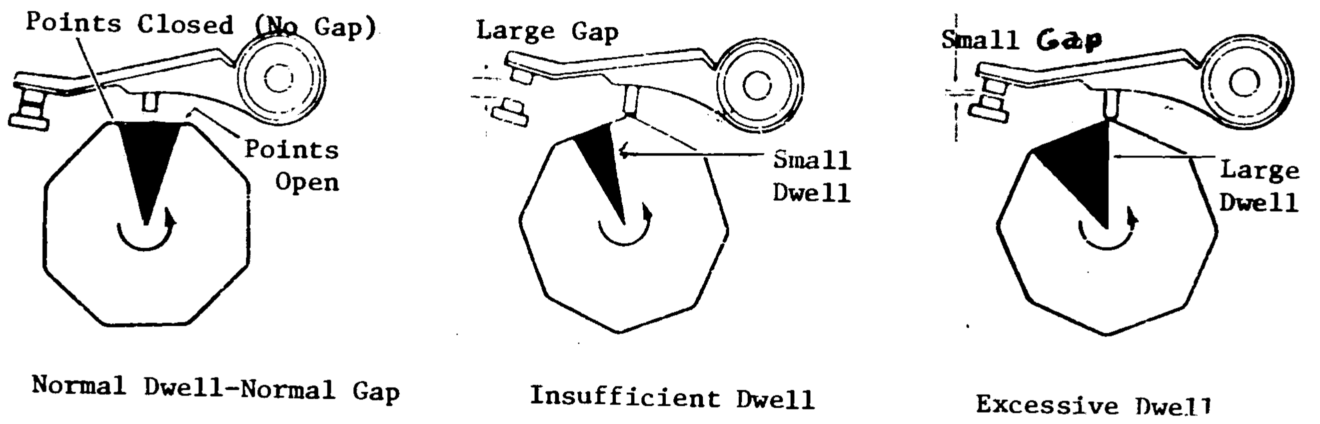
The <u>cam angle</u>, also referred to as degrees of dwell, is the number of degrees the cam rotates from the time the points close until they open again (Fig. 1).



CAM AND BREAKER ARM
Fig.1

This angle is important because the time interval that the points are closed affects the magnetic build-up induced by the primary windings. For example, if the cam angle is too small the points will open prematurely and the magnetic field will collapse before it has built up enough to induce a satisfactory spark.

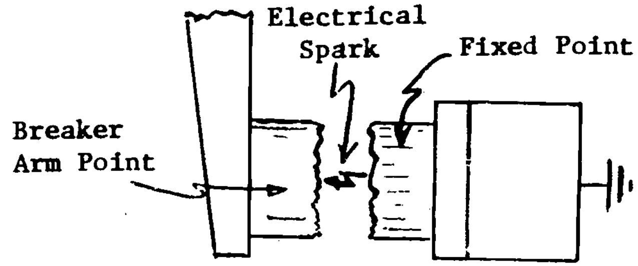
When setting points, one should remember that as the gap is lessened the cam angle is increased. When the gap is enlarged, the cam angle is decreased (Fig. 2).



POINT SETTINGS
Fig. 2

If the point gaps are not properly set, each time the points open there will be a heavy electrical arc across the points. This destroys the points relatively fast. Further, unless the points break the primary circuit quickly and cleanly the magnetic collapse due to the primary windings will be poor, and a satisfactory voltage will not be induced in the secondary windings.

There is a tendency for an electrical current to sustain itself after a circuit is broken, a kind of electrical inertia dur to induction effects. When the contact points open, the magnetic field starts to collapse and induces voltage in the primary circuit. Between the reluctance of the current to stop, and this added surge of induced voltage in the primary circuit, the circuit will not be broken cleanly and a heavy spark will leap across the point opening (Fig. 3). This spark problem can be helped by using a condensor (capacitor), as discussed in the next Resource Package.



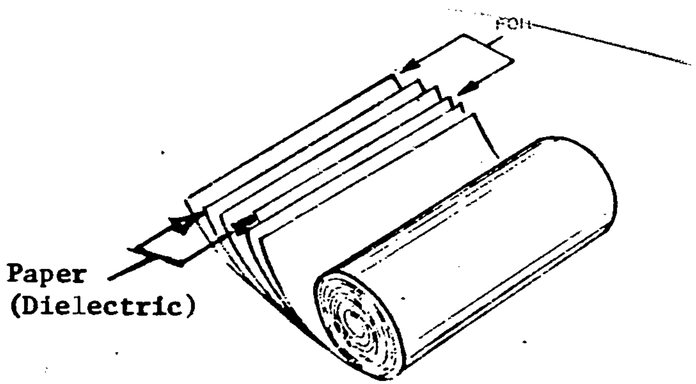
BREAKER POINTS
Fig. 3

RESOURCE PACKAGE 33-1

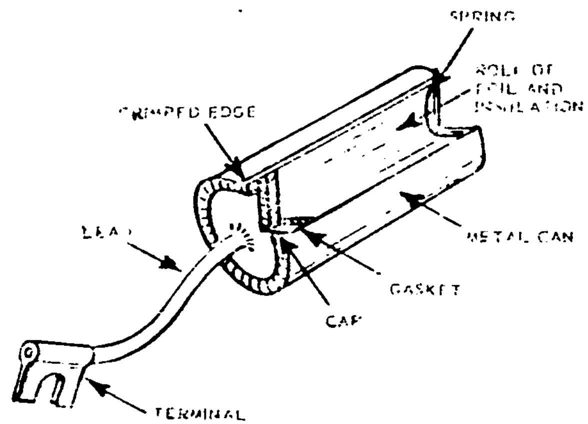
CONDENSER CONSTRUCTION

The condenser (capacitor) is constructed of layers of aluminum foil insulated from each other by layers of high dielectric (insulating) material (See Fig. 1). One layer of aluminum foil extends beyond the dielectric material on one side, while another layer of foil extends beyond the dielectric material on the other side. The layers of aluminum foil and insulating material are then rolled into a tight cylinder and inserted into the condenser case. The layer of aluminum foil extending at one side will contact the bottom of the case and constitute the ground terminal of the condenser. The other layer of foil will contact a disc which is connected to the insulated lead of the condenser (Fig. 2).

Direct current cannot be passed through a condenser.



CAPACITOR LAYERS
Fig 1



AUTOMOBILE CAPACITOR
Fig. 2

When a condenser of proper size is inserted into the primary circuit, heavy arcing at the breaker point will be eliminated and the secondary voltage will reach satisfactory limits. This is accomplished because the condenser provides a place into which the primary current can flow when the points are opened.

Read about capacitors in your text and in other references. In the next Resource Package you will make your own condenser; and by reading and doing you should end up with a working knowledge of these condensers.

You may have wondered about the alternate usage of the words condenser and capacitor. They are words for the same thing. Condenser is the historical term, and it is widely used by mechanics. Capacitor is a more acceptable scientific term, because the device does NOT condense electrical energy but it DOES have a capacity for "storing" energy.

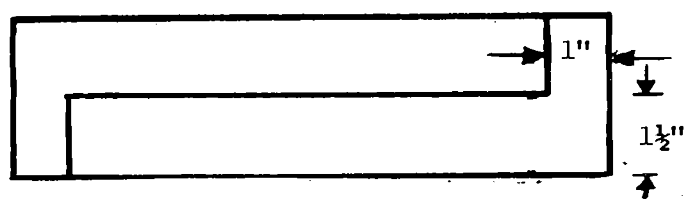
RESOURCE PACKAGE 33-2

CONDENSER

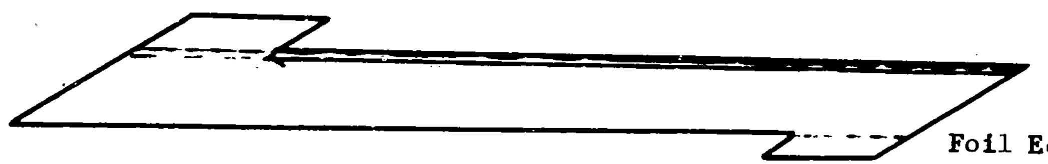
A common variety of condenser is made of the conductor aluminum foil, separated by the dielectric waxed paper. The wire leads extending from the ends of the capacitor connect to the foil plates. The assembly is tightly rolled into a cylinder and sealed with special compounds.

To make a condenser you will need one 3 x 12 inch sheet of aluminum foil, one 1-3/4 x 12 inch strip of waxed paper, some tape, and a candle.

Keep your foil free of wrinkles while cutting it with a razor blade. Cut the 3" x 12" sheet as shown:



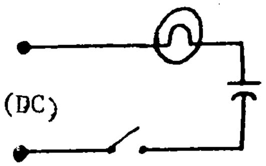
Arrange the components in a layered foil-paper-foil sequence. The foil layers cannot touch each other!



Carefully roll the layers into a tight cylinder. Use tape to hold the cylinder tightly together, and seal both ends with hot wax.

Now to test your condenser, connect it in series to a 6 volt DC source, a 6-volt lamp, and a switch. (See diagram).

6 volts (DC)



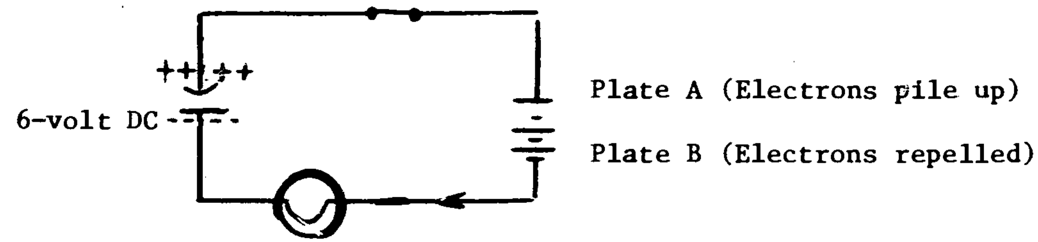
BE CAREFUL WITH CONDENSERS! THEY HOLD A CHARGE AND SHOULD BE DISCHARGED BEFORE WORKING WITH THEM. THIS CAN BE DONE BY SHORTING THEIR ENDS TOGETHER WITH A JUMPER OR AN INSULATED SCREW DRIVER.

Close the switch and observe the light. If no light appears -- GREAT! Otherwise, back to the drawing board, because you've blown it somewhere! If everything fails, use a commercial .1 mfd condenser.

Next, use the same circuit but connect to a 6 volt AC power supply. Does the light glow?

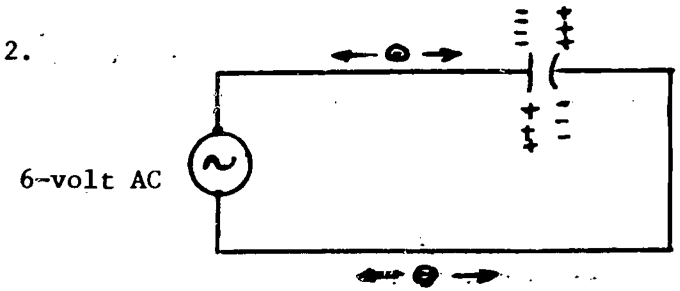
What is your conclusion about the current in a DC series circuit and in an AC series circuit containing a capacitor?

Because DC voltage varies only when it is turned on and off, condensers affect DC circuits only at these times. When the switch is turned on, the electrons drift from the source to the condenser plate A (See Fig. 1). These electrons pile up in excess on plate A, so they repel the electrons on plate B (like charges repel each other). The repelled electrons drift toward the positive post A, thereby causing plate B to become charged positive. Since there is a constant pile-up of electrons at plate A, the charged condenser will remain charged until the switch is opened. After the switch is opened, the displaced electrons have no place to go, so the condenser still remains charged. (There will be a gradual discharge over a long period of time.)



CAPACITOR IN SERIES IN DC CIRCUIT
Fig. 1

A condenser blocks the flow of DC current. But it affects an AC circuit differently, allowing AC drift to occur throughout the circuit. This drift results in a continuous charging and discharging of the condenser plates, as the AC charge carriers are driven first in one direction and then in the opposite direction on each cycle. See Figure 2.

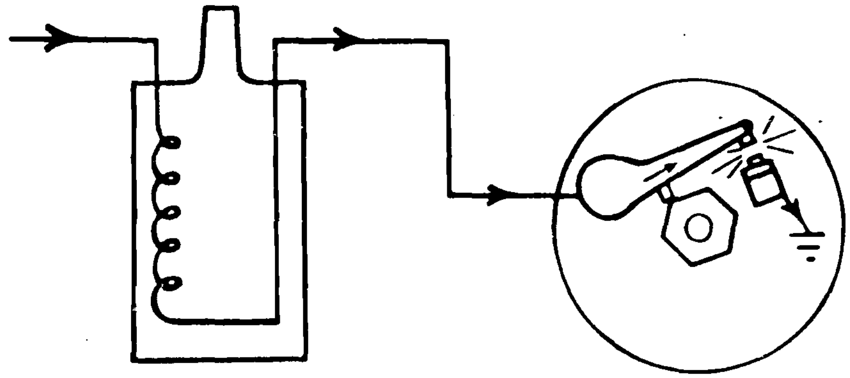


CAPACITOR IN SERIES IN AC CIRCUIT
Fig. 2

RESOURCE PACKAGE 34-1

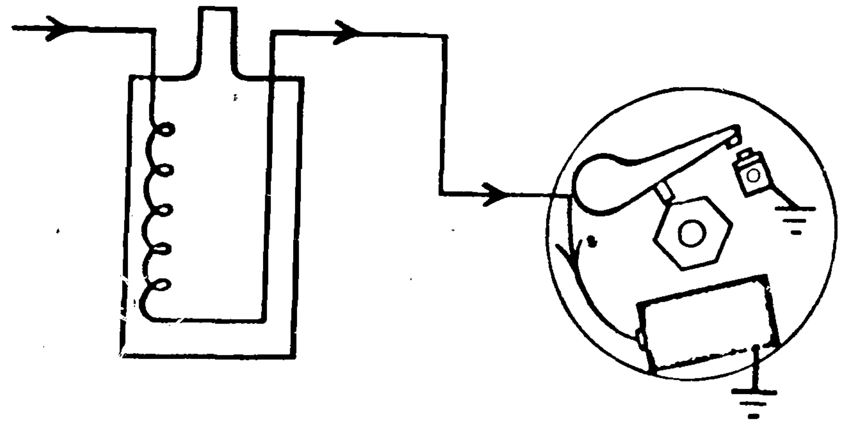
CONDENSER ACTION

The functions of the condenser are to reduce the amount of arcing across the points, and to quickly stop the flow of current in the primary coil windings.



When contacts open, current continues to flow, causing an arc across contacts.

Coil Without Condenser

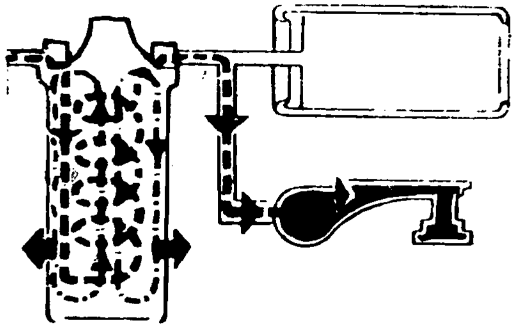


Condenser provides temporary place for primary current to go, reducing arcing at contacts.

Coil With Condenser

CONDENSER ACTION Fig. 1

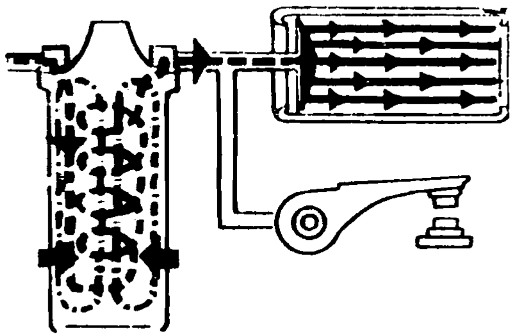
Figure 2 shows a condenser installed in the ignition circuit. The breaker points close and the primary circuit current flows through the points to the ground, and then back to the battery. The primary field is strong.



Capacitor Uncharged

CLOSED POINTS
Fig. 2

In Figure 3, the points have <u>started to open</u>. The primary field has started to collapse, but no current arcs across the points. This non-arcing is because the current energy has been stored in the condenser. The condenser does not have an unlimited energy-storing capacity, but about the time it has become fully charged the points <u>will have opened too far</u> for a current to jump (arc) across the points. The primary field collapse will now be strong and quick.

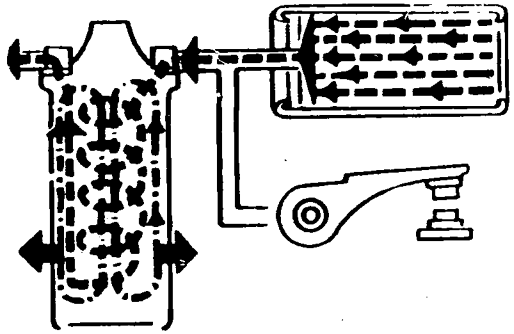


OPEN POINTS
Fig. 3

The instant the spark discharge at the plug occurs, the capacitor energy will be restored to the primary circuit. The capacitor dumps its energy back into the primary circuit because the capactor energy potential is higher than that of the primary after the field collapse occurs.

CAPACITOR DISCHARGE
TO PRIMARY

Fig. 4

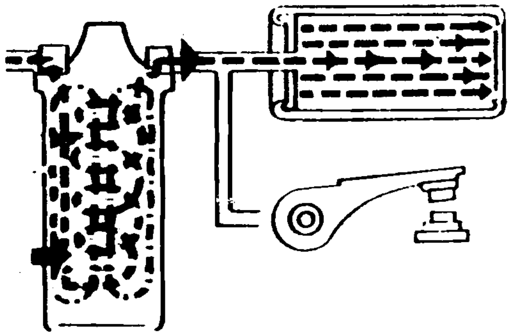


Discharge. Direction
Is To The <u>Left</u>.

Each time the condenser discharges its energy back into the primary windings, the resultant primary current induces a magnetic field in the opposite direction and collapses the one just built up by the prior discharge. This bouncing of energy back and forth is termed oscillatory discharge, and it continues until the capacitor is completely discharged or until the contact points close (Fig. 5). Did you know that this is the way the clouds-earth capacitors discharge?....the lightning stroke is the arc, and the earthward "stroke" you see is in reality more generally a half-dozen or so multiple discharges oscillating first toward and then away from the earth.

OSCILLATORY DISCHARGE
OF CAPACITOR

Fig. 5



Oscillatory Charge Direction Is
To The Right

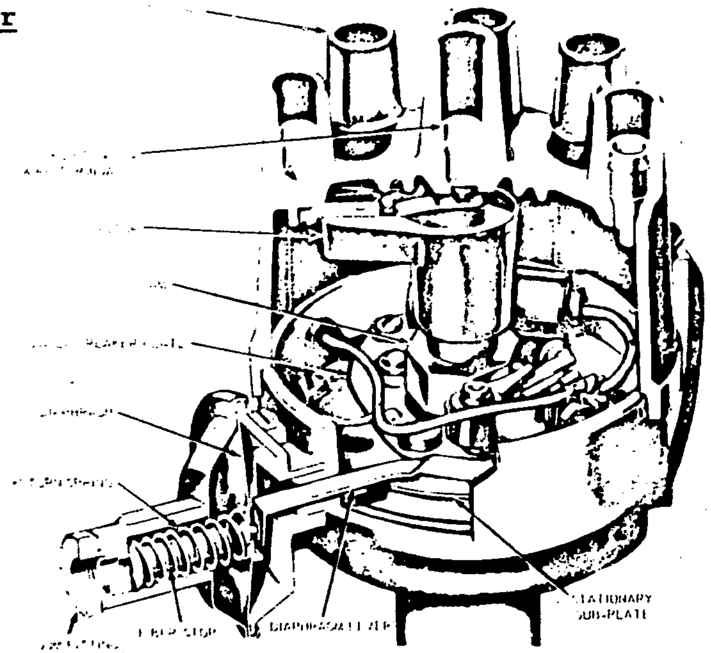
RESOURCE PACKAGE 35-1

DISTRIBUTOR SUBASSEMBLIES

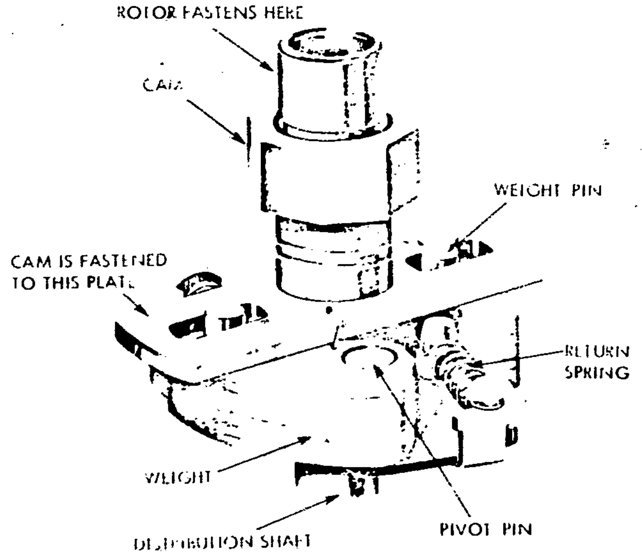
The distributor assembly is made up of several components: cap, rotor, breaker plate assembly (supporting the breaker points and condenser), cam, centrifugal mechanism, vacuum advance unit, and the distributor base (or body).

The distributor cap and rotor are used to distribute the high voltage current developed in the coil to each spark plug in firing-order sequence.

The breaker plate supports the breaker points at the correct position for the cam to open and to close them. The open position is called the gap setting, and require precision to thousandths of an inch.



DISTRIBUTOR HEAD
Fig. 1



DISTRIBUTOR SHAFT AND CAM
Fig. 2

The distributor cam opens the breaker points to interrupt the primary circuit. The cam has the same number of lobes as the engine has cylinders.

The centrifugal advance mechanism varies the position of the cam in relation to engine speed, to insure optimum spark plug firing as the engine speeds change. The vacuum advance unit assists the centrifugal unit with the ignition timing by varying the relative cam-breaker plate assembly angle in response to manifold pressure. Manifold pressure is an indicator of engine performance.

RESOURCE PACKAGE 36-1

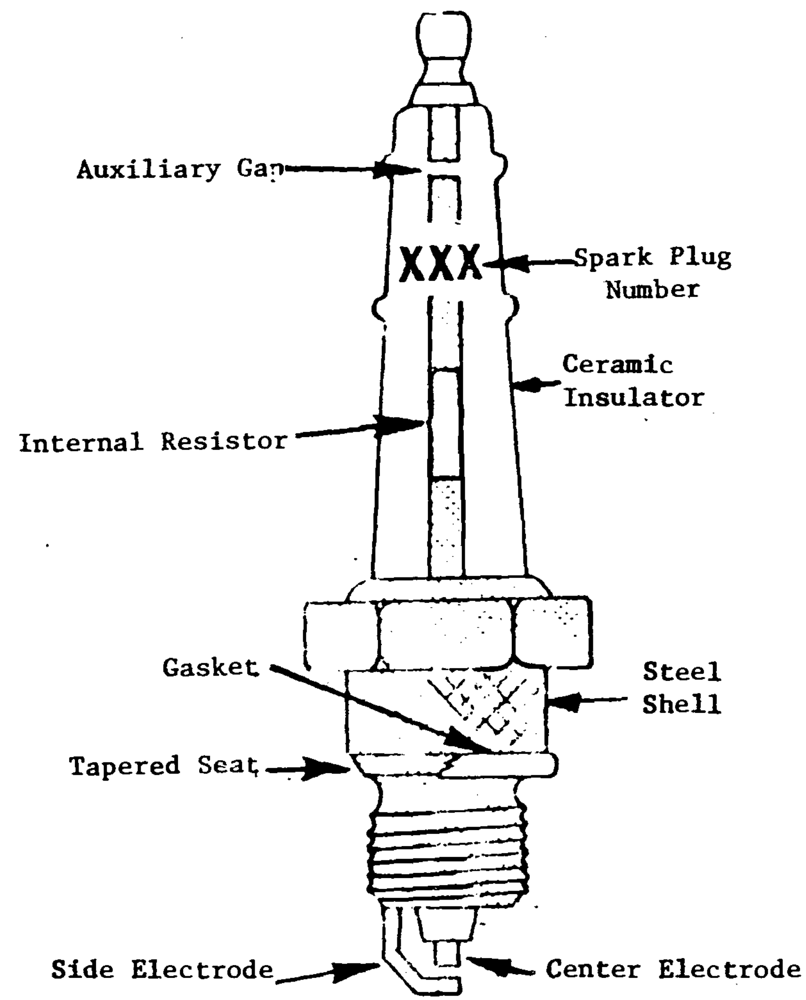
SPARK PLUG

A spark plug (Fig. 36-1) is made up of three major parts: the two electrodes, the insulator, and the shell (See Fig. 1).

Electrodes of a spark plug must be constructed of a material that will be resistant to heat and to oxidation. A typical material is nickel alloy.

In an ordinary spark plug there are two electrodes--the center electrode and the side electrode. There is a space between the two called a plug gap. This gap ranges from .025 inch to .040 inch for most cars. The center electrode is insulated from the rest of the plug by a ceramic insulator.

Insulators must have special properties. They must resist heat, cold, and sudden temperature change. They cannot be damaged by vibration, physical shock,



SPARK PLUG
Fig. 1

or chemical corrosion. A common material used is aluminum oxide, fired (made ceramic) at a high temperature.

The top end of the insulator is often ribbed or grooved to prevent shorting or flash-over.

The center electrode is surrounded by the insulator and placed in an inner steel hull. The steel shell top is generally crimped over to bear against a seal.

The side electrode is welded to the steel shell.

The shell is threaded so that it will screw into a threaded hole in the cylinder head. The shell forms a seal with the cylinder head by means of a copper gasket or a beveled edge that wedges against a bevel in the cylinder head.

RESOURCE PACKAGE 37-1

INDUCTION COIL

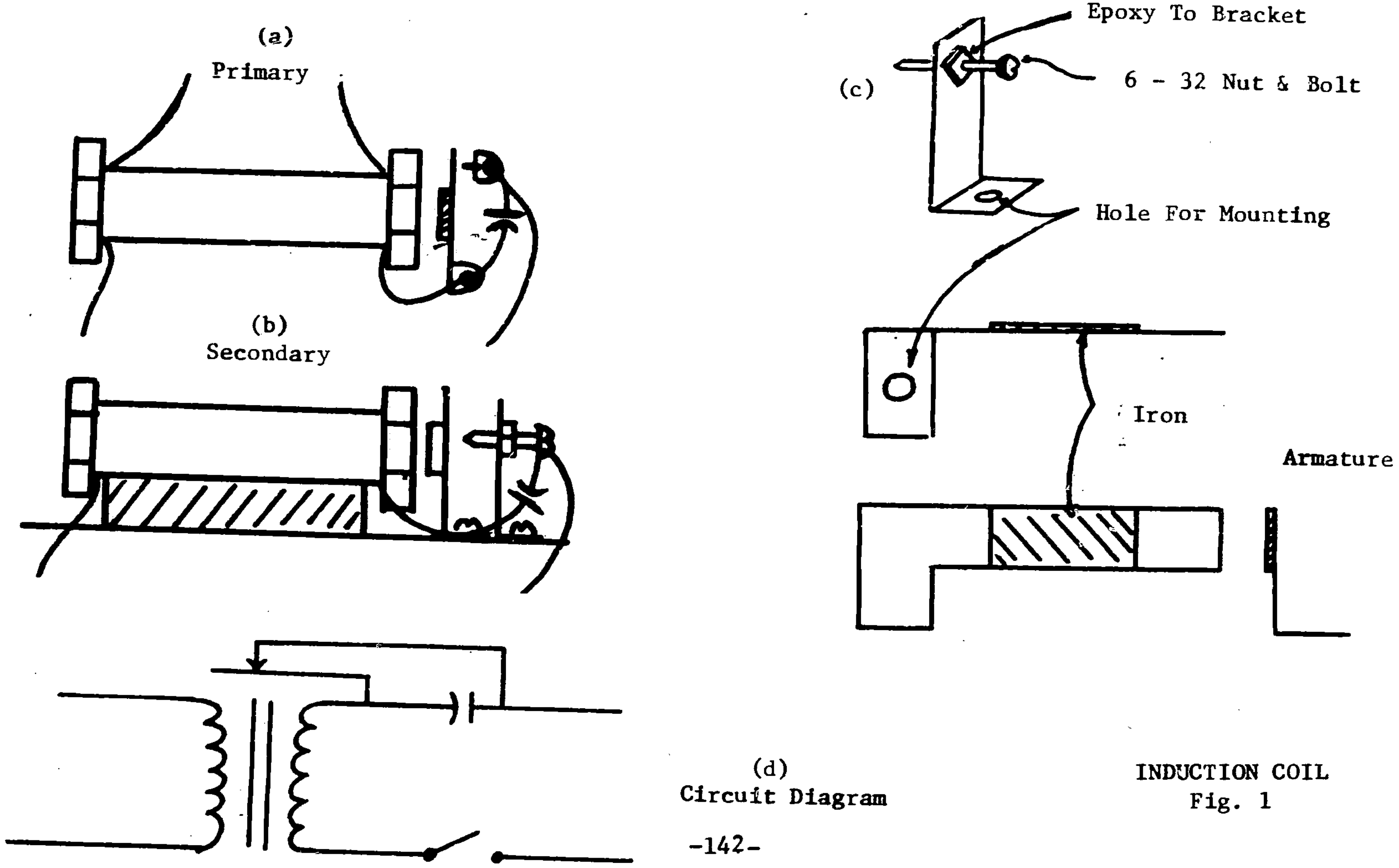
The principle of an induction coil will be demonstrated in this exercise.

In review, if a varying current flows through a coil there will be a varying magnetic field about the coil. The magnetic field strength will rise and fall as the magnitude of the current rises and falls.

If a secondary coil is placed near the first coil so that this varying magnetic field will cut across it, a voltage will be <u>induced</u> in the second coil. The first coil is called the <u>primary</u>. The second coil is called the <u>secondary</u>. The voltage induced in the secondary is directly proportional to the turns ratio of the primary and secondary. For example, ten (10) turns on the primary and one hundred (100) turns on the secondary will produce ten (10) volts across the secondary to every one volt across the primary.

Now you will build an induction coil (See Figs. 1a and 1b). Use the electromagnet made in Resource Package 12-1. You will also need some #26 magnet wire, a "6-32" nut and bolt, a strip of brass, and .1 mfd capacitor.

The core and primary are already assembled. Use the electromagnet from Resource Package 12-1 (See Fig. 1 a). The secondary is wound with two layers of #26 magnet wire (See Fig. 1 b). Leave about 6 inches on both ends for later connections. Wind the secondary similar to the method used when winding the primary (Resource Package 12-1). Cover each layer with tape. Count and record the number of turns in the secondary. This can be done by measuring the distance between a given number of turns (say, 25 turns) and then measuring the length of the two layers.



INDUCTION COIL
Fig. 1

Here is the ratio for calculating primary and secondary relationships:

$$\frac{\text{Number of Turns in Secondary}}{\text{Number of Turns in Primary}} = \frac{\text{Volts in Secondary}}{\text{Volts in Primary}}$$

For example,

$$\frac{\text{100 Turns}}{\text{10 Turns}} = \frac{\text{(X) Volts in Secondary}}{\text{10 Volts in Primary}}$$

$$X = 100 \text{ Volts}$$

After completing the secondary windings, tape the coil to the center of a support board with a 1 x 3 x 4 inch block of wood under the windings (See Fig. 1 b).

The armature is made of spring brass, and the usual piece of iron is taped to it so the electromagnet can attract the armature. The adjustable contact point can be easily made by epoxying a small nut to the contact point support bracket (Fig. 1 c). File the screw to a point, thus making its tip a better electrical contact.

Wiring instructions can be found from the circuit diagram, Fig. 1 d.

The capacitor used is a .1 mfd. It absorbs the electrical energy and eliminates arc across the points.

The capacitor also sends a reverse flow of current through the coil when the points open. This makes the magnetic field collapse faster than it would otherwise.

Connect a 6-volt AC power source to the primary coil, and connect the two wire leads to the secondary coil. Remember to scrape the secondary ends before attaching the leads. Mount the wire leads with an inch space between them. Close the switch. If a spark does not jump across the space between the wire tips, open the switch and move the leads closer together.

What is the maximum distance you can move the leads apart to produce a spark? Record this.

Measure the voltage passing through the primary coil. Then use the equation from page 139

$$\text{Secondary Voltage} = \frac{\text{Turns in Primary}}{\text{Turns in Secondary}} (\text{Primary Voltage})$$

to calculate the voltage in the secondary. Now look up the <u>dielectric constant</u> for air (in terms of volts/inch), and using the data from your spark gap jump you can calculate the arcing voltage. See how closely this voltage approximates your voltage from the equation on page 139.

This induction coil is similar to that in the igniting group in an automobile. Make sure you see the similarities. Draw the schematic of the induction coil. Write the name of the igniting group component next to its counterpart on your schematic.

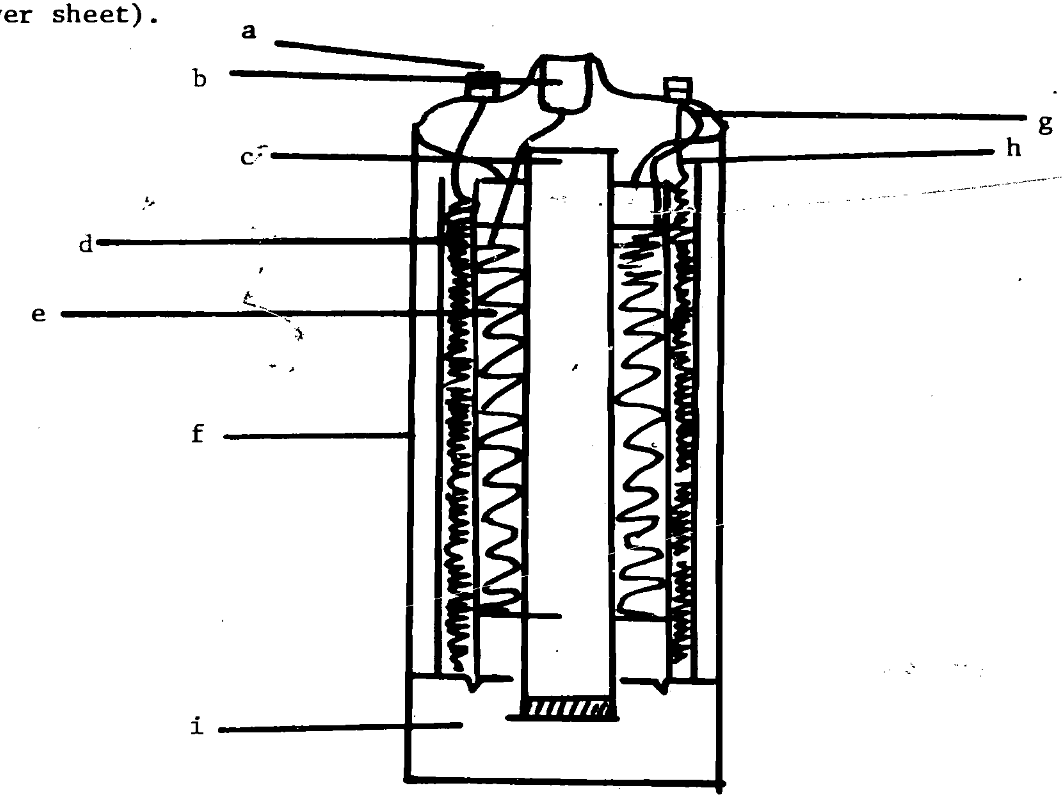
RESOURCE PACKAGE 38-1.1

SELF-TEST

Complete the following on a separate sheet of paper.

1) Name the seven parts of the igniting group and give their function.

2) Write down the proper label for the diagram of the ignition coil given below (letter a through h, on your answer sheet).



3) Why is coil polarity important in the ignition system?

4) Name the nine basic parts of the distributor assembly.

5) Describe the function of a condenser in the igniting group.

6) List some parts of a spark plug.

RESOURCE PACKAGE 38-1.2

SELF-TEST ANSWERS

1) Battery - convers chemical energy to electrical energy during engine starting and also whenever the electrical system demand is greater than the generator output.

Ignition switch - completes the circuit between the battery and the ignition coil.

Ballast resistor - provides for optimum current after engine is started and driving conditions are normal.

Ignition coil - increases battery/generator voltage.

Distributor assembly - makes and breaks the primary ignition circuit, and distributes the induced high voltage current to the proper spark plug.

High tension leads - conduct high voltage current from the coil to the distributor, and from the distributor to the spark plugs.

Spark plug - produces an electrical arc (spark) to combust (fire) the fuel - air mixture in the cylinders.

2) a - primary terminal; b - secondary terminal; c - laminated core; d - primary windings; e - secondary windings; f - steel case; g - primary leads; h - secondary leads; i - support block.

3) Proper coil polarity reduces the resistance to electron drift and thus assures a "hotter" spark with less energy demand and lighter load on the coil.

4) Cap, rotor, condenser, breaker plate assembly, points, cam, centrifugal mechanism, vacuum advance, base assembly.

5) Reduce the amount of arcing across the points, and to quickly stop the current in the primary coil.

6) Auxiliary gap, inner electrode, outer electrode, internal resistor, gasket or tapered seat, steel shell, insulator.

If you did not answer all these questions correctly, you should study this section again.

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