



A Learning Guide for  
**Model Rocket  
Launch Systems**

Revised Edition

by **Robert L. Cannon**  
Updated by **Ann Grimm**



**Including:  
Schematics,  
Electrical Theory,  
and Study Problems**

# TABLE OF CONTENTS

Model Rocket Launch Systems .....	1
Symbols Used in Electrical Circuits .....	2
Principles of Electrical Circuits .....	3
Electrical Operation of Launch Control Systems .....	7
Electrical Mathematics .....	8
Electrical Problems Involving Electrical Ignition Systems .....	12
Multiple Launcher Circuits .....	15



Est. 2811

© Copyright 1969, 1976, 1999 Centuri Corporation.  
All rights reserved.

# MODEL ROCKET LAUNCH SYSTEMS

A launching system for model rockets must perform two different jobs. The first job is to hold the rocket before and during launch. The second job is to ignite the rocket's engine. The Electron Beam®



Launch Controller provides a reliable, portable ignition with its own built-in power supply.

To have a safe, predictable flight, the model rocket must be held in position before launch and guided during the first fraction of a second of flight until it is going fast enough for its fins to keep it flying in the proper direction.

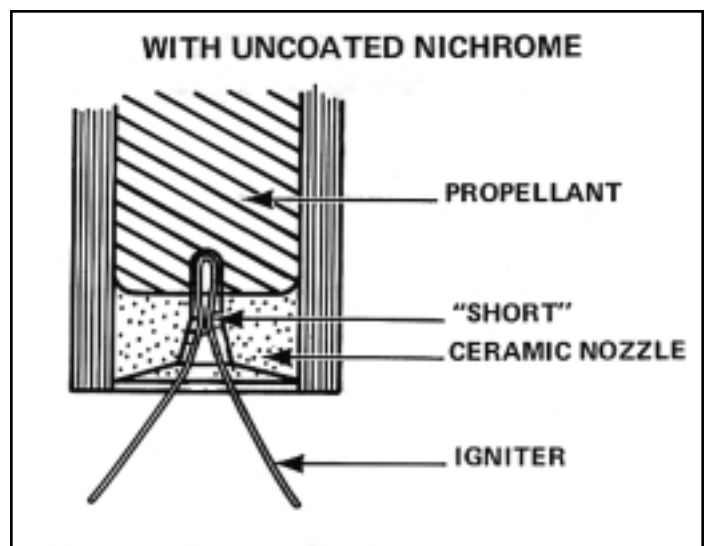
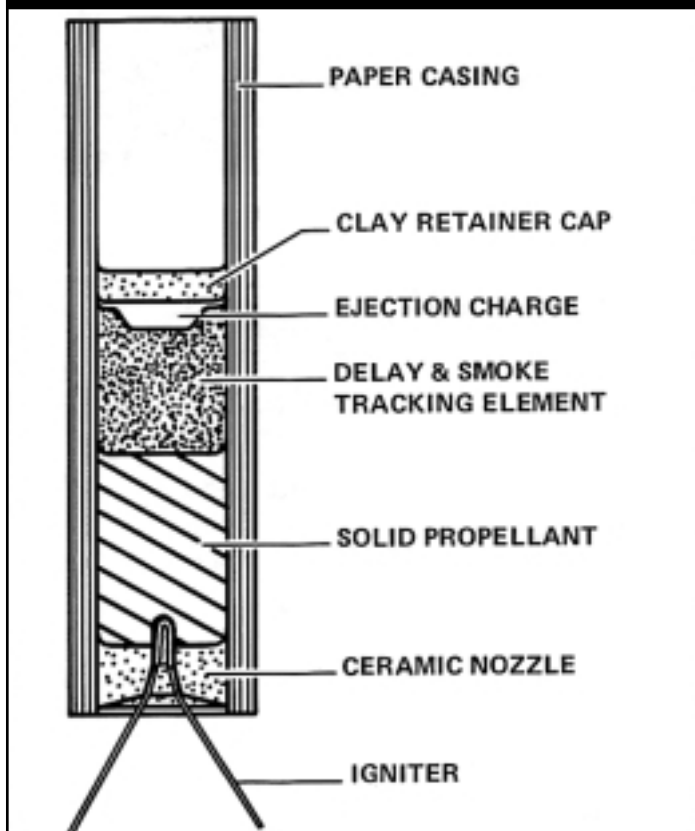
The device performing this function should be designed to aim the rocket straight up. It may be made adjustable so that the model can be "aimed" either vertically or within 30° to any side of vertical to correct for wind conditions.

A small tube (launch lug) on the model fits over the rod, keeping the rocket straight on the rod. By the time the model rocket's launch lug leaves the launch rod the rocket is going fast enough for its fins to provide adequate guidance to keep it moving in the desired direction.

The second function a launch system must perform is to provide adequate electrical current to cause engine ignition. The electrical current accomplishes engine ignition by heating the igniter which produces enough heat to cause the solid propellant to ignite.

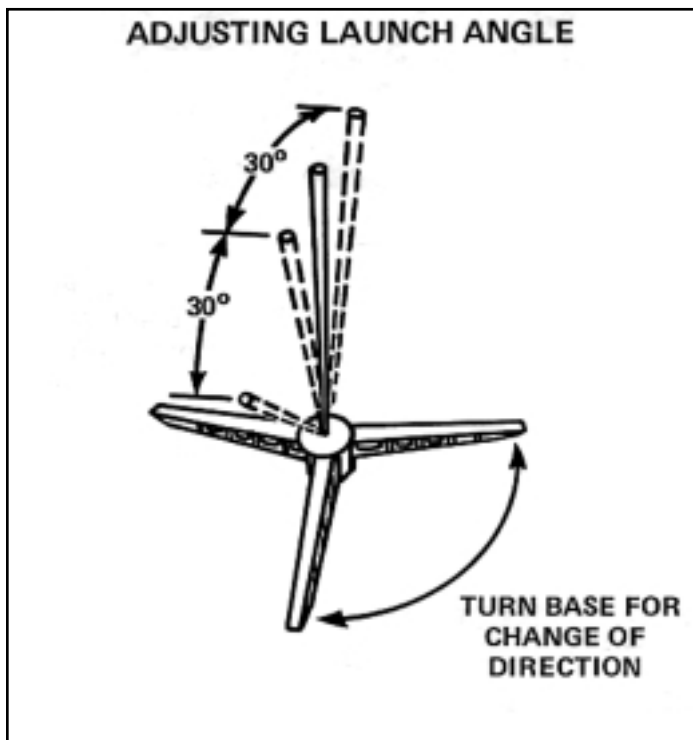
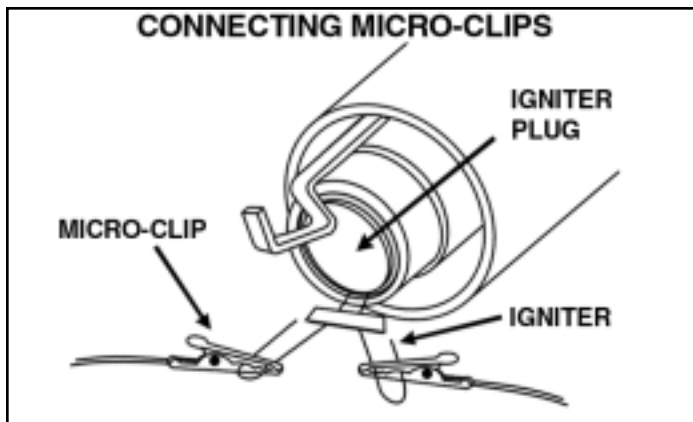
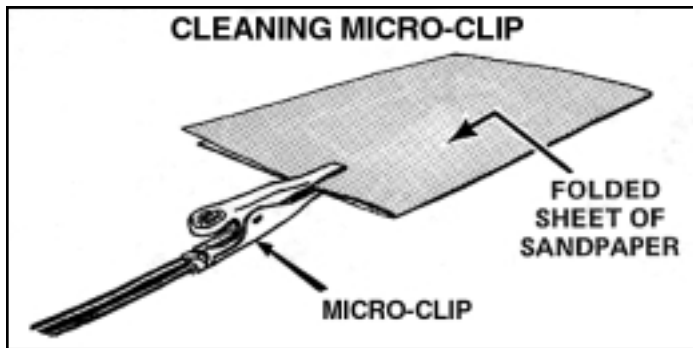
The igniter must be placed with its bend all the way to the bottom of the nozzle and firmly in contact with the propellant. The igniter must be held firmly in place with an igniter plug so that the weight of the micro-clips and wire will not pull it away from the propellant. About 90% of launch failures are caused by this rule not being followed.

## MODEL ROCKET ENGINE



The electrical current delivered by the ignition system is adequate to heat the igniter, which causes the propellant to ignite. The thermoplastic coating on the end of the igniter helps protect against the igniter "shorting out" against itself resulting in inadequate heat reaching the propellant to produce ignition. The coating on the igniter also burns when the igniter is heated, producing additional heat for rapid engine ignition. Loose connections will not properly conduct the full electrical current required.

The micro-clips which attach to the igniter provide good connections to securely hold the igniter and a good path for the electrical current. If necessary, micro-clips can be cleaned before each flight.



A blast deflector plate is used to protect the plastic base of the Porta Pad® II from the heat of the rocket's exhaust.

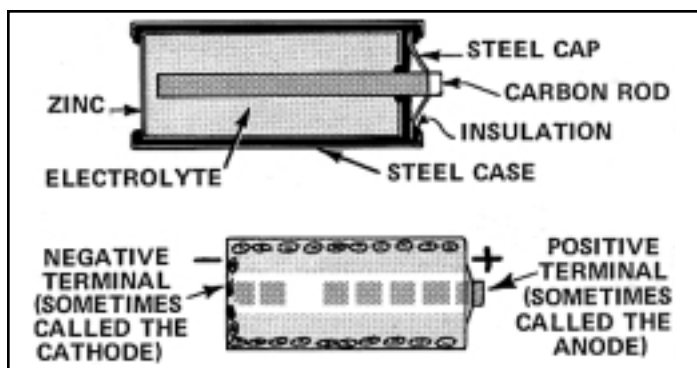
# SYMBOLS USED IN ELECTRICAL CIRCUITS

	GROUND
	WIRE
	TWO CONNECTED WIRES
	TWO WIRES NOT CONNECTED
	THREE CONNECTED WIRES
	FOUR CONNECTED WIRES
	TWO WIRES NOT CONNECTED
	SWITCH (OPEN)
	SWITCH (CLOSED)
	RESISTOR
	ELECTRIC LIGHT
	SINGLE DRY CELL (PRODUCES 1.5 VOLTS)
	BATTERY (A BATTERY IS TWO OR MORE CELLS CONNECTED IN SERIES)

# PRINCIPLES OF ELECTRICAL CIRCUITS

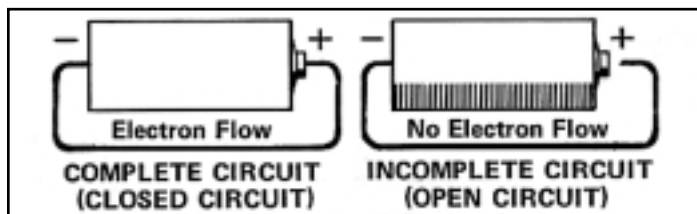
An electrical current is a flow of electrons. A circuit is the path the electric current follows. The electrons will flow only when a circuit is complete. In effect, electricity must come from some place and have somewhere to go. Any point beyond which the electron cannot go, because of a loose connection or unconnected wire, interrupts the path the electrons should follow and hence breaks the circuit.

When a circuit is complete, electrons will flow from the negative terminal of a power source through the circuit and return to the same source through its positive terminal. A flashlight dry cell is a common source of electrical power.

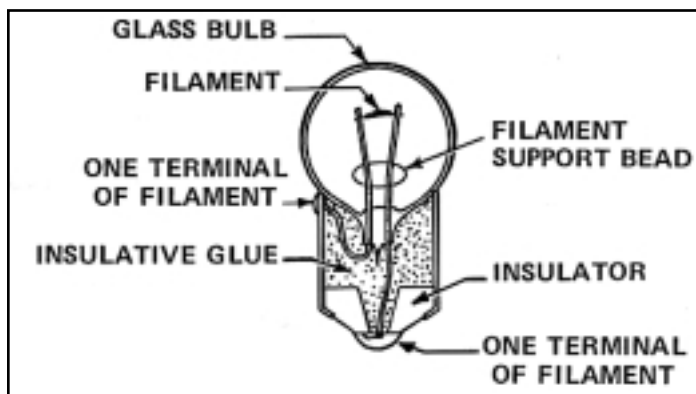


A "dry" cell releases electrons by chemical reactions occurring within the cell. The construction of a typical "dry" cell is shown in the illustration above. The black "paste" electrolyte is made of carbon particles and chemicals. The chemical reactions release electrons which accumulate on the zinc. These electrons travel through the zinc since it is a conductor of electricity. This concentration of electrons on the zinc produces a surplus of electrons at the negative (zinc) terminal of the "dry" cell.

When a complete circuit is made by connecting the two terminals together with a wire, the electrons that are concentrated at the negative terminal will flow through the wire to the positive terminal. This flow is an electrical current.

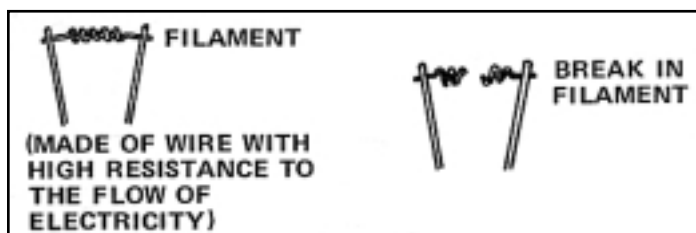


These electrons cannot leave the negative terminal unless they have a way to flow back into the cell through the positive terminal. When this pathway exists we say we have a *complete* circuit or a *closed* circuit. If there is a break in the pathway we call it an *open* circuit.



An electric bulb (such as the pilot bulb for an ignition system) will not light unless the electricity flows through it. The two terminals of the bulb are shown in the above drawing. The electrons can enter through either terminal and leave through the other one.

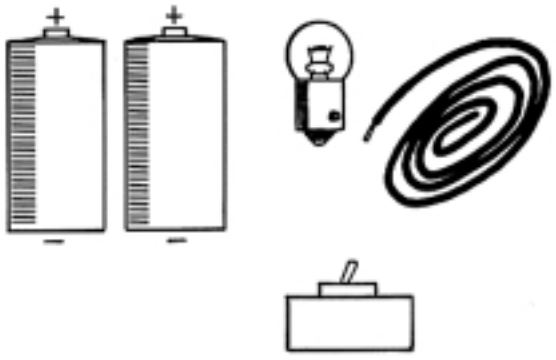
The bulb gives light because electricity flowing through the bulb makes the wire filament inside the bulb get hot. Enough heat is produced to make the bulb incandescent (so hot that it glows). Resistance, a kind of "electrical friction" caused by the electrons moving through the filament heats it. The filament glows when enough electricity flows through it.



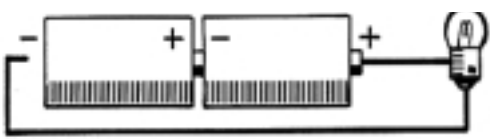
The filament will not glow when the electrical circuit is not complete. The most common type of failure in electrical bulbs occurs when a portion of the filament melts or breaks, thus making the circuit incomplete. Since the filament is enclosed inside a sealed glass bulb, once it is broken or melted into two separate parts the bulb is useless. Breaking the bulb to reconnect the two pieces of filament may complete the circuit, but only temporarily as breaking the bulb lets oxygen into contact with the filament. Once the filament reheats, it will rapidly oxidize ("burn") and be destroyed. A sealed bulb contains nitrogen or an inert gas which will not react with the hot filament.

To check what you have learned about electrical circuits, study each question and the accompanying diagram carefully, then decide upon an answer to the question.

If we take two 1.5-volt flashlight dry cells (often incorrectly called flashlight “batteries”), a switch, wire and a flashlight bulb we can make a type of flashlight.



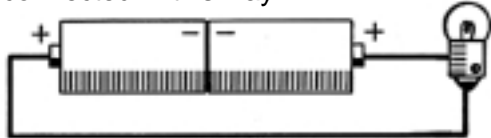
**1** Will the bulb glow if the parts are connected as shown below?



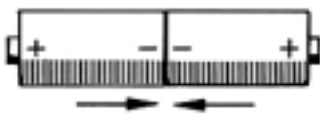
**Answer:**

No. The wire from the bulb is not connected to the negative terminal of the second dry cell so the circuit is incomplete.

**3** Will the bulb glow when the circuit is connected in this way?




**Answer:**



No. The two dry cells are placed with their negative terminals together. The electricity will not flow from the negative terminal of one dry cell into the negative terminal of the other dry cell since the two dry cells have equal voltages that act in opposite directions.


**2** What will happen if the circuit is wired as shown here?



**Answer:**

Nothing. The circuit is still incomplete. The electricity cannot flow since the terminals of the two dry cells do not touch.

**4** What will happen if the circuit is wired this way?



**Answer:**

The two dry cells will quickly become discharged. The bulb will not light since the electricity does not flow through the bulb. The circuit is complete without the bulb. The wire carrying the electricity will heat. This heating occurs because of the large amount of electricity passing through the wire as it “short-circuits” the dry cells and allows all of the electrical energy to be wasted.

**5** What would happen if the circuit is wired this way?



**Answer:**

The bulb would barely glow because only one-half of the amount of electricity normally used to make the bulb produce light is passing through it. This amount of electricity does not produce enough “electrical friction” to cause the filament to get hot enough to glow brightly.

**6** What would happen if the circuit is wired in this manner?



**Answer:**

The bulb would glow weakly like it did last time. The second dry cell is connected only at its positive terminal and cannot contribute to the flow of electrons through the bulb.

**7** If the wiring is connected this way, what will happen?



**Answer:**

The bulb would still glow weakly. Even though the second dry cell is connected to the circuit at its negative terminal, the second dry cell is not connected at the positive terminal to form a complete circuit so it cannot contribute electrons to the flow of electricity through the bulb.

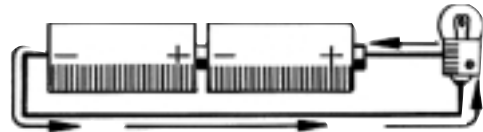
**8** What will happen if we connected the circuit in this way?



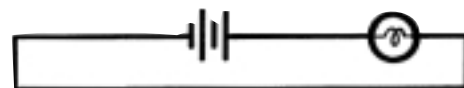
**Answer:**

The bulb will glow brightly! This is the way the circuit should be wired. The electricity (electrons) can flow from the negative terminal of the first dry cell through the second dry cell and out at the negative terminal. The electrons then flow through the filament of the bulb, out to the bulb and into the positive terminal of the first dry cell completing the circuit.

**9** Draw a circuit diagram of the **above circuit**. If you have forgotten the correct electrical symbols, refer to page 2 before drawing this diagram.



**Answer:**



Using symbols in a circuit diagram like this is a kind of shorthand used to clearly show the parts of a circuit and the way they are connected.

10

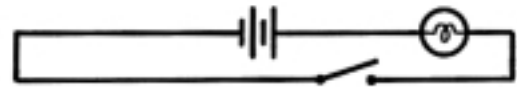
One draw-back is that if we left this circuit connected as in step 9, the dry cells would soon lose their ability to produce electricity. This occurs because all of the chemical energy would be converted to electrical energy and heat and light energy. The cells would become unable to produce more electricity. Instead of connecting and disconnecting the wires each time we want to turn the flashlight off and on, we can simply install a switch.

**Answer:**

Dry cells connected in this way are said to be connected in "series".



Draw a circuit (schematic) diagram of this electrical circuit.

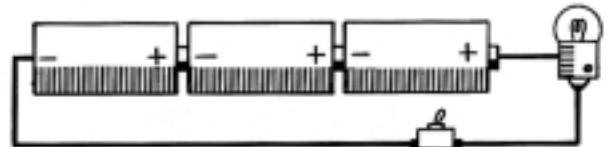


11

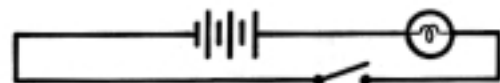
What will happen if an extra dry cell is properly added to the circuit?

**Answer:**

The bulb will produce more light because more electrons will flow. As a result of the increased flow of electrons, the bulb produces more light (and more heat).



Draw an electrical diagram of this circuit.



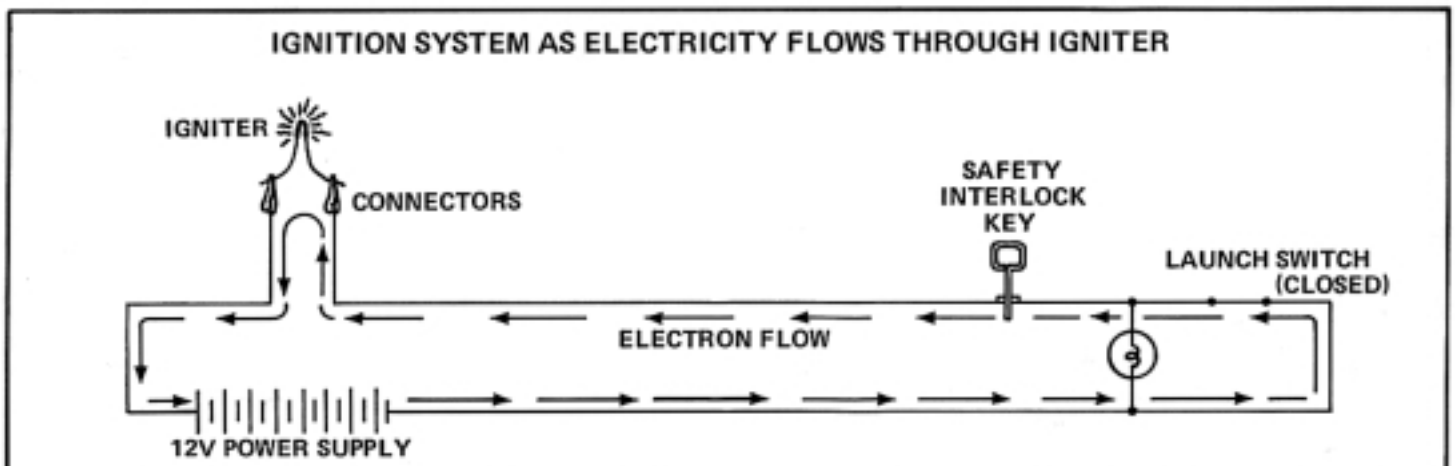
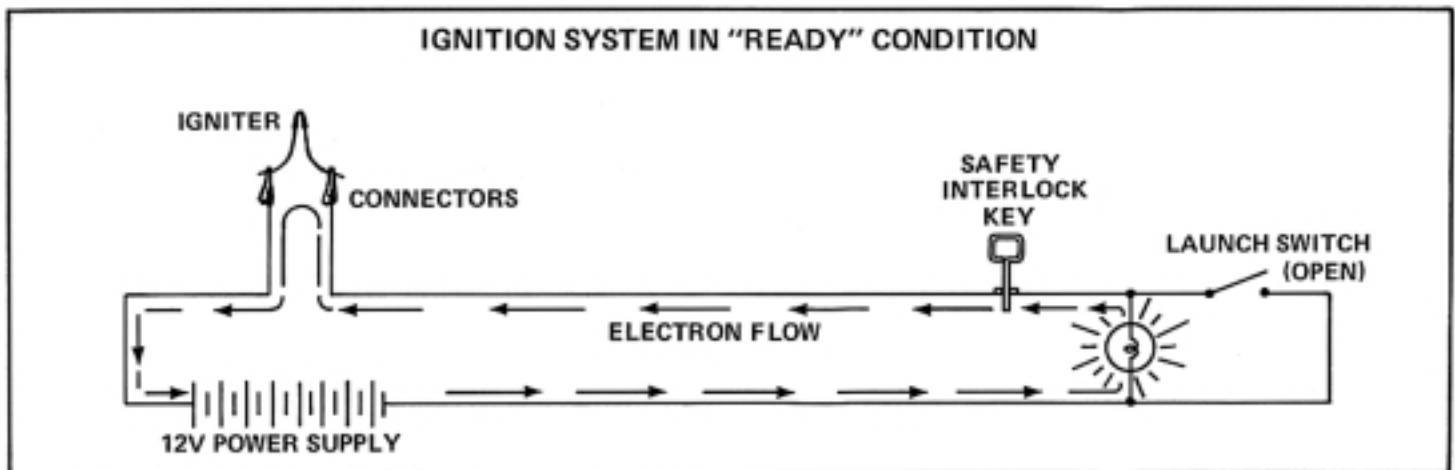


# ELECTRICAL OPERATION OF LAUNCH CONTROL SYSTEMS

The safety interlock switch is an unusual kind of switch. It is always open (incomplete circuit) unless the safety interlock key is inserted into it to complete the circuit. Once this key is inserted, the electricity can flow from the dry cells, through a wire to a micro-clip, through the igniter attached to the micro-clips, through the other of the long pair of wires to the bulb, through the safety interlock key, through the bulb and back to the dry cells. (NOTE: The electricity may flow through the parts in the switch case in the opposite direction, depending upon which way you connected the long pair of wires between the launcher base and the control switch case.) This flow will occur only if all of the connections are properly made. If electric current does not flow, check the wiring of the system and make certain all of the dry cells are properly positioned.

With the safety interlock key inserted, the continuity bulb will glow if the igniter is properly connected to the micro-clips. The bulb will not light unless electricity is flowing through the igniter or the micro-clips are shorted. In a series circuit, all parts are connected together, one after the other, like beads on a necklace. The resistance of the bulb is so great that not enough electricity can flow in this series circuit to cause the igniter to become hot.

Pressing the launch button closes a switch which lets the electricity by-pass the bulb. This "shorts out" the bulb and lets the electricity flow through the igniter without also flowing through the high-resistance bulb. Enough electricity now flows through the igniter to heat it to the propellant's ignition temperature. Very quickly after the propellant ignites, the rocket takes off.



# ELECTRICAL MATHEMATICS

An electric current is a flow of electrons. This flow may be compared to a flowing liquid.



WIRE WITH FLOW OF ELECTRONS



PIPE WITH FLOW OF WATER

Any substance that easily conducts or carries a flow of electricity is called a conductor. Most metals are good conductors of electricity. Some other materials are also good conductors of electricity.



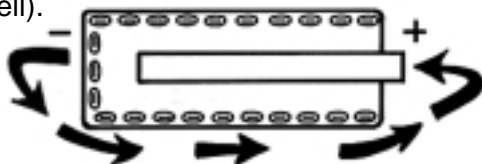
ELECTRONS MOVING THROUGH CONDUCTOR

Some substances are not good conductors of electricity. These substances which do not readily conduct electricity are called insulators. Many non-metals, such as glass, wood and porcelain are good insulators.



ELECTRONS MOVING THROUGH INSULATOR

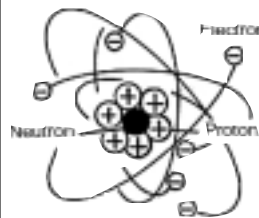
Electrons will flow from a place where they are concentrated (as at the negative terminal of a dry cell) to a place where they are less concentrated (as at the positive terminal of a dry cell).



ELECTRON FLOW

The amount of electric current which flows is determined by the number of electrons moving through the conductor. The unit used to measure this flow of electric current is a coulomb. (A coulomb is equal to about 6,250,000,000,000,000 electrons. Although this number is very large, you will recall that an electron is extremely tiny.)

## ONE IDEA OF AN ATOM



The protons and neutrons occur in the central portion, the nucleus. The electrons occur as orbital electrons around the nucleus. The tiny electrons make up only a very small portion of the mass of an atom.

When one coulomb of electrons flows through a wire in one second, the current is flowing at a rate of one ampere. The ampere is the unit used to measure the rate at which electricity is flowing. An ampere is equal to one coulomb per second.

The pressure or force pushing the electrons can also be measured. Each electron carries a negative charge. Electrons repel each other since they carry like electrical charges. Electrons try to move from where they are concentrated together to places where the concentration is not so great. This tendency of electrons to move produces electrical pressure. This force is sometimes called electromotive force. A volt is the unit used to measure this electromotive force. This force is also called electrical potential.

The greater the difference is in the concentration of electrons at two points connected by wires, the greater is the pressure on the electrons trying to move from the area of greater concentration (the negative pole or terminal) to the area of lesser concentration (the positive pole or terminal). The greater this pressure, the greater the voltage in the circuit.

Electrical power is measured in watts. One ampere of electricity along with one volt of electrical potential is one watt of electrical power. Watts are the units used to measure the amount of electricity at work in a circuit.

$$1 \text{ watt} = 1 \text{ ampere} \times 1 \text{ volt}$$

**1**

What is the voltage in this circuit?

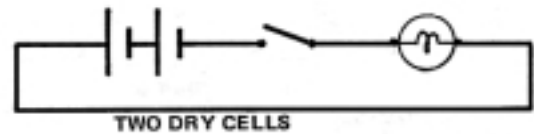


**Answer:**

The Answer is 1.5 volts.

**4**

How much voltage can be provided by this circuit?

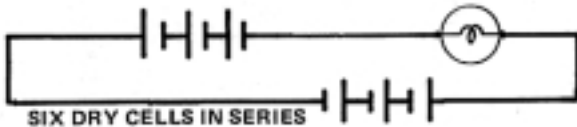


**Answer:**

Three volts. The two 1.5 volt cells are wired in series to produce 3 volts. When two or more cells are connected together we call it a battery.

**2**

What is the voltage of the electricity across the bulb in this circuit? Each dry cell provides 1.5 volts in these problems.

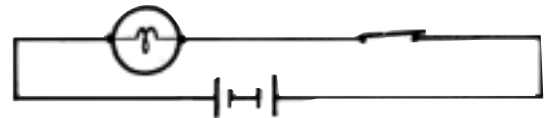


**Answer:**

Nine volts. Six dry cells, each supplying 1.5 volts of electrical pressure, produce nine volts. ( $6 \times 1.5 \text{ volts} = 9.0 \text{ volts}$ )

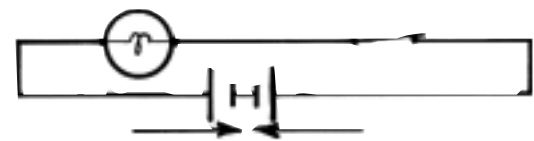
**5**

What is the voltage operating in this circuit?

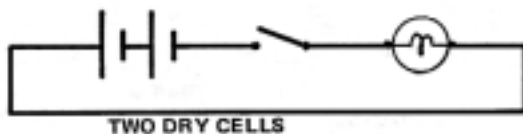


**Answer:**

None. The two negative poles of the dry cells are together so the electricity will not flow in the circuit.

**3**

How much electricity is flowing in this circuit?

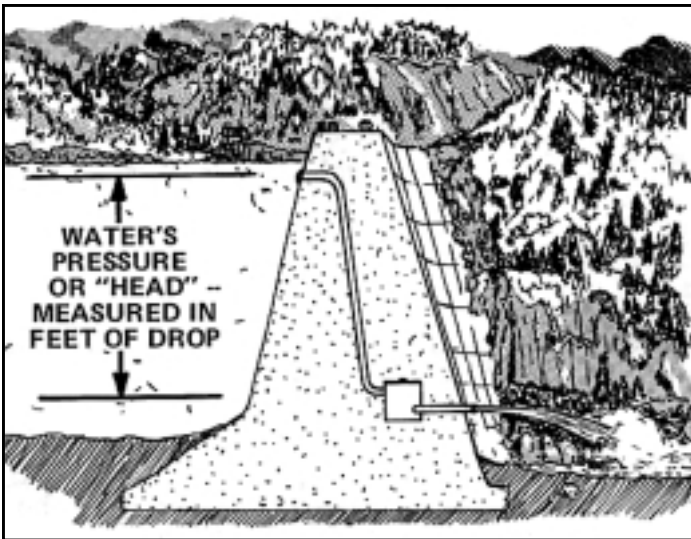


**Answer:**

None. The switch is open so the circuit is not complete and electrons cannot flow.

Some people like to compare an electric current to the flow of water in a pipe. The amount of water flowing is measured in gallons per second. The amount of electrons flowing is measured in amperes (coulombs of electrons per second).

The force with which the water moves is determined by the pressure of the water. The water pressure in a gravity-powered water system is determined by the height of the column of water in the pipe. The greater the height of the water above the bottom of the pipe, the more pressure the water possess. This is why most electric turbines are placed near the bottoms of dams so the water can effectively fall in pipes to product a great pressure to turn the blades of the turbines. The water's pressure is sometimes measured by measuring the number of feet the water can fall.

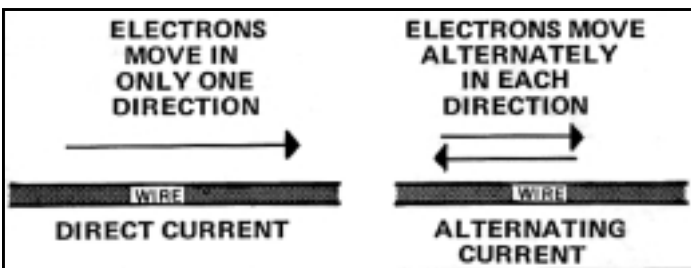


The pressure in an electrical circuit is measured in volts.

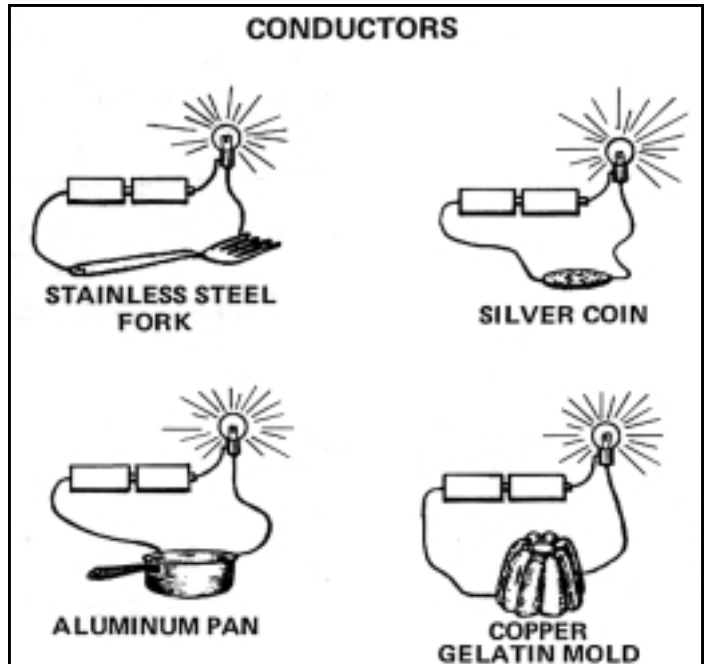
The power of the water moving in a pipe is determined by how much water is moving and the pressure of the water. The power of the electricity flowing in a circuit is determined by how many amperes of electricity are flowing and the voltage "pushing" them. This total amount of electricity with which to do work is measured in watts.

**AMPERES X VOLTS = WATTS**

In the type of electrical circuit we have worked with so far, the electricity flows in one direction only. When the electricity flows in only one direction in a circuit, we call the flow of electricity a direct current. When the flow of electricity rapidly changes direction back and forth, we say that we have an alternating current. The electricity flowing in your house is alternating current. We will study only direct current here. Many things such as flashlights, your car's electrical system and the model rocket electrical launch system operate on direct current.

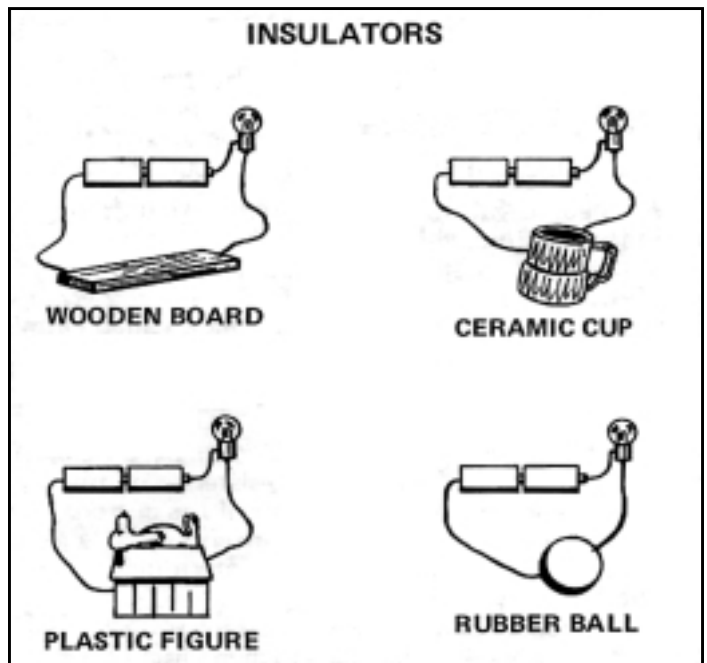


Whenever electricity flows through an object, the object presents some resistance to the flow of electricity. Some substances present very little resistance to the flow of electricity. Such objects conduct electricity with very little loss and are called conductors. Most metals are good conductors.

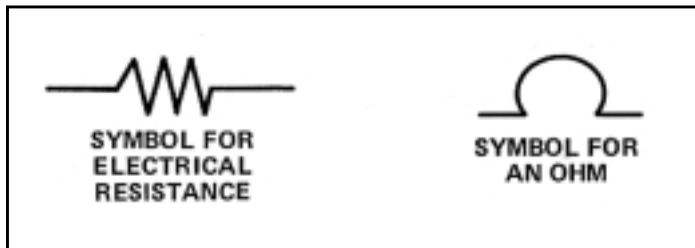


Whenever a substance presents resistance to the passage of electricity through it, part of the electricity is changed to heat. Unless we want heat, this is wasted energy. Even good conductors have a little resistance to the flow of electricity through them so they change a little electrical energy into heat energy.

Substances which have a high resistance to the passage of electricity are called insulators. They are very poor conductors. Such substances as rubber, wood, many plastics and porcelain are good insulators. These materials are used to make things through which we do not want electricity to flow.



The units used to measure the amount of electrical resistance are called ohms. For a given voltage (electromotive force), the less resistance (fewer ohms) an object has, the greater the amount of current which will flow.



**6** In which of these two circuits will more current flow?

A 10 Ω

B 20 Ω

**Answer:**

More current will flow in circuit A because it has less electrical resistance.

The amount of heat produced by the passage of electricity through an object depends upon the amperage of the current, the electrical resistance of the object and the amount of time the current flows.\*

We need to know several things to determine the amount of current which will flow from a given power supply through a specific object. The current which will flow may be determined by dividing the voltage by the resistance in ohms. This formula is called Ohm's Law.

\*The heat generated in a conductor by an electric current is proportional to the resistance of the conductor, the square of the strength of the current and the time during which the current flows. The exact amount of heat produced may be determined by solving the following equation:

**Calories = ohms x amperes<sup>2</sup> x seconds x 0.24**  
(A calorie is a unit for measuring heat).

$$I = \frac{E}{R} \quad \text{Current} = \frac{\text{Electromotive Force}}{\text{Resistance}}$$

I = amperes of current flowing in the circuit  
E = electromotive force in volts  
R = resistance in ohms

The number of amperes of current which will flow in a circuit may be determined by dividing the voltage of the power supply by the resistance (in ohms) of the circuit.

For example, if a 6-volt supply is connected into a circuit where total resistance is found to be 2 ohms, three amperes of electrical current will flow.

$$\frac{E}{R} = I \quad \frac{6 \text{ volts}}{2 \text{ ohms}} = 3 \text{ amperes}$$

This relationship is useful for determining either the number of amperes which will flow, the voltage used or the resistance of the circuit if the other two are known.

The formula  $I = \frac{E}{R}$  can also be stated  $R = \frac{E}{I}$  or

$E = R \times I$ . Problems can be solved using any of these versions of the formula.

**7** For example, if six volts causes a current of 0.5 amperes to flow, what is the resistance of this circuit?

**Answer:**

The resistance of the circuit is 12 ohms,  
since  $R = \frac{E}{I}$ ,  $\frac{6 \text{ volts}}{0.5 \text{ amperes}} = 12 \text{ ohms}$ .

**8** If a current of 0.2 amperes flows through a resistance of 100 ohms, how much voltage is being applied in the circuit?

**Answer:**

A voltage of 20 volts is being used.  $E = R \times I = 100 \text{ ohms} \times 0.2 \text{ amperes} = 20 \text{ volts}$ .

# ELECTRICAL PROBLEMS INVOLVING ELECTRICAL IGNITION SYSTEMS

The electrical igniter used in launching model rocket engines must develop enough heat to cause the temperature of the propellant to reach about 288° C or 550° F.\* This is the ignition temperature of the propellant used in model rocket engines.

The Estes igniter must have a least two amperes of electricity flowing through it to produce enough heat to cause rapid ignition of the propellant. The special insulator-igniter coating burns when it reaches a high temperature producing extra heat for extremely rapid engine ignition.

**1** If your Electron Beam® Launch Controller has four “AA” size alkaline dry cells in it, what is the voltage available to your igniter?  
**Answer:**

Six volts. 1.5 volts x 4 = 6.0 volts

**2** If your Electron Beam® Launch Control System uses two six-volt batteries in series, what is the voltage available to your igniter?  
**Answer:**

Twelve volts. 6.0 volts x 2 = 12.0 volts

\* (F stands for Fahrenheit, a temperature scale. Celsius, abbreviated C, is the temperature scale used by scientists. The formula to find the Celsius temperature when the Fahrenheit temperature is known is:

$$C = \frac{5(F-32)}{9}$$

The Celsius scale was formerly known as Centigrade temperature scale.)

Below is a table of electrical resistances of some common objects. Also below is a table of the typical characteristics of some dry cells and some batteries. You will need to refer to these again.

**TABLE I  
RESISTANCES**

Material	Resistance
Estes Igniter #302301	0.80 ohm each
#32 Nichrome Wire	0.88 ohm per inch
#30 Nichrome Wire	0.56 ohm per inch
#16 Copper Wire	0.006 ohm per foot
#18 Copper Wire	0.010 ohm per foot
#24 Copper Wire	0.038 ohm per foot
#51 Pilot Bulb (6 volt)	30 ohms each
#53 Pilot Bulb (12 volt)	120 ohms each
Lantern Battery (12 volt) as RCA-VS-346 (NEDA-926)	1.2 ohms each

**TABLE II  
TYPICAL BATTERY CHARACTERISTICS (FRESH)**

Type	Voltage	Internal Resistance
“D” Flashlight (Eveready #950) NEDA-13F	1.5	0.38 ohm
Lantern (4 “F” Cells) (Eveready #509) NEDA-918	6.0	0.86 ohm
“AA” Alkaline Dry Cells (RCA-VS-1334) NEDA-15A	1.5	0.40 ohm
6 volt Car Battery	6.0	0.02 ohm
12 volt Car Battery	12.0	0.40 ohm

**3** The current must flow through 18 feet of wire in the Electron Beam® Launch Control System. What is the amount of resistance the wire presents to the current if #18 copper wire is used? (For calculation purposes, we neglect the small resistance present in the micro-clips and in the contact strips in the launch control unit). Do not forget that we are using two-conductor wires so the electricity must flow through 36 feet of conductor.  
**Answer:**

36' x 0.010 ohms per foot = 0.36 ohms

The pilot light in the launch control system serves two purposes. It lights when electricity flows through it to show that the circuit is complete. It also limits the amperage which can flow through the circuit preventing ignition of the engine before the launch button is depressed. The circuit is complete only when the igniter is in good electrical contact with each of the two micro-clips and the safety interlock key is properly inserted.

Notice that the igniter must be properly connected or the circuit will not be complete. Once the igniter is in place, the circuit still is not complete until the safety interlock key is inserted.

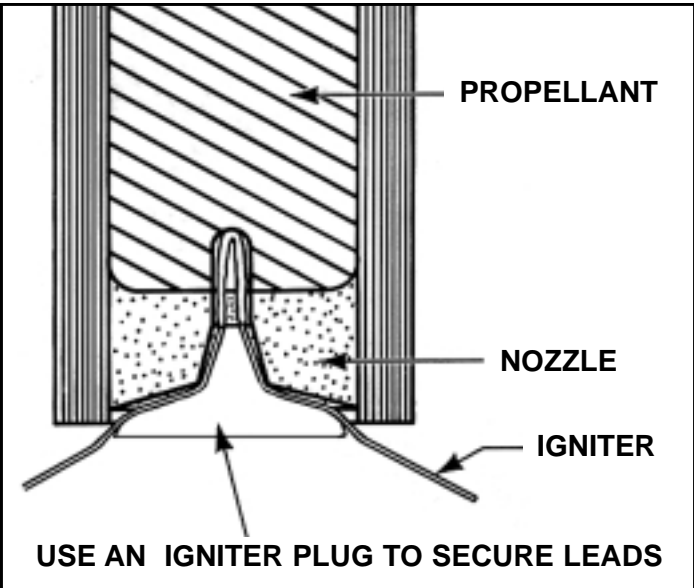
**4** When the safety interlock key is inserted in the Electron Beam® Launch Control System to complete the circuit, the electricity flows through the circuit. However, the pilot light (#53 pilot bulb for 12 volts) has a resistance of 120 ohms. What is the total resistance of the circuit in ohms if #18 wire is used for the wiring and a 12-volt car battery is the power supply for an Estes igniter?

**Answer:**

0.36Ω wire  
 0.40Ω 12 volt car battery  
 1.0Ω igniter  
 120.00Ω #53 pilot bulb  


---

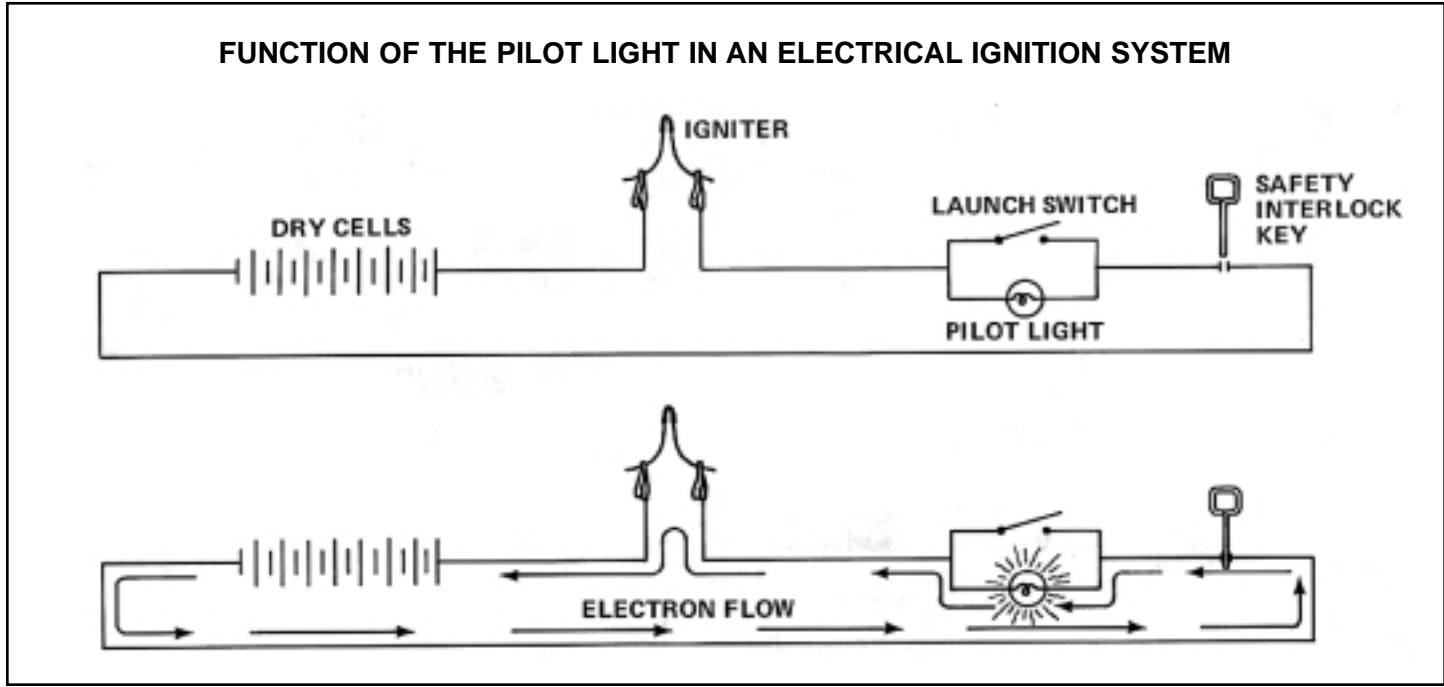
 121.76Ω total resistance



What is the total current (in problem 4) which can flow in the completed 12 volt circuit before the launch button is pushed?

$$I = \frac{E}{R} \quad I = \frac{12v}{121.40\Omega} = 0.099 \text{ amps}$$

This current is not sufficient to heat the igniter enough to cause ignition, but is adequate to light the pilot bulb. The pilot bulb is used as a continuity check to be sure the igniter is properly connected to make a complete circuit. When the circuit is complete the pilot light glows, indicating the connections to the igniter are good. (However, *the igniter still can not cause ignition if it is not properly installed in the model rocket engine.*)



If all the connections are correct, the current flows as soon as the launch button is pushed and held down and will rapidly heat the igniter to ignite the engine. Usually the igniter wire will either melt from the heat or the exhaust will force the igniter out of the nozzle and forcibly break the electrical connections.

*(Refer to illustration at the bottom of page 12)*

The pilot light and the launch button (the momentary switch which completes the circuit only while it is held down) are wired into the circuit in series with the rest of the circuit. However, these two parts are wired in parallel to each other (wired side by side so the electricity can flow through either or both at the same time). As long as the launch button is not pushed, the switch stays open so the electricity has to flow through the high resistance pilot light (120 ohms for the #53 bulb used in a 12-volt launch controller). When the launch button is held down, the launch switch is closed permitting the electricity to readily flow through this part of the circuit. Since electricity will flow through the path of least resistance when more than one path is open to it, nearly all of the electric current will now flow through the switch. Very little electrical current will flow through the bulb so it will not light. In effect, the lamp circuit is now by-passed by electricity flowing through the switch. This prevents electricity from flowing through the bulb since an alternate path of much lower resistance is available to the electricity.

**5** What is the total resistance in the circuit when the launch switch is closed if #16 wire is used instead of #18 in wiring the Electron Beam® Launch Control System (18 feet of wire) connected to a 12-volt car battery?

**Answer:**  
 0.22Ω wire  
 1.00Ω igniter  
 0.40Ω 12-volt car battery  
 1.62Ω total resistance if #16 wire is used

**6** Calculate the amperes of current which will flow when the launch button is pushed on an Electron Beam® Launch Control System wired with #18 wire and using an Estes igniter and a 12-volt car battery.

**Answer:**

$$I = \frac{E}{R} \quad I = \frac{12.00 \text{ volts}}{1.40 \text{ ohms}} = 8.57 \text{ amperes}$$

Two amperes are needed at six volts or more to ignite an Estes igniter. This value of 8.57 amperes is easily adequate to cause igniter ignition in less than one second. As the dry cells or batteries age and are used, the amount of electricity they can produce decreases so the time required for ignition increases.

**7** What amperage would have flowed had #16 wire been used?

**Answer:**

$$I = \frac{E}{R} \quad I = \frac{12.00 \text{ volts}}{1.26 \text{ ohms}} = 9.52 \text{ amperes}$$

The value of 9.52 amperes of current is adequate since only 2 amperes are needed to heat the Estes igniter enough to cause ignition of the solid propellant in the model rocket engine.

The larger the size (the smaller the number) of the electrical wire used, the less resistance the wire presents to the flow of electricity. However, the larger wire is more expensive than the smaller wire. All three sizes of wire discussed are useful. Size #18 was chosen for the Electron Beam® Launch Control System because it presents the best combination of low resistance and low cost.



## SAFETY

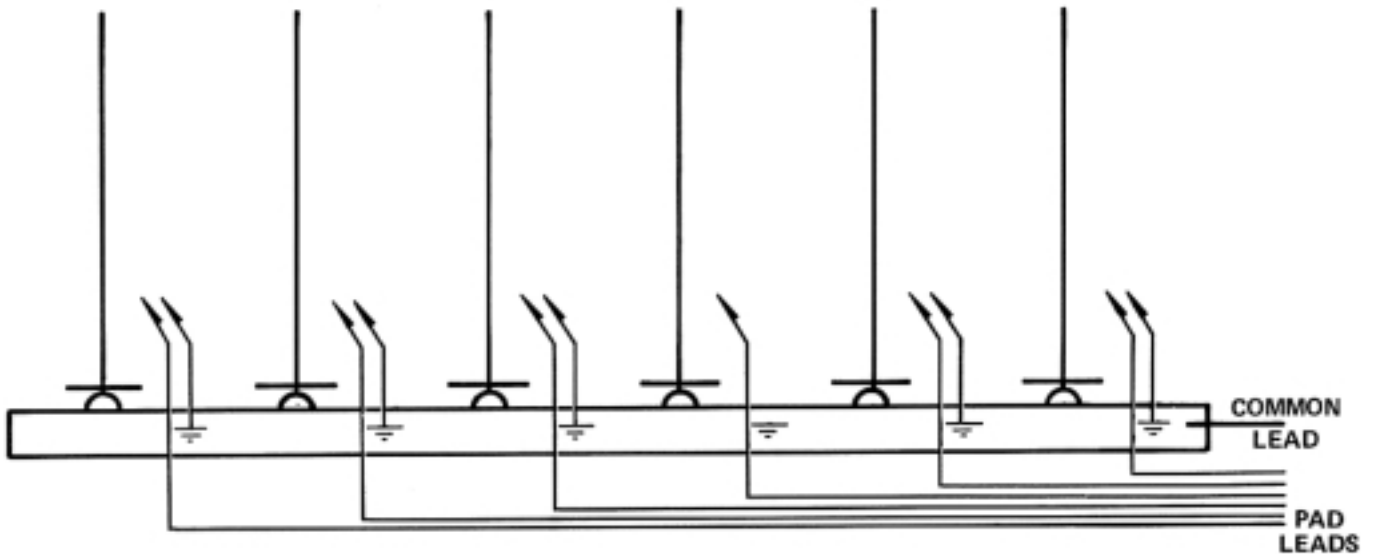
Model rocket launch systems provide safe, reliable means of launching your model rockets by remote control. The safety circuits, guidance devices and absolute control you experience over the rocket until the instant of launch provide a miniature version of the system used to launch our full-sized space rockets.

# MULTIPLE LAUNCHER CIRCUITS



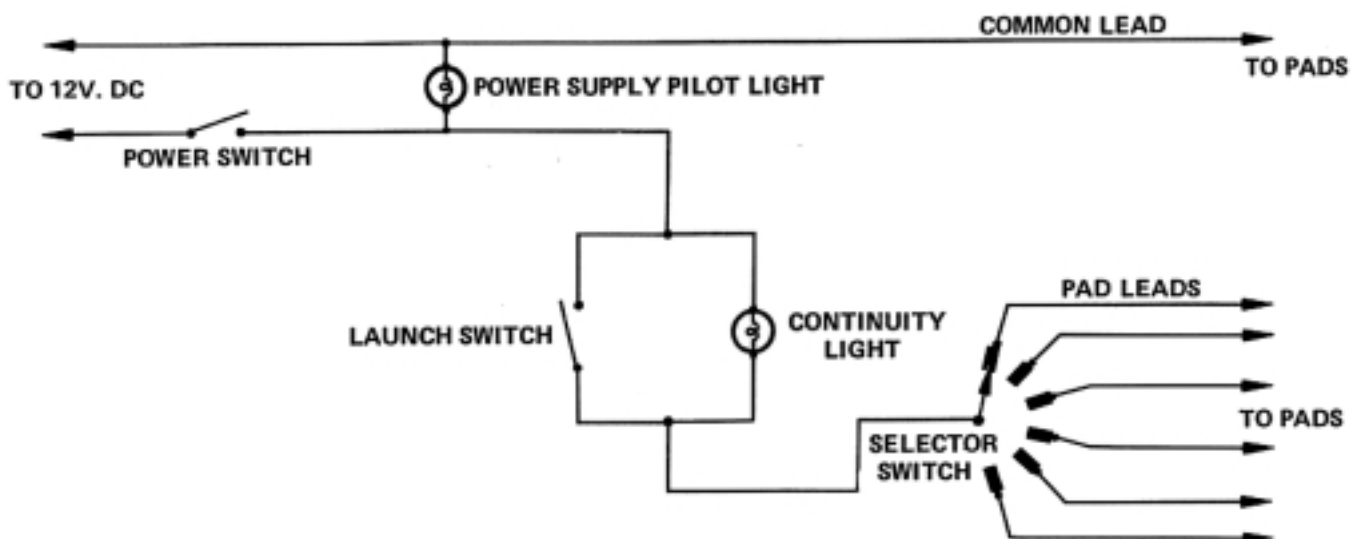
A launcher with several launch pads is a convenient device for flying many model rockets in rapid sequence. A multi-pad system provides a number of launcher set-ups (adjustable rods or rails, blast deflector plates and micro-clip connectors) attached to one power supply and control unit.

## A TYPICAL MULTIPLE LAUNCHER



The electrical power supply to the micro-clips is usually a separate wire to each launch pad to carry the electrical current to that pad and a common (shared) return or “ground” wire.

## PARTIAL SCHEMATIC DIAGRAM FOR A TYPICAL MULTIPLE LAUNCHER



The control panel for a multiple launcher usually incorporates a key-operated power supply switch (to turn power supply off and on), a power supply pilot bulb (to indicate when the power supply is on), a rotary selector switch (to direct current to the pad in use only), a continuity light to indicate if the electrical circuit through the igniter is complete and a launch switch.

A multiple launcher can be easily built. It is very handy for contest and demonstration launches.