

# GENIACS<sup>®</sup>:

## SIMPLE ELECTRIC BRAIN MACHINES, AND HOW TO MAKE THEM

Also:  
Manual for Geniac<sup>®</sup> Electric Brain Construction Kit No. 1

Edmund C. Berkeley

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## Introduction

In 1944 the first "electric brain", an automatic machine for reasoning and calculating, began to work. In the years since then, more and more people have studied and built machines that handle information in reasonable ways, machines that "think" or at least seem to think. Thousands of such machines have now been made. This development is becoming so important that it is often called the Second Industrial Revolution.

Since 1945 we have been interested in helping people understand these machines and how they behave. And we know that equipment that you can take into your own hands, play with, and do exciting things with, will often teach you more, and give you more fun besides, than any quantity of words and pictures.

In 1950, for educational purposes, we constructed a miniature electric brain called Simon. Although only  $1\frac{1}{4}$  cubic feet in size, and limited in capacity, it was a complete automatic computer, and it could show how a machine could do long sequences of reasoning operations. The picture of Simon has appeared on the front cover of two magazines, "Scientific American" and "Radio Electronics"; the machine itself has been demonstrated in more than eight cities of the United States. Over 350 sets of Simon plans have been sold. But this machine costs over \$300 for materials alone, and is therefore too expensive for many situations in playing and teaching.

The same summer that Simon was finished we began work to develop a really inexpensive electric brain. Now, four years later, we have gathered and worked out descriptions of over 30 small electric brain machines, most of them simple, some of them complicated, and all of them interesting, which can be made with very simple electrical equipment. These machines are described in the first part of this report.

In order to make the assembling of these small electric brain machines as easy as possible, we have also developed a construction kit costing less than \$18 (in Jan., 1956) which will make any one of these little machines (with the exception that some of the machines require a few more nuts and bolts). The name of the kit is "Geniac Kit No. 1"; the word "Geniac" comes from the phrase "Genius Almost-Automatic Computer"; and we call the little machines that can be made "Geniacs". This report is also the manual for the kit; and the second part of this report describes the kit and how to assemble machines from it. The name "Geniac" has been registered as a trademark.

The kit contains basically: (1) the materials for six, all-purpose, multiple, electrical switches, of a new and versatile design, for calculating and reasoning; (2) ten flashlight bulbs, for signaling answers; and (3) one flashlight battery for power. Every Geniac, although unable to run automatically, is able to calculate and reason automatically; and the Geniac manual and kit as a whole demonstrate many different and exciting small machines that "think", at least to the extent of reasoning and calculating.

The kit, though inexpensive and convenient for constructing Geniacs, is however not necessary; and some persons will prefer to construct their Geniacs using other materials. We know however that the kit will make any one of more than a hundred simple little electric brain machines.

We hope that you find this report of interest to you, and that you will enjoy playing with the kit, and entertaining your friends with the little machines that you make. And when you work out new electric brain machines, send us the descriptions: we plan to give prizes from time to time for the best ideas sent in to us.

If you find you have at first some difficulty in understanding all that is in this report: TAKE YOUR TIME and think; make first the simpler machines; then try the more complicated ones. To make a machine that will reason and calculate, you, too, need to reason and calculate.

In this report, in stating the design of a number of different circuits, we have used a number of different styles of statement (several styles of drawings, lists of wiring instructions, etc.) A reader may believe that we should have used one and only one style. Such uniformity of style is not practical for two reasons. First, some circuits are simpler and easier to see in one style of statement, while others are simpler and easier to see in another style of statement. Second, the literature on circuits uses different styles of statement; and becoming accustomed to the different styles used here is a better introduction to the literature.

We have had great help from several outstanding computer men in the design of about one third of the Geniac circuits described in this report. We express our thanks to them, and regret that they feel they have to remain anonymous.

It is too much to hope that this report contains no errors. We shall be very grateful to any reader who sends us corrections, and comments and suggestions for later editions of this report.

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## Part I: Simple Electric Brain Machines:

### General Description

An electric brain machine is a machine containing electrical circuits which is able to calculate or reason, that is, perform operations that are reasonable or mathematical. For a simple example, consider a flashlight. It performs a single, very reasonable operation: the light turns on when you turn the switch to the "on" position; and the light turns off when you turn the switch to the "off" position.

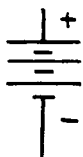
The machines which we shall talk about will be made of: a battery, or source of electric current; wires, which conduct it; switches, which change the paths along which the current flows; lights, which show where the current is flowing. In all of these machines the current starts from one end of the battery and flows in a path or circuit that eventually returns to the other end of the battery.

The diagram of the circuit or circuit diagram shows the scheme of connection of batteries, switches, lights, etc., in order that the machine will function as it is supposed to. The diagram does not necessarily show the physical location of the material but only its relative arrangement, its connections.

The symbols used in circuit diagrams are shown in Table 1. We need pay attention only to five kinds of material.

Table 1

#### CIRCUIT DIAGRAM SYMBOLS



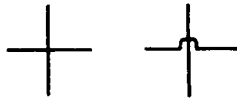
A battery. -- The long and short lines supposedly represent the two kinds of plates in a battery by means of which an electrical current is generated.



Wire. -- A line in a circuit diagram represents an insulated wire, a connector from some point to some other point.



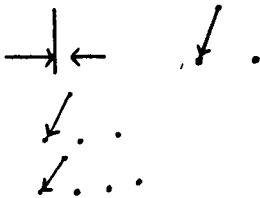
Electrical connections. -- The dots represent points where electrical connections are established, by fastening two wires together so current can flow easily between them.



No electric connection intended. -- Here two wires cross (drawn in either one of two ways) but there is no electrical connection between them. One wire is either above or below the other.



A light. -- This is a light bulb. The two dots are its connections.

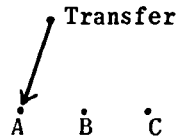
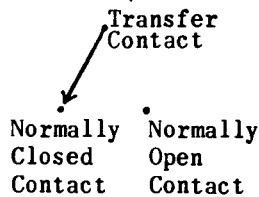


Switches. -- Here is a two-position switch (drawn in either one of two ways).

Here is a three-position switch.

Here is a four-position switch. Etc.

Contacts. -- In any switch, the contacts have names:



A single switch may be constructed having two or three or more electrically nonconnecting sections so that as it is turned, it simultaneously switches two or three or more electrically independent paths. In circuit diagrams this property of a switch is conveniently shown by using a name for the switch and numbers 1, 2, 3, etc., for the sections. In Figure 1 for example two, not three, switches are shown: diagram (a) represents section 1 of the switch called "Wife", diagram (b) pictures section 2 of the same switch, and diagram (c) shows section 1 of the switch called "Husband". Sometimes a section of

a switch is called a deck or a pole or a level. In Figure 1 both switches have the same two positions, called "in canoe" and "not in canoe".

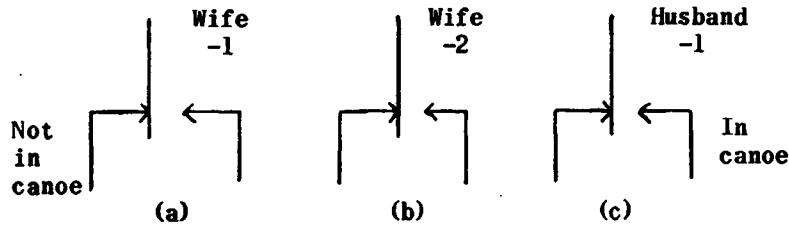


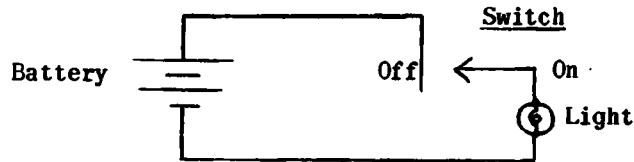
Figure 1 — Switches, Names of Switches, and Names of Positions

With these preliminaries out of the way, let us consider the first machine.

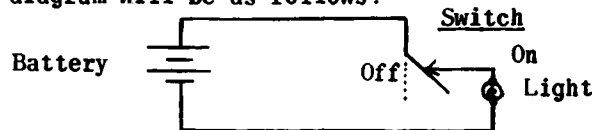
### 1. THE FLASHLIGHT

**Problem:** A man desires to make a flashlight, which will shine when he turns the switch on, and go dark when he turns the switch off.

**Solution:** This is accomplished in the following circuit:



The circuit is regularly drawn with all switches in the off or or zero position. As it is drawn, we can see that no current will flow, because there is a gap; so the light will be off. But when the switch is turned to the on position, then the circuit diagram will be as follows:



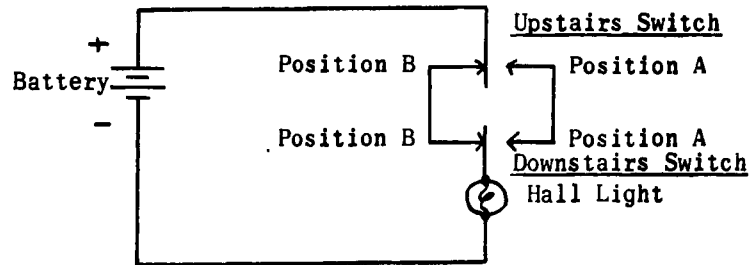
We see that current will now flow and the light will shine. (For the detailed wiring using the kit materials, see p. 59)

## 2. THE HALL LIGHT

**Problem:** A man desires to turn off or turn on the downstairs hall light either from the downstairs hall or from the upstairs hall. He wants a circuit so that if either switch is turned, the light will go on if it was off, and will go off if it was on.

This is a practical problem, if you should ever have to install this kind of wiring. And it is not as easy as it may seem at first glance.

**Solution:** Here is the solution expressed in a circuit diagram:



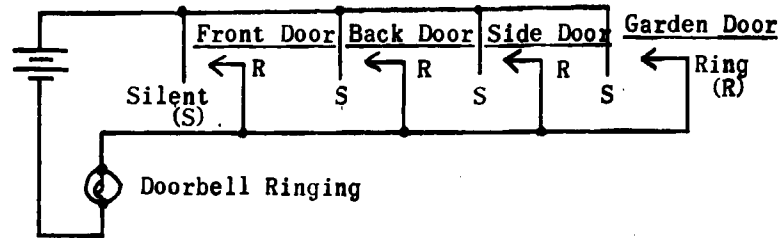
We can see that if both switches are turned to Position B, then the light will shine. If both switches are turned to Position A, then the light will also shine. If only one switch is in Position A and the other switch is in Position B, then the light will not shine. This circuit therefore meets the requirements. (For detailed wiring, see p. 60)

## 3. THE DOORBELL

**Problem:** A man has four doors to his house, a front door, a back door, a side door, and a door to the garden. If anyone comes to any of these doors, and rings, the doorbell should ring. What is a circuit that will accomplish this?



Solution:

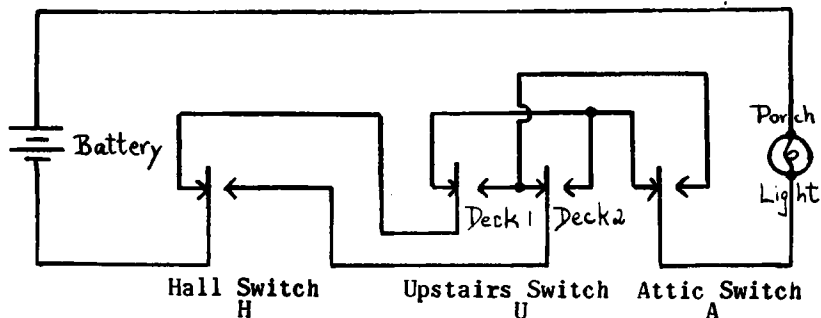


We can see that if all four switches are in the position "Silent", the path is interrupted, and the light that means "Doorbell Ringing" will be dark. But if any one or more of the switches is turned to the "Ring" position, then the light meaning "Doorbell Ringing" will shine. (For detailed wiring, see p. 61)

4. THE PORCH LIGHT

Problem: A man has a light on his front porch which lights up his front steps and his yard. He wants to be able to turn that light on or off from any one of three places: his downstairs front hall (H), the upstairs landing (U), and the attic (A). Three switches are to be put in and wired so that throwing any switch one way turns the light on if it is off, and turns the light off if it is on.

Solution: Here is the circuit. Note that the upstairs switch, Switch U, must have two decks, two sections.

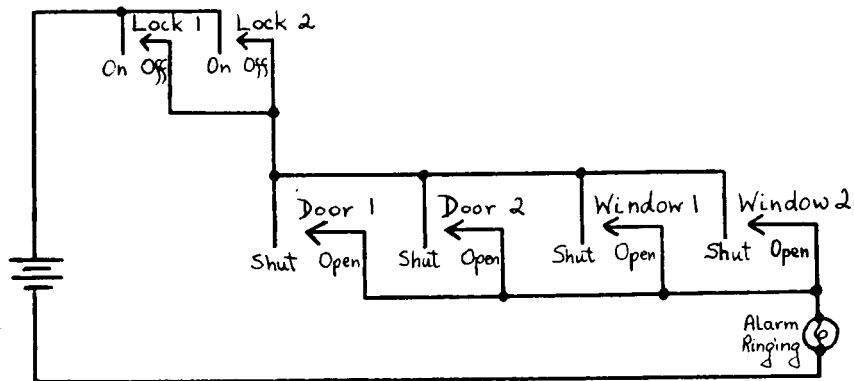


The two decks in the upstairs switch are mechanically fastened together so that when the switch is turned, the two transfer contacts in Deck 1 and in Deck 2 are both turned. Otherwise the circuit would not work. (For detailed wiring, see p. 61)

## 5. THE BURGLAR ALARM

**Problem:** A man has two doors to his house, and two large windows on the ground floor. He believes that if a burglar should try to enter his house, the burglar would come in through one of the doors or one of the big windows. He desires an alarm system. If either door is opened or if either one of the two big windows is opened, after either one of two locking switches (one indoors for use at night, one outdoors in the garage for use when the house is left with no one in it) has been closed, then the burglar alarm is to ring.

**Solution:** We shall need six switches labeled Lock One, Lock Two, Door One, Door Two, Window One, Window Two. Each will be a two-position switch, and only one deck of each switch will be used. Following is a circuit:



In reality, each door and window must be closed shut against a button containing a strong spring, so that when the door or window is opened, the spring pushes the button out and closes a contact. (For the detailed wiring, see p. 62)

## 6. THE AUTOMATIC OIL FURNACE CIRCUIT

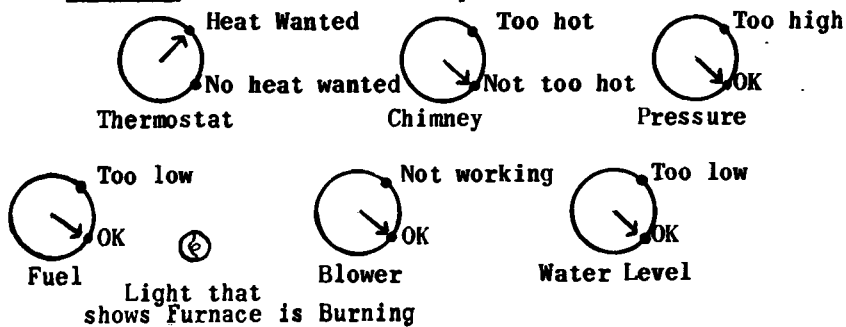
**Problem:** A man has an automatic oil furnace which burns oil and makes water into steam to heat the radiators in the house. The flame starts when the thermostat in his living room calls for heat, and stops when the thermostat stops calling for heat. But if any one of the following conditions exists, the furnace is not allowed to heat:

-- the chimney is too hot

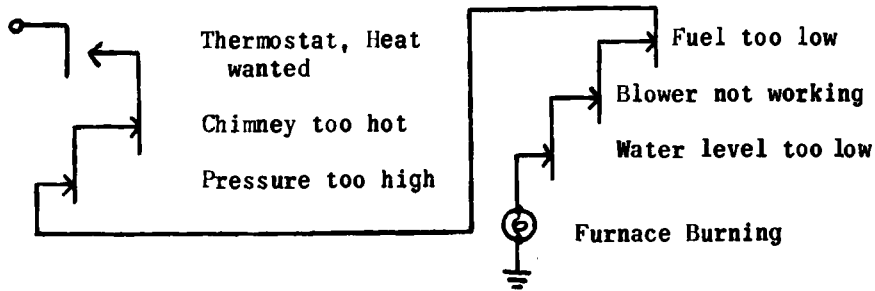
- the pressure in the boiler is over 15 pounds per square inch above atmosphere
- the fuel in the tank is too low
- the blower that mixes air with oil and blows the mixture into the furnace is not working
- the water level in the boiler is below a certain mark.

Set up a circuit which will imitate the behavior of the automatic oil furnace.

Solution: The front of the panel will look like this:



The circuit is as follows. (NOTE: Here  $\circ$  denotes "source of current" or "one side of battery";  $\equiv$  denotes "sink of current" or "ground" or "other side of battery"; these are common symbols.)



## 7. PRIVATE SIGNALING CHANNELS

Problem: Set up a machine so that each one of three boys, George, Tom, and Dick can signal any one of the other two.

Solution: We shall have three switches, one for each boy. Each switch will have two settings, one for each other boy.

There will be six lights, indicating who is signaling and who is being signaled.

The wiring will be as follows:

1. Wire from one end of the battery to the transfer of one deck on each switch.
2. Wire from the outputs of each switch to the lights, as follows, and from the other side of the lights back to the other end of the battery.

<u>Switch</u>	<u>Output</u>	<u>Light</u>
George	Tom Dick	George calling Tom George calling Dick
Tom	George Dick	Tom calling George Tom calling Dick
Dick	George Tom	Dick calling George Dick calling Tom

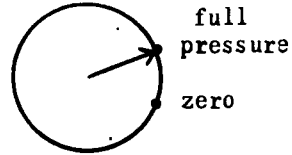
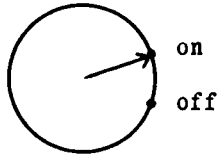
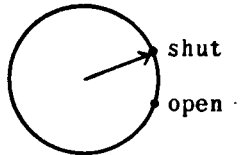
NOTE: In this case, instead of furnishing a circuit diagram, we have given a statement of the circuit in the form of a set of wiring instructions. This is logically equivalent, and often in practical situations a good deal better.

#### 8. MACHINE FOR A SPACESHIP'S AIRLOCK

Problem: The airlock of a space ship has: an inner door that goes from the airlock to the inside of the space ship; an outer door which goes from the airlock to the surface of the strange planet, which is assumed to have no atmosphere; a pump which pumps the air from the airlock into the space ship; a valve which allows air from the space ship to flow into the airlock; and a pressure gage which reports the air pressure in the airlock and which may be either high or low. There are four lights in the airlock: safe to open the inner door; safe to open the outer door; dangerous to open either door, conditions OK; dangerous to open either door, conditions bad. We want a warning circuit and automatic locks corresponding.

Solution: The front of panel will look like the following:

Valve from Spaceship to Airlock      Pump from Airlock to Spaceship      Gage, showing Pressure in Airlock



Light 1:

Safe to open the inner door; automatic lock of outer door

Light 2:

Safe to open the outer door; automatic lock of inner door

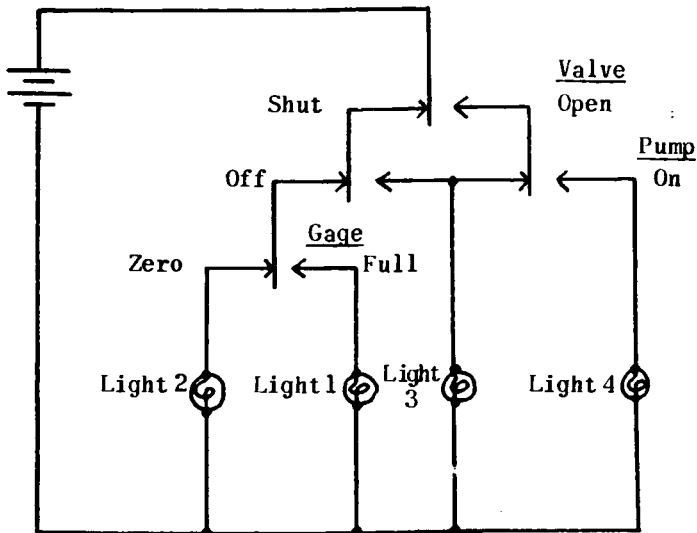
Light 3:

Dangerous to open either door; automatic lock of both doors; conditions OK

Light 4:

Dangerous to open either door; automatic lock of both doors; conditions bad

The circuit is as follows:

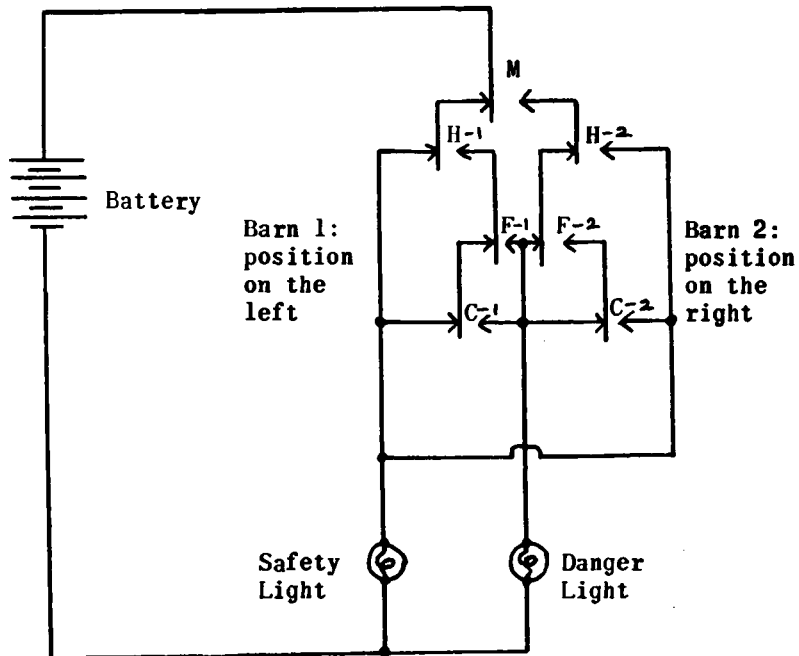


9. THE FOX, HEN, CORN, AND HIRED MAN: THE FARMER'S MACHINE

Problem: A farmer had a fox, a hen, some corn, and a hired man, and two barns, where one or more of them could be at any one time. He did not trust his hired man's carefulness. He wanted a warning robot to shine a danger light (1) when the fox was with the hen in either barn, the hired man being in the other barn, and (2) when the hen was with the corn in either barn, the hired man being in the other barn, and a safety light on other occasions.

There will be a switch for the hired man (M), a switch for the fox (F), a switch for the hen (H), and a switch for the corn (C); and one position of each switch will mean "it is in Barn 1" and the other position will mean "it is in Barn 2".

Solution: Here is the circuit:



## 10. THE MACHINE FOR THE TWO JEALOUS WIVES

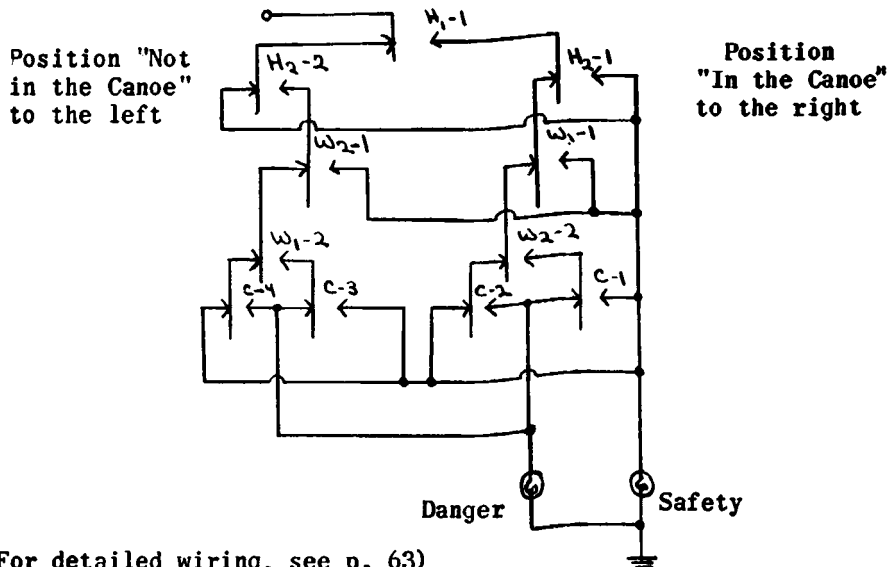
**Problem:** One summer two families vacation in neighboring bungalows on the shore of a pleasant lake. The two wives are jealous, and one day agree that the husband of either one may not go canoeing alone with the other wife, unless accompanied by a chaperon. They also believe that the chaperon might be more attractive than they would wish, and consequently they agree that neither husband should go canoeing alone with the chaperon.

They arrange with an electrician to set up an apparently innocuous wiring system in the boat house, and they arrange with the boat boy to turn switches to show who is out in the canoe. In their living rooms, they arrange a danger light to shine when the situation is contrary to their agreement, and a safety light to shine on all other occasions.

How should the circuit be wired?

There are five two-position switches marked Husband One ( $H_1$ ), Husband Two ( $H_2$ ), Wife One ( $W_1$ ), Wife Two ( $W_2$ ), Chaperon ( $C$ ). One position I stands for "in the canoe". The other position N stands for "not in the canoe".

**Solution:** Following is a circuit which will work. The decks of each switch are numbered; thus C-3 is the 3rd deck of the Chaperon switch.

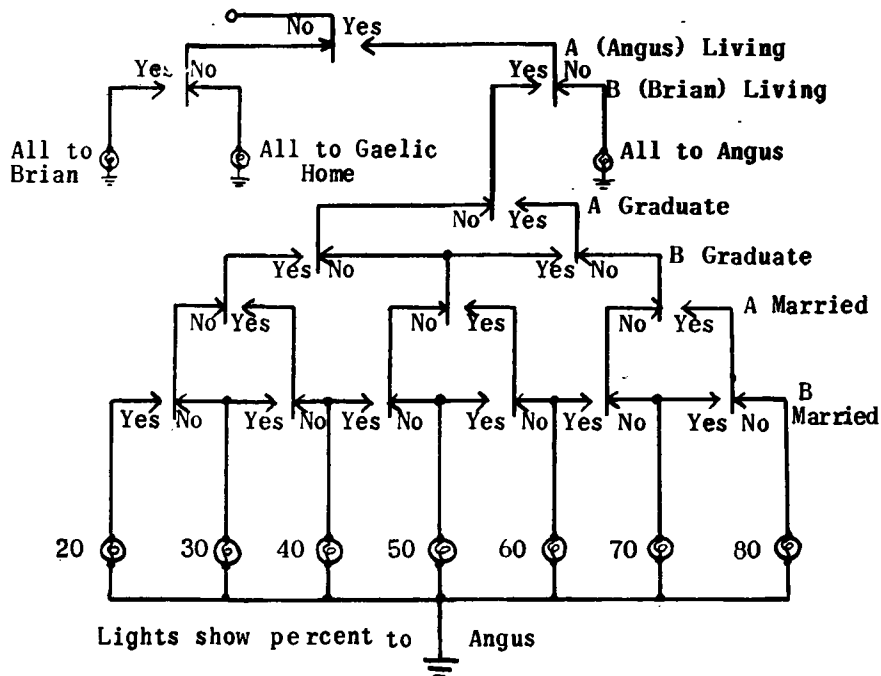


11. THE MACHINE FOR DOUGLAS MACDONALD'S WILL

**Problem:** The provisions of Douglas Macdonald's will are as follows: "If my son Angus survives me and my son Brian does not, all my estate goes to Angus. If Brian survives me and Angus does not, all my estate goes to Brian. If neither survives me, my estate is to go to the Gaelic Home for the Aged and Indigent. If both Angus and Brian survive me, and if at the time of my death neither is married nor is a graduate of Edinburgh University, then each shall have 50% of my estate. If both are married and neither is a graduate, or if both are graduates, and neither is married, or if both are married and both are graduates, then each shall have 50% of my estate. If only one of my sons is a graduate, his share shall be increased by 20% of my estate and the other's decreased accordingly. If only one of my sons is married, his share shall be increased by 10% and the other's decreased accordingly." What happens when Douglas Macdonald dies?

We wire up a circuit having six switches showing all the conditions for Angus and Brian (living or not, graduate or not, married or not) and ten output lights, showing what happens in any one of the 64 possible events.

**Solution:** Following is the circuit:

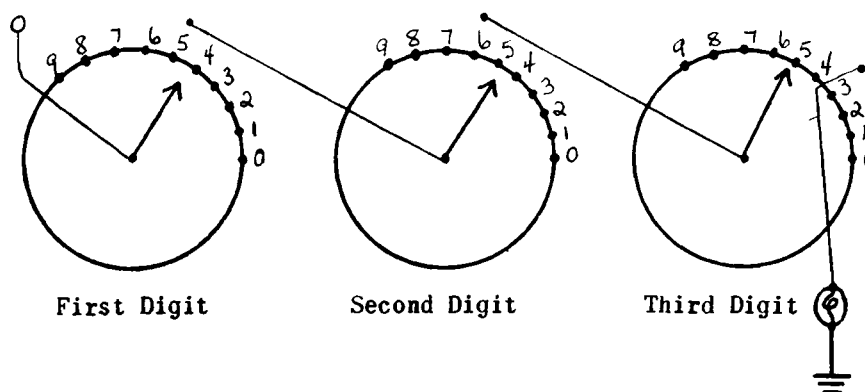




## 12. THE SPECIAL COMBINATION LOCK

**Problem:** Set up a machine with the following properties: each one of three switches may be set at any digit from 0 to 9; when and only when the first switch is set at 5, the second switch is set at 6, and the third switch at 3, a light "Open" will glow.

**Solution:** Here is the circuit:

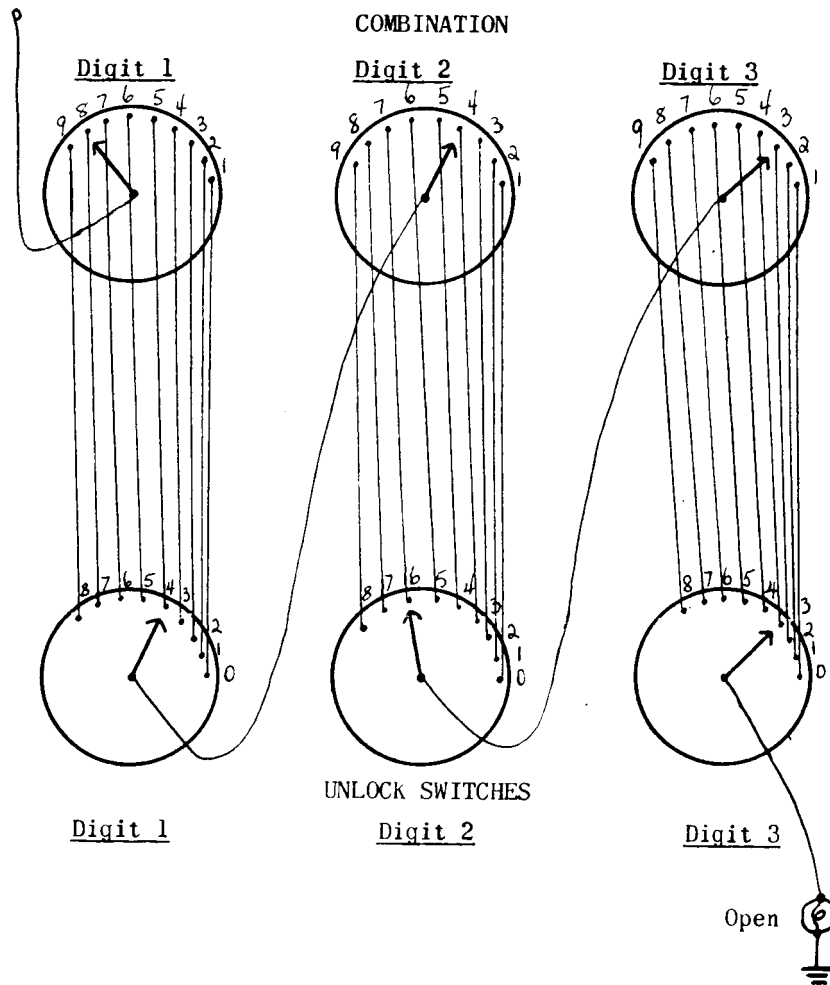


Obviously, the combination can easily and quickly be changed by altering the location of a wire or two.

### 13. THE GENERAL COMBINATION LOCK

**Problem:** Set up a machine with the following properties: you may use any three digit combination with digits 1 to 9 on three switches; when and only when three more switches are set with the same combinations but each digit one less, a light "Open" will glow:

**Solution:** Here is the circuit:

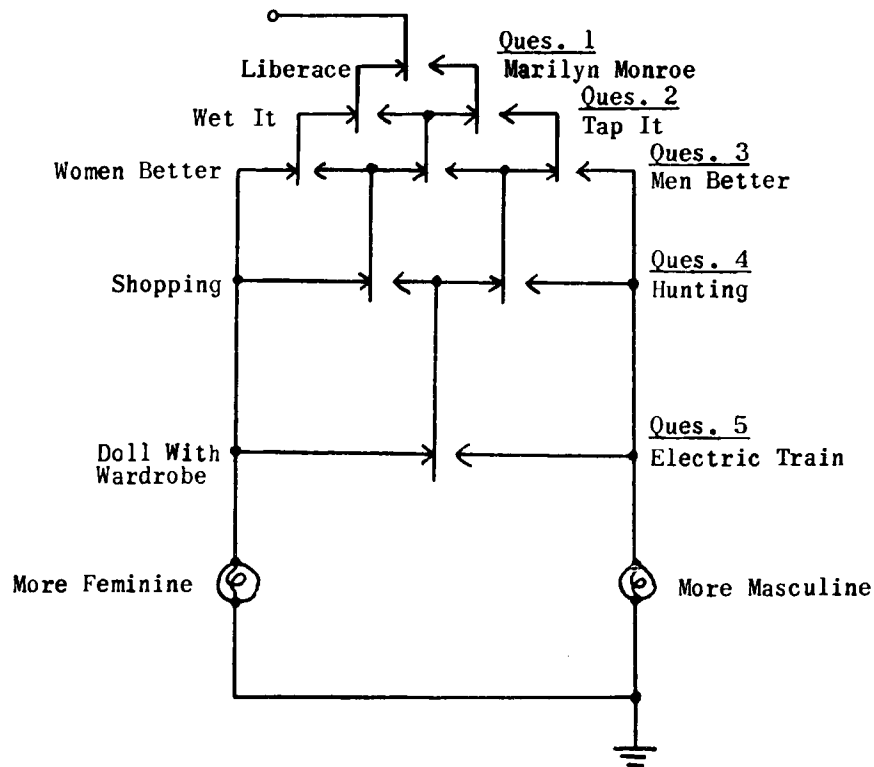


#### 14. MASCULINE-FEMININE TESTING MACHINE

**Problem:** Set up a machine which will determine whether the person who answers five questions (if he or she answers them truthfully) is more masculine or more feminine:

1. Whom do you prefer: (a) Marilyn Monroe? (b) Liberace?
2. How would you put a thread into a small hole: (a) wet it? (b) tap it?
3. Which would you agree with? (a) Women are better drivers than men because they are more careful. (b) Men are better drivers than women because they get more practice and are more skilled.
4. Would you rather spend a day: (a) Shopping on Fifth Avenue? (b) Hunting in the woods?
5. Which makes a better toy for a child: (a) electric train? (b) a doll with a complete wardrobe?

**Solution:** Following is the circuit.



15. ADDING MACHINE
16. SUBTRACTING MACHINE

**Problem:** We have two switches A and B, each able to be set at any one of four positions 5, 6, 7, 8. We have seven lights labeled 10, 11, 12, 13, 14, 15, 16. We want a circuit so that the machine will show the sum of the numbers set on the A and B switches.

**Solution:** Here are the wiring instructions:

1. Wire one end of the battery to the transfer on one deck of switch A. This deck of switch A has four outputs 5, 6, 7, 8.
2. Wire each one of these four outputs to each one of four transfers on switch B, one on each deck. Call these decks 5, 6, 7, 8, according to the A output wired to it. Now switch B will have sixteen outputs.
3. Wire these outputs to one side of the lights according to the following table of instructions (use column (1) ).

<u>Deck</u>	<u>B output</u>	(1)	(2)
		<u>Light</u>	<u>Light</u>
5	5	10	-3
	6	11	-2
	7	12	-1
	8	13	0
6	5	11	-2
	6	12	-1
	7	13	0
	8	14	1
7	5	12	-1
	6	13	0
	7	14	1
	8	15	2
8	5	13	0
	6	14	1
	7	15	2
	8	16	3

4. Wire the other side of each light to the other side of the battery.

Notes: (1) Any four consecutive numbers and their sums can be substituted, using other labels; and the machine will still work correctly. (2) The machine will work as a subtracting machine giving A minus B if the positions of the B switch are labeled 8, 7, 6, 5, instead, and the lights are labeled as shown in column (2) above, instead.

### 17. MULTIPLYING MACHINE

Problem: We have two switches A and B, each able to be set at four positions 6, 7, 8, 9. We have ten lights labeled 36, 42, 48, 49, 54, 56, 63, 64, 72, 81. We want a circuit so that the machine will show the product of the A and B numbers set on each switch, by shining the appropriate light.

Solution: Here are the wiring instructions:

1. Wire one end of the battery to the transfer on one deck of switch A. This deck of switch A has four outputs 6, 7, 8, 9.
2. Wire these four outputs to each one of four transfers on switch B, one on each deck. Call these decks 6, 7, 8, 9 according to the A output. Thus switch B will have sixteen outputs.
3. Wire these outputs to the lights according to the following table of instructions:

<u>Deck</u>	<u>B Output</u>	<u>Light</u>	<u>Deck</u>	<u>B Output</u>	<u>Light</u>
6	6	36	8	6	48
	7	42		7	56
	8	48		8	64
	9	49		9	72
7	6	42	9	6	54
	7	49		7	63
	8	56		8	72
	9	63		9	81

4. Wire the other side of each light to the other end of the battery.

Note: This same machine can be relabeled according to the following system, and will still tell the truth:

6 7 8 9	36 42 48 49 54 56 63 64 72 81
2 3 4 5	4 6 8 9 10 12 15 16 20 25

In fact any four consecutive numbers, none smaller than 2, and their appropriate products can be inserted.

#### 18. DIVIDING MACHINE

Problem: We have two switches, A and B, each able to be set at any one of 0, 1, 2, 3. We have ten lights labeled 0,  $1/3$ ,  $1/2$ ,  $2/3$ , 1,  $1\frac{1}{2}$ , 2, 3,  $\infty$ , ? We want a circuit so that the machine will show the quotient of A divided by B, where A and B are the numbers set on the switches.

Solution: Here are the wiring instructions.

1. Wire one end of the battery to the transfer on one deck of switch A. This deck of switch A has four outputs 0, 1, 2, 3.
2. Wire each one of these four outputs to each one of four transfers on switch B, one on each deck. Call these decks 0, 1, 2, 3 according to the A output wired to it. Now switch B will have 16 outputs.
3. Wire these outputs to one side of the lights according to the following table of instructions:

<u>Deck</u>	<u>B Output</u>	<u>Light</u>
0	0	?
	1	0
	2	0
	3	0
1	0	$\infty$
	1	1
	2	$1/2$
	3	$1/3$

<u>Deck</u>	<u>B Output</u>	<u>Light</u>
2	0	
	1	2
	2	1
	3	2/3
3	0	
	1	3
	2	1½
	3	1

4. Wire the other side of each light to the other side of the battery.

#### 19. MACHINE FOR ARITHMETICAL CARRYING

Problem: We have two switches, A which may be set at any one of the numbers 3, 4, 5, 6 and B which may be set at any one of the numbers 2, 3, 4, 5, 6, 7. We have two lights Carry One, and No Carry. We want a machine so that these lights will be turned on properly.

Solution: Here are the wiring instructions.

- Wire one end of the battery to the transfer on one deck of switch A. This deck has four outputs 3, 4, 5, 6.
- Wire each one of these four outputs to the transfer of each one of four decks of switch B. Call these decks 3, 4, 5, 6 according to the A output wired to it.
- Wire the outputs of the B switch to one side of the lights as follows:

<u>Deck</u>	<u>B Output</u>	<u>Light</u>	<u>Deck</u>	<u>B Output</u>	<u>Light</u>
3	7	Carry One	5	5 to 7	Carry One
	2 to 6	No Carry		2 to 4	No Carry
4	6, 7	Carry One	6	4 to 7	Carry One
	2 to 5	No Carry		2, 3	No Carry

4. Wire the other side of the lights to the other end of the battery.

Note: Similar machines may be made for other cases of arithmetical carrying. But relabeling this machine for other cases of carrying is not likely to work out very well.

## 20. COMPARING MACHINE

Problem: We have two switches A and B, each able to be set at any one of four numbers 6, 8, 10, 12. We have three lights labeled GREATER, EQUAL, LESS. We want a circuit that will show whether A is greater than B, or A is equal to B, or A is less than B, where A and B are the numbers set on the switches.

Solution: Here are the wiring instructions.

1. Wire one end of the battery to the transfer of one deck of switch A. This deck of switch A has four outputs 6, 8, 10 and 12.
2. Wire each one of these four outputs to just one of four transfers on switch B, one on each deck. Call these decks 6, 8, 10, 12 according to the A output wired to it.
3. Wire these outputs to one side of the lights according to the following table of instructions:

<u>Deck</u>	<u>B Output</u>	<u>Light</u>
6	6	E
	8	L
	10	L
	12	L
8	6	G
	8	E
	10	L
	12	L
10	6	G
	8	G
	10	E
	12	L



<u>Deck</u>	<u>B Output</u>	<u>Light</u>
12	6	G
	8	G
	10	G
	12	E

4. Wire the other side of the lights to the other end of the battery.

Note: This same machine can be relabeled using any other four numbers in sequence.

## 21. REASONING MACHINE

Problem: Switch A can be set at any one of these four positions:

1. All fighter pilots are bomber pilots.
2. No fighter pilots are bomber pilots.
3. Some fighter pilots are bomber pilots.
4. Some fighter pilots are not bomber pilots.

Switch B can be set at any one of these four positions:

5. All bomber pilots are jet pilots.
6. No bomber pilots are jet pilots.
7. Some bomber pilots are jet pilots.
8. Some bomber pilots are not jet pilots.

We have six lights:

9. All fighter pilots are jet pilots.
10. No fighter pilots are jet pilots.
11. Some fighter pilots are jet pilots.
12. Some fighter pilots are not jet pilots.

13. Some jet pilots are not fighter pilots.
14. It is not possible to deduce from the given statements any true assertion connecting fighter pilots and jet pilots.

We want a machine which will reason correctly.

Solution: Here are the wiring instructions.

1. Wire one end of the battery to the transfer on one deck of switch A. This deck of switch A has four outputs, 1, 2, 3, 4.
2. Wire outputs 1, 2, 3 to just one of three transfers on three separate decks of switch B, one on each deck. Call these decks 1, 2, 3 according to the A output wired to it. Now switch B will have 12 outputs.
3. Wire these twelve B outputs and the A 4 output to one side of the lights according to the following table of instructions, and wire the other side of the lights to the other end of the battery.

<u>Deck</u>	<u>B output</u>	<u>Light</u>
1	5	9
	6	10
	7	14
	8	14
2	5	14
	6	14
	7	13
	8	14
3	5	11
	6	12
	7	14
	8	14
<u>A output</u>		
4		14

Note: The following replacements of fighter pilots (a's),

umber pilots (b's), and jet pilots (c's), may be made if desired and the same machine will reason correctly:

a's	b's	c's
baseball players	football players	basketball players
associates	colleagues	followers
flesh eaters	leaf eaters	grain eaters
merchants	traders	dealers
clients	customers	patrons
pastry cooks	barbecue cooks	regular cooks

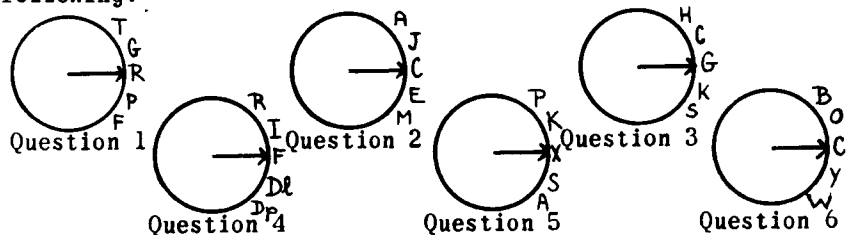
etc., etc.

22. INTELLIGENCE TESTING MACHINE

**Problem:** Following are six questions, each with five answers, only one of which is correct:

1. What is the middle letter of a nine-lettered word meaning an instrument for talking over a distance along a wire?  
 T     G     R     P     F
2. The statement "I wonder how he earns his living?" indicates what on the part of the speaker?  
 Amusement     Jealousy     Curiosity  
 Eagerness     Meditation
3. Which of the words below does not belong in the list?  
 Herder     Cowboy     Gardener  
 Keeper     Shepherd
4. Wit is to dullness as approval is to:  
 Respect     Improvement     Flattery  
 Disliking     Disproving
5. If the words below were arranged to make the best sentence, with what letter would the last word of the sentence end?  
ax    good    keeps    sharp    lumberjack    his    a  
 P     K     X     S     A
6. Which of the following words makes the truest sentence?  
A mother is always ..... than her daughter.  
 Bigger     Older     Calmer     Younger  
 Wiser

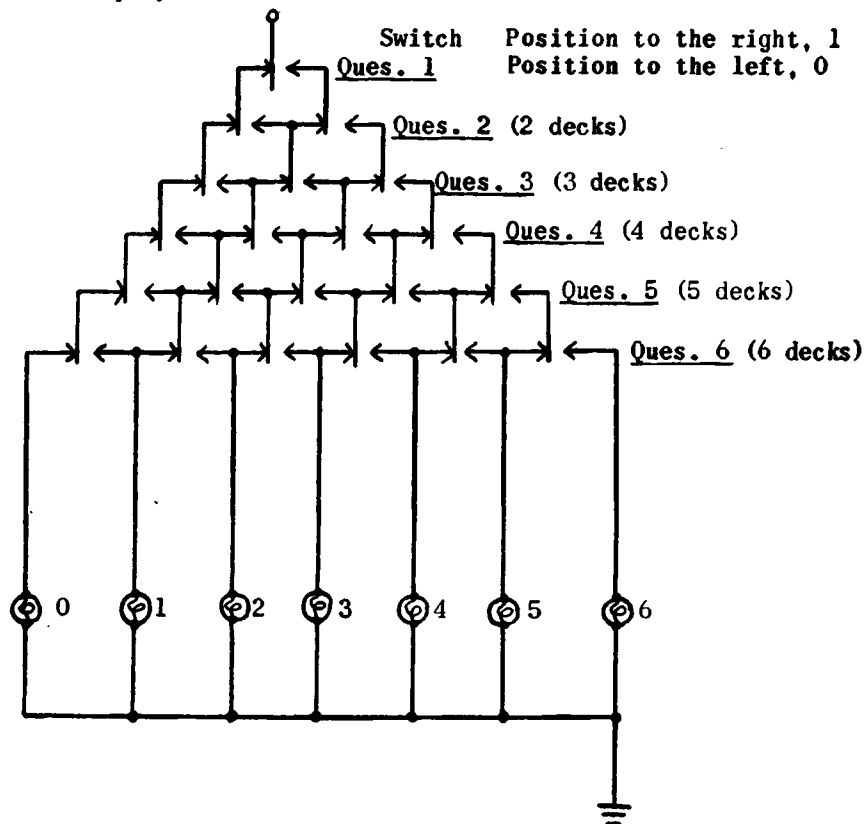
**Solution:** This problem uses six switches. The front of the board with the switches labeled on it will look like the following:



The desired machine will score the test, and show in seven lights from 0 to 6 the number of correct answers.

The correct answers to the questions are these: 1 - P; 2 - C; 3 - G; 4 - Disliking; 5 - P; 6 - O. On the other side of the panel mark with 1 the position of the switch that shows this answer. Connect together the other four positions of the switch (on the other side of the panel) and mark them 0. We now have the equivalent of a two-position switch.

The circuit which will give the correct number of answers is now displayed below:



Notes: This machine can be used for any kind of 6-question intelligence test changing a few wires so that differently located alternatives are the correct answers to the questions.

### 23. THE URANIUM SHIPMENT AND THE SPACE PIRATES

Problem. A uranium shipment from one of Jupiter's Moons, Callisto, to Earth consists of a freighter rocket ship loaded with uranium and a fighter escort rocket ship disguised as a freighter. Space pirates are known to be lurking on one of the two asteroids, Pallas or Hermes. The pirates suspect that one of the rocket ships is a disguised fighter; therefore they may either attack the first ship or wait in hiding for a second ship. The commander of the uranium shipment can send either ship by the Pallas or the Hermes route and can send the fighter either first or second. If the pirate attacks the fighter, the pirate will be destroyed. If the pirate attacks the uranium ship and the fighter has already passed or taken the other route, then the pirate captures the uranium. If the pirate attacks the uranium ship, and the fighter is taking the same route, and is behind the uranium ship, the pirate is destroyed but during the battle, the pirate destroys the uranium ship. Of course, if the pirates do not attack, there is no combat.

What happens to the uranium shipment?

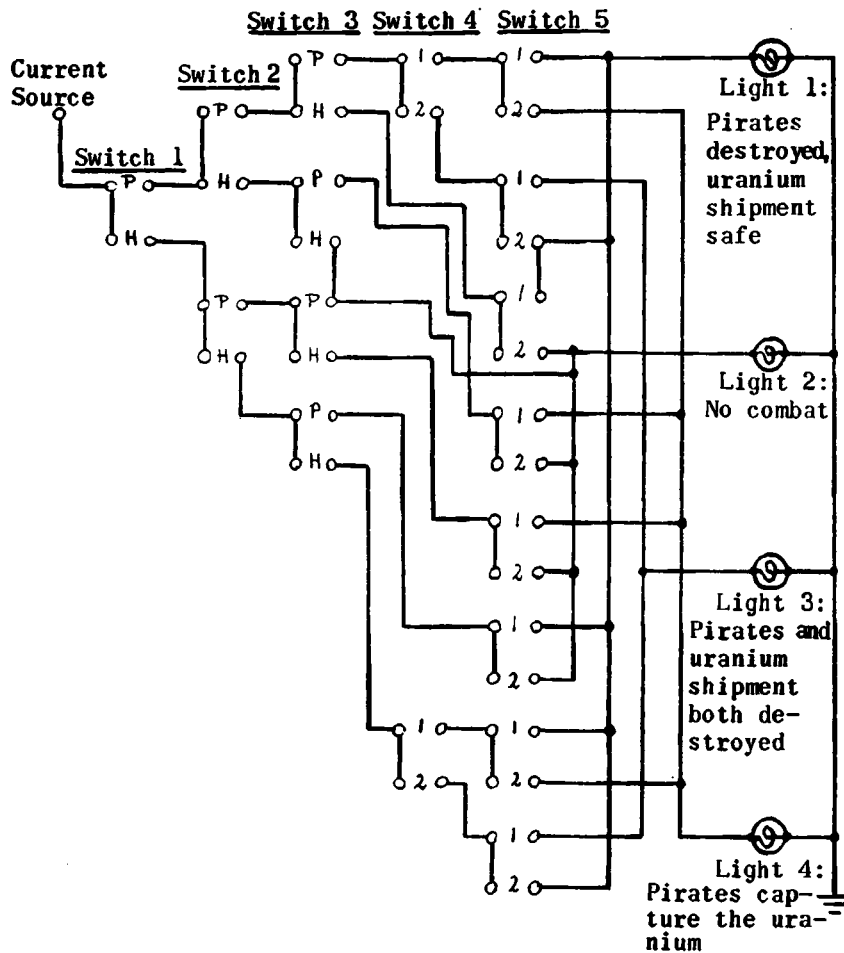
Solution. There will be five two-position switches to express either one of the two possibilities for each of the five conditions:

1. Pirates lurking on Pallas or Hermes (1 deck)
2. Fighter travels via Pallas or Hermes (2 decks)
3. Uranium shipment travels via Pallas or Hermes (4 decks)
4. Fighter travels first or second (2 decks)
5. Pirate attacks first ship or waits for second ship (8 decks)

There will be four lights to express any one of the four possible outcomes:

1. Pirates destroyed, uranium shipment safe
2. No combat
3. Pirates and uranium shipment both destroyed
4. Pirates capture the uranium

Following is the circuit:

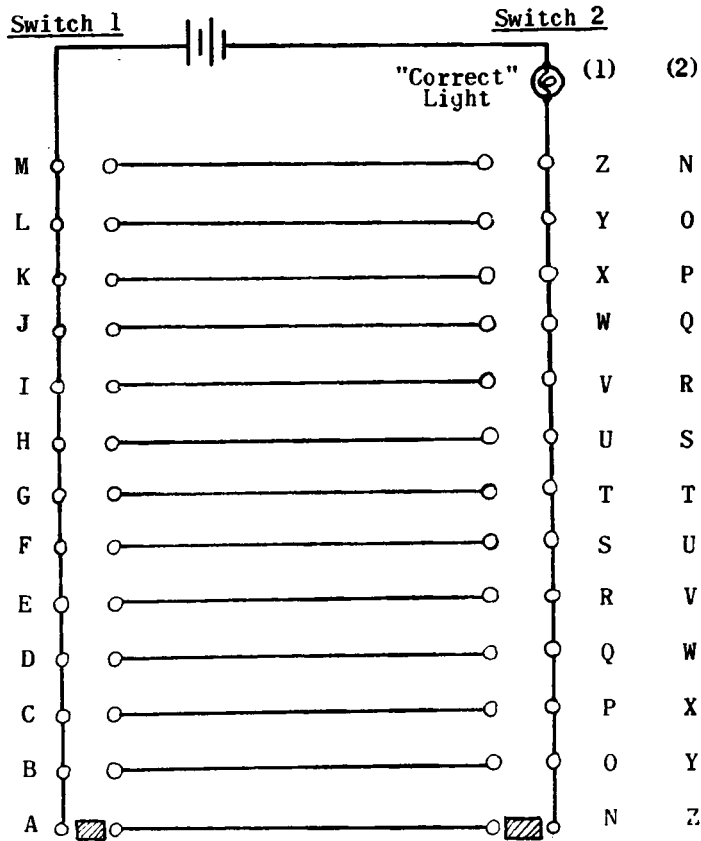



**Note:** In this case another way of showing the wiring of the switches has been used. The set of terminals on the switches has been shown as a column of pairs of small circles, and the two positions of the switches have been designated with letters or numbers.

24. SECRET CODER  
 25. SECRET DECODER

**Problem.** Set up a machine which will encipher a message, putting it into cipher, and which can also be used to decipher the message, putting it back into plain text.

**Solution.** Following is the wiring for a machine which will do this:



Each of these two switches is a switch with one deck and 13 positions. The lamp signals when the pairing of letters is correct. The sign  designates the jumper.



This machine will both encipher and decipher a message. To encipher, set a letter from the message on whichever dial it occurs. Then turn the other dial until the lamp lights. Use the letter from the second dial for the code message. The same process decodes the message.

The labels in column (1) give a Caesar-type Cipher, so called because this type was used by Julius Caesar.

Here are some messages in the Caesar Code for you to decipher:

JR NER FHEEBHAQRQ FRAQ ERVASBEPRZRAGF  
TBVQ VF HAQRE SBEG XABK  
BAR VS OL YNAQ NAQ GJB VS OL FRN

If the labels in column (2) are used, the machine expresses a Reverse Caesar Cipher. Here are some Reverse Caesar messages for you to decipher:

ULINFZ RH YVSRMW GSV KRXGFIV LU YRMXLOM  
YVDZIV GSV TILXVI SV RH Z IVW HKB  
ZOO RH OLHG UOVV ULI BLFI ORUV

You can compose your own secret code by scrambling the wires that run from switch 1 to switch 2. Make sure that one and only one wire runs from each of the 13 positions on switch 1 to each of the 13 positions on switch 2.

There are more than 6 billion different ways of connecting these switches; therefore you may be sure that if you mix the wires up well, no one will stumble on your manner of connection by chance.

Solutions to the Ciphers: (Caesar)

WE ARE SURROUNDED SEND REINFORCEMENTS  
GOLD IS UNDER FORT KNOX  
ONE IF BY LAND AND TWO IF BY SEA

(Reverse Caesar)

FORMULA IS BEHIND THE PICTURE OF LINCOLN  
BEWARE THE GROCER HE IS A RED SPY  
ALL IS LOST FLEE FOR YOUR LIFE

## 26. MACHINE TO PLAY NIM

Problem. There are several ways of playing the game of Nim. One way is to set up four piles of matches, with the number of matches in each pile 4, 3, 2 and 1. The two players take turns. Each player must during his turn take one or more matches from any one pile (and may take the whole pile). The player taking the last match wins the game.

Here is a sample game:

- (1) the player going first takes 2 out of the first pile, leaving 2, 3, 2, 1;
- (2) the second player now takes 2 out of the second pile, leaving 2, 1, 2, 1;
- (3) the first player now takes 1 from the last pile, leaving 2, 1, 2, 0;
- (4) the second player now takes 2 from the first pile, leaving 0, 1, 2, 0;
- (5) the first player now takes 1 from the third pile, leaving 0, 1, 1, 0;
- (6) it is now clear that the second player loses, for whichever match he takes, the first player takes the other one and wins.

The problem is to set up this variation of the game of Nim in a machine. The machine is to signal what move it makes in response to any position left by the human player. The four piles of matches are represented by four switches. Their positions correspond to the number of matches left in the pile at any time. Switch A has positions 0 and 1; Switch B has positions 0, 1, 2; Switch C has positions 0, 1, 2, 3; and Switch D has positions 0, 1, 2, 3, 4. There is also a fifth switch, E, which has two positions, M, for Machine's Turn to Play, and P for Player's Turn to Play.

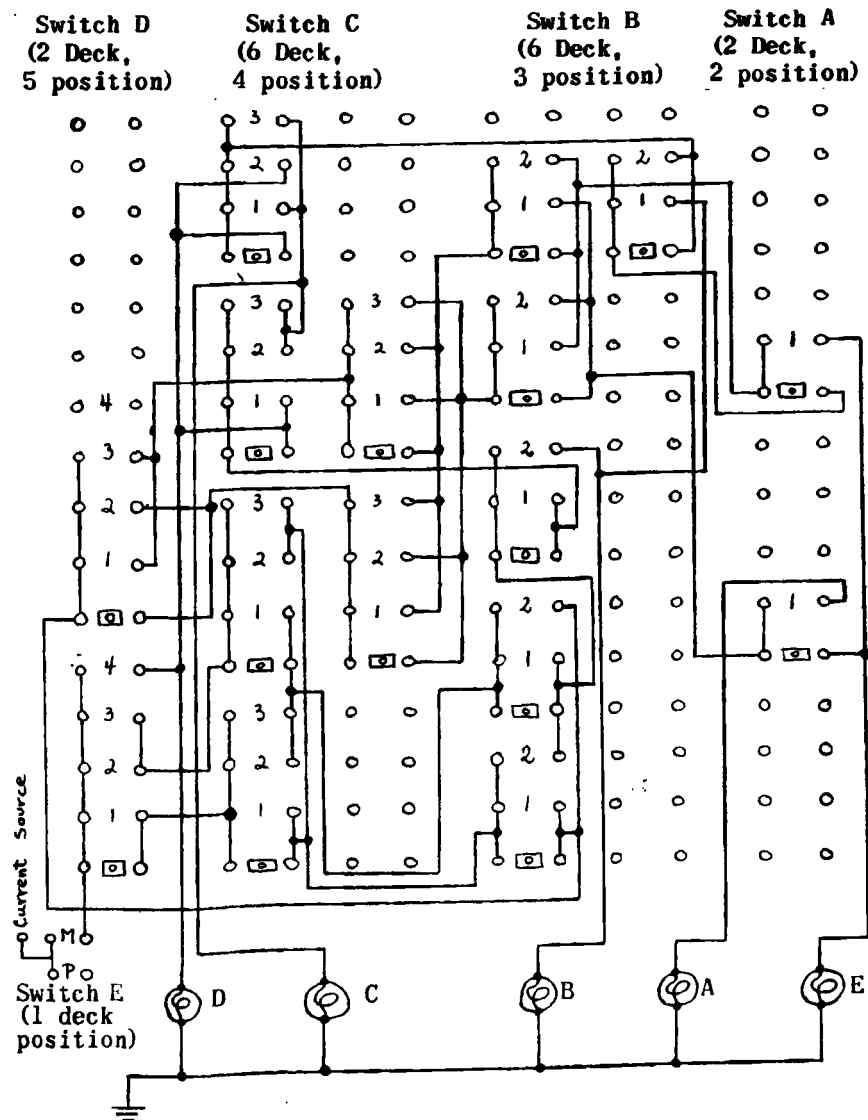
The machine is to accept any move by the human player, and is to be able to signal unmistakably its own move.

The machine is to play either first or second. If the machine plays first, it should always win; if the machine plays second, it should win if the player makes any mistakes.

The game is to start with the switches set in positions A 1, B 2, C 3, and D 4.

How should the machine be designed?

Solution. Following is a circuit for the machine:



To operate the machine, if it is the machine's move, set each switch at the position of the number of matches which is in the corresponding pile. Then turn the switch E to "Machine". If any one of the lamps A, B, C or D is lit, but the lamp E is not lit, turn the corresponding switch down (irrespective of whether other lights flicker on or off) until the lamp E lights. If any one of the lamps A, B, C or D is lit, and the lamp E is also lit, select the switch having the largest setting and turn it down by one. This is the machine's move.

If it is the player's move, turn the switch E to "Player", and then turn down that one of the switches which gives effect to the player's move.

## 27. MACHINE TO PLAY TIT-TAT-TOE

Problem. The usual way to play tit-tat-toe is of course familiar to nearly everybody. The game is played on a criss-cross set of lines:



and the two players enter naughts "O" and crosses "X" until one player gets three marks together in a straight line and thereby wins. If neither succeeds, the game is a draw.

The problem is to set up a machine which will play tit-tat-toe with a human player, assuming that the machine plays first.

Solution. Here is a solution. Let the squares of the board be numbered as follows:

1	2	3
8	9	4
7	6	5

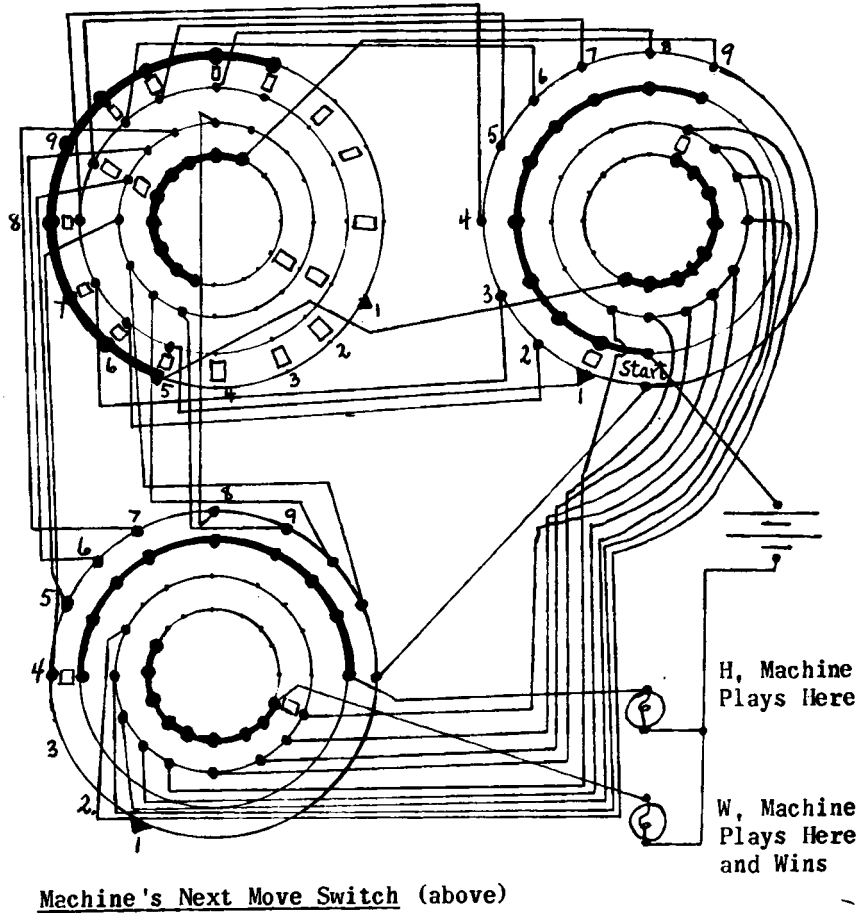
There are three switches:

1. Machine's Last Move: 2 decks, 10 positions (Start, 1 to 9)
2. Player's Current Move: a special three-deck switch (see the circuit diagram) with 18 jumpers and 9 positions (1 to 9).
3. Machine's Next Move: 2 decks, 9 positions (1 to 9).

There are two lights: H, Machine Plays Here; W, Machine Plays Here and Wins.

Following is the circuit diagram (in the form of a template, showing the rear or wiring side):

Player's Current Move Switch:    Machine's Last Move Switch:



All wipers are shown with the switch in the No. 1 position. Note the special arrangement of wipers on the Player's Current Move Switch.

The rules for playing with this machine are as follows:

- (a) The machine plays first; and all switches are turned to the start position.
- (b) Turn the Machine Next Move Switch until Lamp H lights
- (c) Then enter "X" on the board in the square indicated by the Machine Next Move Switch; and then set the Machine Last Move Switch at the same number as the Machine Next Move Switch.
- (d) Then you as the human player enter "O" on the board in the square you choose, and turn the Player's Current Move Switch to indicate the square where you played.

Repeat steps (b) through (d) until the game is over.

If the lamp W lights, the machine plays where indicated, and wins.

If the machine tries to play in a square already occupied, play in the opposite square instead (this happens on the last play when the game is already a tie).

Sample games produced by this machine are shown below:

0 <sub>1</sub>	X <sub>2</sub>	0 <sub>3</sub>	0 <sub>2</sub>	X <sub>3</sub>	0 <sub>4</sub>	0 <sub>1</sub>	X <sub>2</sub>	X <sub>4</sub>	0 <sub>2</sub>	X <sub>3</sub>	0 <sub>1</sub>
0 <sub>4</sub>	X <sub>1</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>1</sub>	0 <sub>1</sub>		X <sub>1</sub>	0 <sub>3</sub>	0 <sub>3</sub>	X <sub>1</sub>	0 <sub>1</sub>
X <sub>3</sub>	0 <sub>2</sub>	X <sub>5</sub>	X <sub>4</sub>	0 <sub>3</sub>	X <sub>2</sub>	X <sub>3</sub>	0 <sub>2</sub>			X <sub>4</sub>	X <sub>2</sub>

## 28. TRANSLATOR FROM BINARY TO DECIMAL

Problem. A kind of notation for numbers which is very widely used in automatic computers, "giant brains", is not decimal notation but binary notation. The first dozen numbers in binary notation are 0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011. Here the digits are only 0 and 1, and the successive positions report powers of two. Starting at the right, the positions report 2 to the zero power or one, 2 to the first power or two, 2 to the second power or four, 2 to the third power or eight, etc. In this way, 1011 is one one, one two, no fours, and one eight, or a total of eleven.

The reason why binary notation is very useful in automatic computers is that many devices for storing definitely and calculating rapidly are devices which have just two states: on or off; magnetized north-south or south-north; conducting or not conducting; etc.

Furthermore, the addition and the multiplication tables in binary arithmetic are easy and simple, as follows:

$$\begin{array}{r|cc} + & 0 & 1 \\ \hline 0 & 0 & 1 \\ 1 & 1 & 10 \end{array}$$

$$\begin{array}{r|cc} \times & 0 & 1 \\ \hline 0 & 0 & 0 \\ 1 & 0 & 1 \end{array}$$

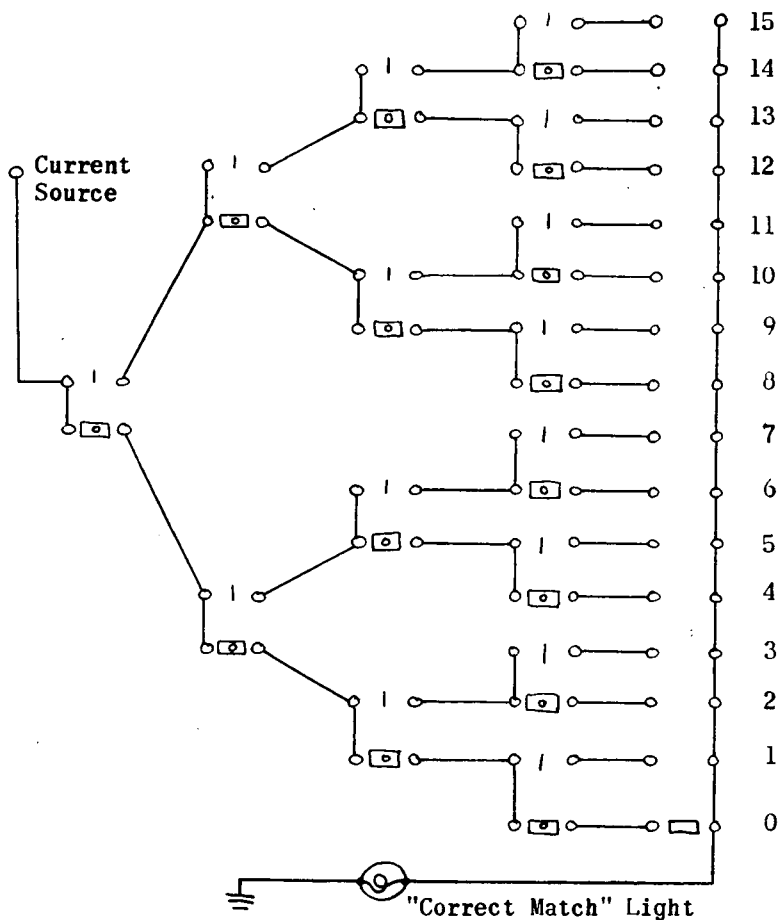
One of the operations needed is to translate from binary numbers to decimal numbers.

What is a machine that will translate the binary numbers from 0 to 1111 into decimal?

Solution. The machine will have five switches: one each for the eight's digit, the four's digit, the two's digit, and the one's digit; and a fifth switch for testing the decimal number which corresponds with the binary number. Following is the circuit. All the wipers are drawn in the zero position.



Binary 8's digit Switch	Binary 4's digit Switch	Binary 2's digit Switch	Binary 1's digit Switch	Decimal Number Switch
-------------------------------	-------------------------------	-------------------------------	-------------------------------	-----------------------------



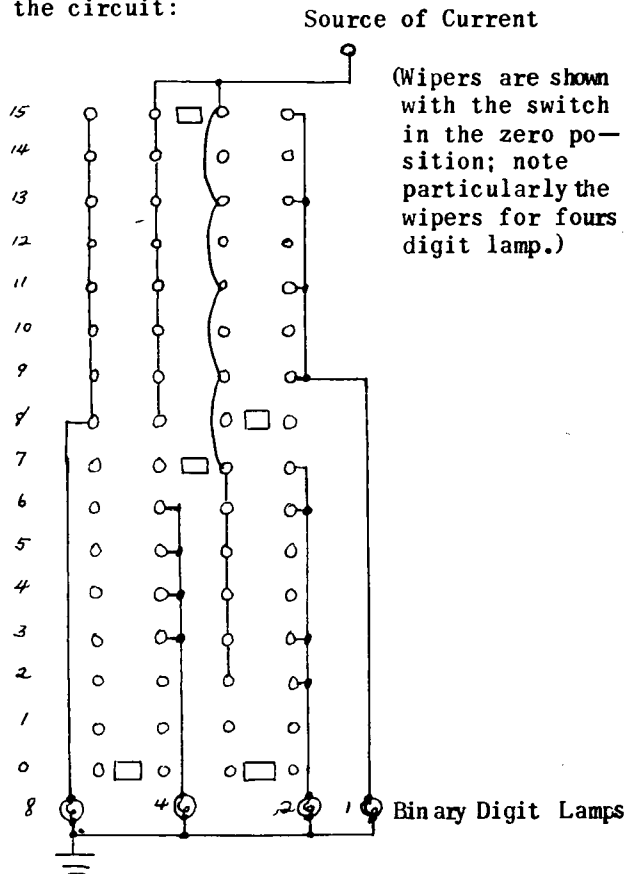
To operate this machine, first set up the binary number on the 4 binary dials. Then turn the decimal dial until the light is lit. The decimal dial indicates decimal equivalent.

29. TRANSLATOR FROM DECIMAL TO BINARY

Problem. Another operation needed is translation from decimal notation to binary notation. What is a machine that will translate from decimal numbers 0 to 15 to binary numbers from 0 to 1111?

Solution. This machine may be obtained by wiring a single switch with sixteen positions and five wipers, using the following circuit. There will be four lamps, for the eights, fours, twos, and ones binary digits. When a lamp glows, it indicates that the binary digit is 1; when the lamp is dark, it indicates that binary digit is zero.

Following is the circuit:



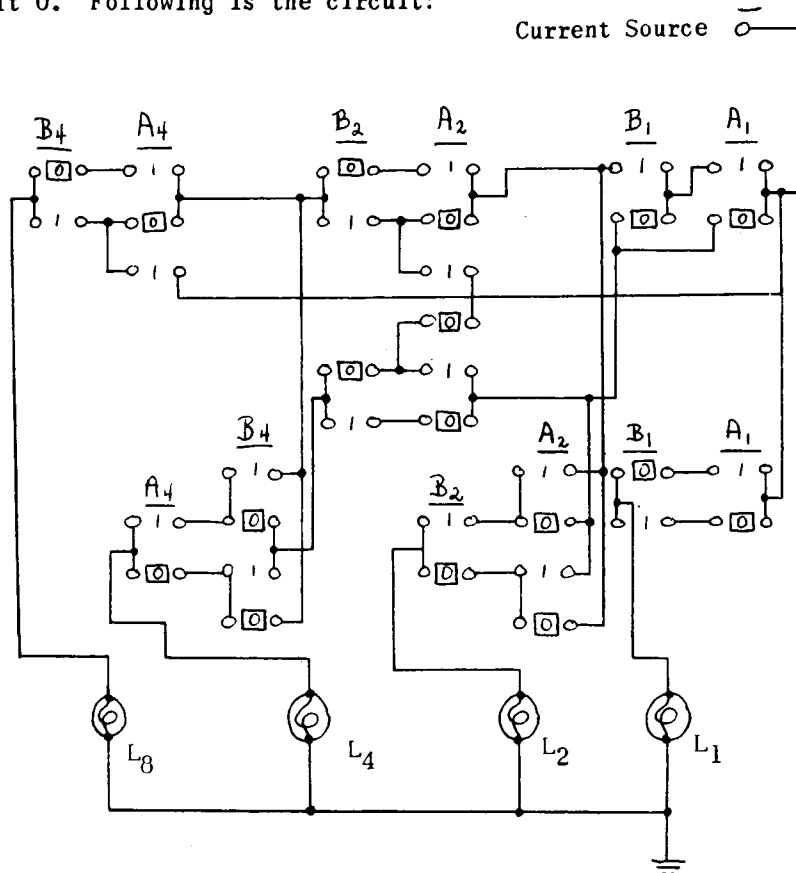
To operate this machine, turn the switch to indicate the decimal number, and the corresponding binary number may be read in the lamps. Here lamp ON = 1, lamp OFF = 0. Note: This translator and previous one can be wired at the same time.

### 30. BINARY ADDING MACHINE

Problem. Given two binary numbers, each of three digits. What is a machine which will give their sum, in binary?

Solution. The input of this machine is six switches, three for the number A, and three for the number B. The binary digits are called successively the 4, 2, and 1 digits. Each of these switches has two positions, one for digit 0 and one for the digit 1.

The output of this machine is four lamps  $L_8, L_4, L_2, L_1$ , corresponding to the 8, 4, 2, and 1 digits. When a lamp glows, it represents the digit 1; when it is dark, it represents the digit 0. Following is the circuit:

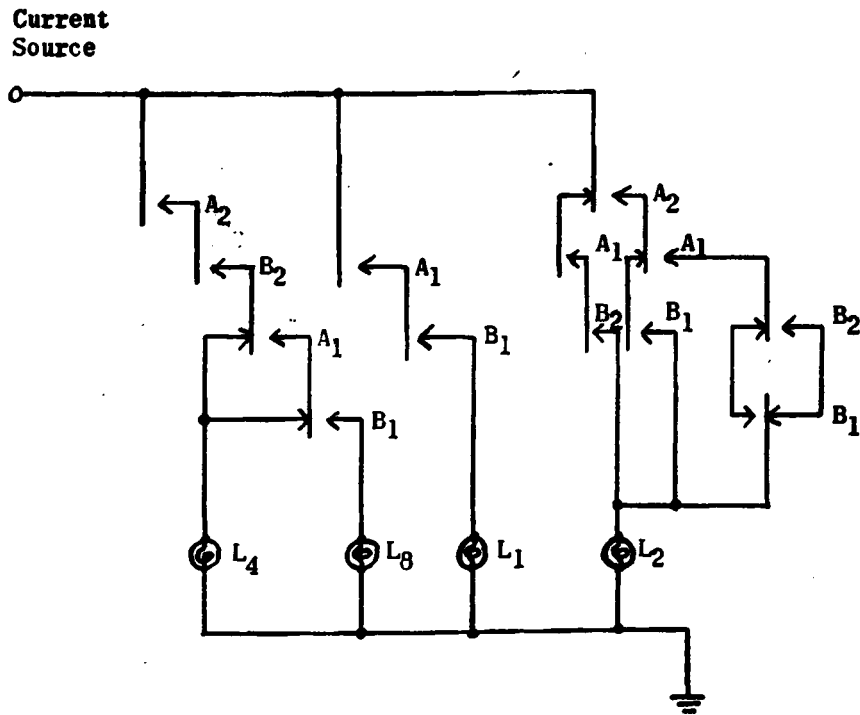


### 31. BINARY MULTIPLYING MACHINE

**Problem.** Given two binary numbers, each of two digits. What is a machine which will give their binary sum?

**Solution.** The input of the machine will consist of four switches, A<sub>2</sub> and A<sub>1</sub> for the number A and B<sub>2</sub> and B<sub>1</sub> for the number B. Each of these switches will have two positions, one for the digit 0 and one for the digit 1.

The output of this machine will consist of four lamps L<sub>3</sub>, L<sub>4</sub>, L<sub>2</sub>, and L<sub>1</sub>, corresponding to the four digits in the 8, 4, 2, and 1 columns, of the binary number, which is the product of A and B. When a lamp glows, it will represent the digit 1; when it is dark, it represents the digit 0. Following is the circuit:



### 32. BINARY COMPARISON MACHINE

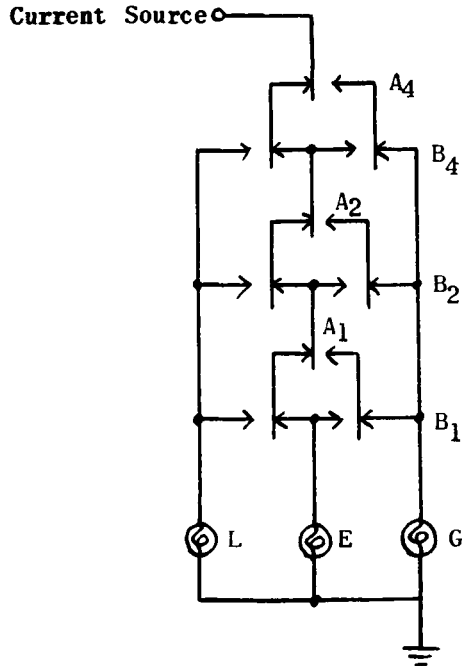
**Problem.** If we use binary notation, we can within the limits of the same hardware compare two numbers that are larger than we can with decimal notation.

Given two binary numbers each of three digits. What is a machine which will report whether A is greater than B, or A is equal to B, or A is less than B?

**Solution.** The input of the machine will consist of six switches. Three of the switches will express the three digits, 4, 2, 1 of the number A. The other three switches will express the three digits 4, 2, 1 of the number B. Each of these switches will have two positions, one for the digit 0 and one for the digit 1.

The output of this machine will consist of three lamps, G for "A greater than B", E for "A equal to B", and L for "A less than B".

Following is the circuit:



### 33. "TWO-OUT-OF-FIVE" CODE TRANSLATOR

**Problem.** In some computers and some telephone exchanges, there is an advantage in representing decimal digits by selecting just two out of five possibilities (lamps, lines, relays, etc.), no more and no less. In this way if a unit of equipment fails, one or three possibilities will be selected, and an error signal can be at once produced.

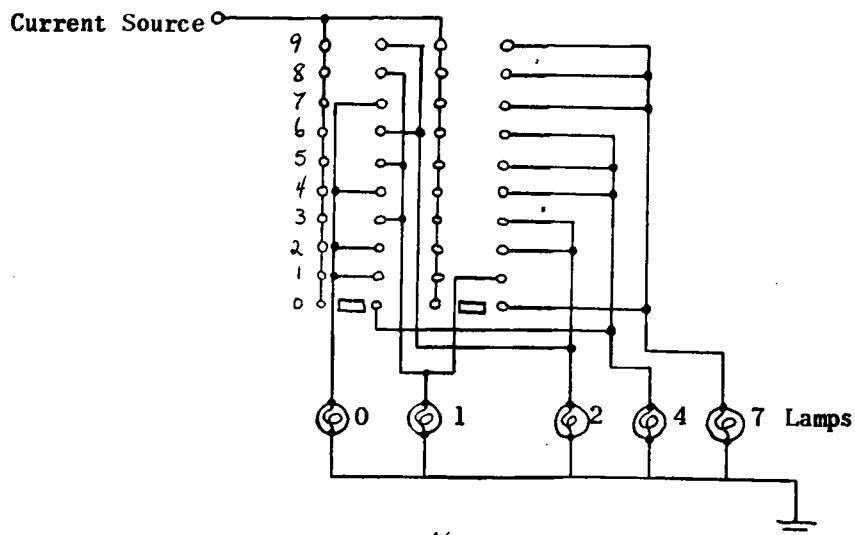
One of the "two out of five" codes which is widely used is the following:

Decimal Digit	2 out of 5 Code	Decimal Digit	2 out of 5 Code
1	0 and 1	6	2 and 4
2	0 and 2	7	0 and 7
3	1 and 2	8	1 and 7
4	0 and 4	9	2 and 7
5	1 and 4	0	4 and 7 (special)

What is a machine that will give this code automatically?

**Solution.** The input of this machine is one switch, with 10 positions and two decks wired as shown in the following circuit.

The output of this machine consists of five lamps bearing the labels 0, 1, 2, 4, 7.



Part II: Materials in the Geniac Electric Brain  
Construction Kit No. 1 and Explanation of Them

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Part II: Materials in the Geniac Kit,  
and Explanation of Them

The Geniac Electric Brain Construction Kit is a kit by means of which anyone can put together the machines of the types described in Part I (and many more besides) so that they will perform operations of reasoning and computing.

The kit is harmless. It runs on one flashlight battery. Wires are connected by fastening them to the same nut and bolt and tightening the connection by gripping them between two bolts. No heat or soldering iron is required. DO NOT CONNECT this kit or any part of it to any home or industrial electrical power outlet: you are likely to destroy the material, and you may hurt yourself.

The kit is simple, but nevertheless it takes effort and work to put the material together to make a functioning electric brain. We urge you to take your time. If necessary, read the instructions several times. If the instructions are still not clear, read ahead and then return.

1. Parts list. In Table 2-1 appears a list of the parts contained in the kit. (All figures over 20 are approximate.)

Table 2-1

50 feet	Wire, insulated
1	Battery, dry cell, flashlight, 1½ volts
1	Battery clamp
10	Bulbs, flashlight, 1½ volts
10	Sockets for flashlight bulbs
90	Bolts, 6/32, ½ inch
160	Nuts, 6/32
1	Screwdriver
1	Spintite blade
1	Crayoff pencil
1	On-Off Switch, assembled
1	Panel, masonite, punched
6	Multiple Switch Tops, circular, masonite, punched
25	Bolts, 6/32, 7/8 inch, for center pivot, etc.
18	Washers, hard



6	Washers, sponge rubber
25	Jumpers, metal, brass plated
1	Manual

2. Wire. The kit gives you about 50 feet of wire covered with insulation. This is like the wire which you will find connecting a lamp to a wall plug, or a telephone to the telephone box, but adapted for handling much smaller currents and voltages. Instead of two wires wound together, here is one wire only. In the wiring that you will need to do, your two wires will be taken care of when you make for yourself a complete circuit, running from one end of the battery around some kind of loop to the other end of the battery.

Your wire will need to be cut apart with a cutting pliers into lengths. Convenient lengths for the wire to be cut into are: 15 pieces about 6 inches long; 15 pieces about 12 inches long; and 15 pieces about 18 inches long.

About three quarters of an inch of the insulation will need to be trimmed off at each end of each piece. You can trim this off neatly with a dull knife; you should try to avoid cutting or nicking the wire.

Two remaining feet of wire should be stripped of insulation and cut into pieces  $1\frac{1}{4}$  or  $1\frac{1}{2}$  inches long. These pieces of bare wire will be used for making transfer contacts on the multiple switches, as will be explained later.

3. Battery. This is an ordinary flashlight battery, of about one and a half volts. A volt is a unit of electric push, or electric pressure, or electric potential. All these terms mean the same thing.

You can think of a battery as a pump, which is able to push electrons, or little marbles of electricity, away from the plus end of the battery and towards the minus end of the battery, waiting for some kind of circuit at the minus end so that the electrons can flow around the circuit back to the plus end of the battery. A flow of electrons is an electric current.

The filament in the bulb through which the electrons flow provides a resistance or restriction or narrowness for the flow of electrons, so narrow in fact that it heats up and glows with friction as the electrons go through it.

If at some time your battery will not light a bulb, or

will only make it glow feebly with a dim orange light, then your battery has run down.

4. Battery Clamp. This consists of a metal clip that fastens into the panel and which will grip your battery and hold it. You then can fasten connections to the battery clamp and yet snap out your battery when it is weak and snap in another stronger battery in place of it when you need to.

5. Bulbs. You have ten small light bulbs in the kit. They will glow from a single flashlight battery. In order to make them light, you have to run one wire from the bottom metal plate of the battery to the side of the bulb, and another wire from the top of the flashlight battery to the center of the base of the bulb. Your connections must be clean, not oily, or corroded.

Examine your bulbs closely from time to time and make sure that the filament, the little slender wire that you can see inside the glass bulb, is all in one piece. If it is broken, the bulb is spoiled.

6. Sockets. You have ten sockets for flashlight bulbs. The sockets may be fastened to the panel. They are for holding the light bulbs, so that they can be screwed in and out of their sockets.

7. Nuts and Bolts. For fastenings, connections, and terminals, here and there all over the machine you have a supply of bolts (90) and a supply of nuts (160). The bolts are of steel, the nuts are of steel, and they should give good electrical connections. A bolt is inserted through any hole; then a nut is screwed down tight on the bolt holding it in position; then the connecting wire is wound around the end of the bolt coming through; then a second nut is screwed down tight on the wire and the bolt so as to give a tight electrical contact. (For one or two of the machines you may need a few more nuts and bolts.)

8. Screwdriver and Spintite. In order to fasten your nuts and bolts easily, you have a small screwdriver, which fits in the slot of the bolt and enables it to be turned, or aligned. You also have a small piece of hexagonal tubing (a spintite blade) which fits over and grips the hexagonal bolt and enables it to be spun quickly down the shaft of the bolt, and tightened.

9. Crayoff Pencil. For writing the names or letters

designating switches, switch-positions, and lights, you have a white "crayoff" pencil. This kind of pencil is made with a soap base formula, and the marks it makes can be wiped off any surface with a wet cloth. Thus you can very easily change the labels from one experiment to the next.

10. On-Off Switch. In the kit is a small assembled switch which is used for turning a machine on or off, and so we call it the on-off switch. This is the switch which enables you to put suspense and drama into your machine; for you set everything the way it should be, then talk about it and explain it, and finally when you have your listener all keyed up and ready, you (or he) throws the switch that turns the machine on. Then you both can see (if everything has been prepared correctly) that the machine behaves as it should.

11. Panel. In order to assemble your materials together into a machine, you have a rectangular panel consisting of masonite (thin pressed fiberboard). It contains holes for nuts and bolts so that the various parts of the set may be mounted together and assembled firmly.

If you examine the panel, you will see two patterns of holes. One pattern (shown in Figure 2-1) consists of 102 holes arranged mainly in two rows through the middle of the panel from end to end.

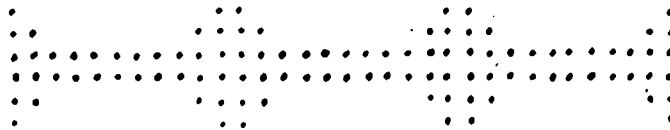


Figure 2-1

In this set of holes, all the hardware of a machine is mounted except the "multiple switches", which will be explained in a moment. The second pattern consists of 6 rosettes of 65 holes in a circular arrangement (shown in Figure 2-2). These are the 6 "bases" of the multiple switches.

12. Multiple Switches. The remaining material which you have in the kit consists of 6 round pieces of masonite, each containing 65 holes in the same circular arrangement (see Figure 2-2), and the hardware for assembling them into multiple switches, switches which are able to switch many circuits at the same time. Each of the circular pieces of masonite is

about 4 3/8 inches in diameter, is illustrated in Figure 2-2, and is called a multiple switch top (or switch disc, or switch dial).

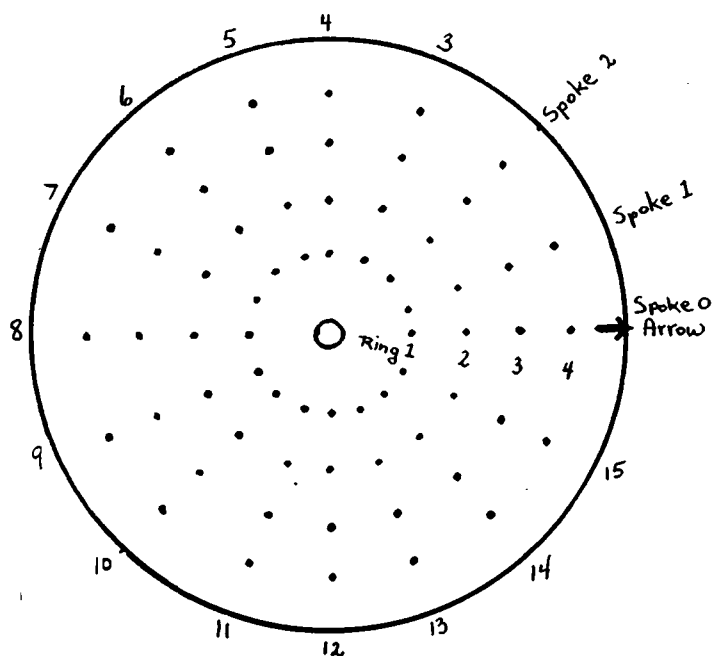


Figure 2-2

In the panel each of the exactly similar sets of 65 holes is called a multiple switch base. In an early stage of the design of the kit, the switch bases were 6 separate pieces of masonite; but then it became evident that mounting of the hardware to make a machine would be better accomplished by having all the switch bases solidly connected.

The top of a switch is fastened to the base of a switch by means of a center pivot, consisting of a long bolt, washers, and a sponge rubber washer; the assembly of the center pivot is shown in Figure 2-3.

The holes (except the center hole) in each switch base and switch top are arranged in 4 rings and 16 spokes. The rings are called Ring 1, 2, 3, 4 going outward, and the spokes are called Spoke 0, 1, 2, 3 and so on around, to Spoke 15,

starting with the spoke directly to the right, and going counterclockwise. See Figure 2-2.

Each of the holes in the switch base may or may not contain a brass bolt, called a terminal, for making connections. The connections are made using two steel nuts, one for fastening the bolt securely to the switch base, and the second for holding and tightening a wire around the bolt so as to make a good electrical connection with the bolt (see Figure 2-4).

Each pair of holes in a switch top, from Ring 1 to Ring 2 or from Ring 3 to Ring 4 (or very rarely from Ring 2 to Ring 3) may or may not contain a jumper (also called a wiper), a small piece of brass plated metal like a T fastener, as shown in Figure 2-5. The two brass arms fit into holes in the switch disc and are pressed down like a clasp. A jumper serves to make and break electrical contact as the switch is turned.

13. Assembly of the Multiple Switches. Before any of the multiple switches can function, however, it must first be assembled. Into the base we have to insert a number of nuts and bolts to hold wire connections. Just where these are inserted depends on the type of switch we desire to construct, two-position, or four-position, or some other type.

Into the top of the switch we must insert a number of jumpers in order to make and break contacts. Each jumper is inserted along a spoke between one ring and the next. Just where the jumpers are inserted again depends on the type of switch we desire to construct.

In order for the switch to stay in a position to which it is turned, the body of the jumper must line up with the slots in the heads of the bolts, and these slots must be in line with the spoke, and then the jumpers will have a tendency to catch in the slots of the screws, as they should, to hold the switch in position (see Figure 2-6). Note that in Figures 2-6 and 2-7 the rings and spokes are drawn as thin lines: these lines are not actually drawn on the switch discs nor the switch bases, nor do they represent electrical lines connecting terminals; instead they are drawn to make the layout clearer.

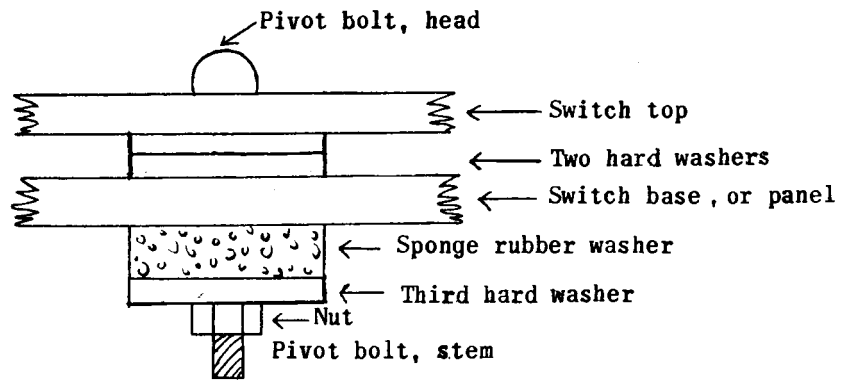


Figure 2-3 -- Center Pivot Assembly

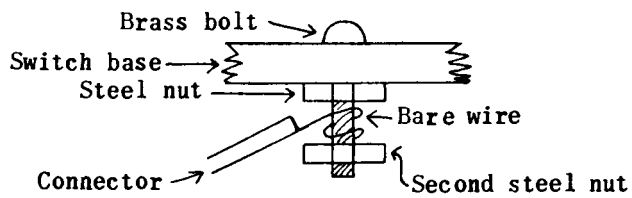


Figure 2-4 -- Assembly of Terminal Bolt and a Wire Connector

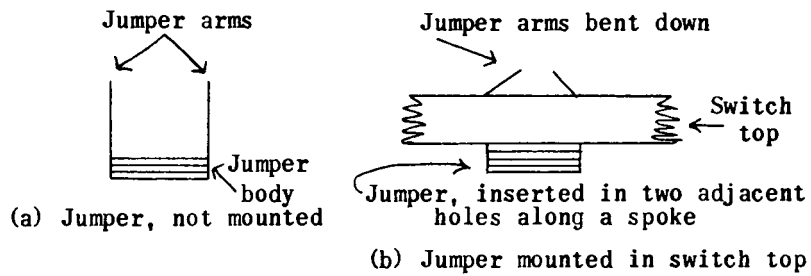


Figure 2-5 -- Jumper

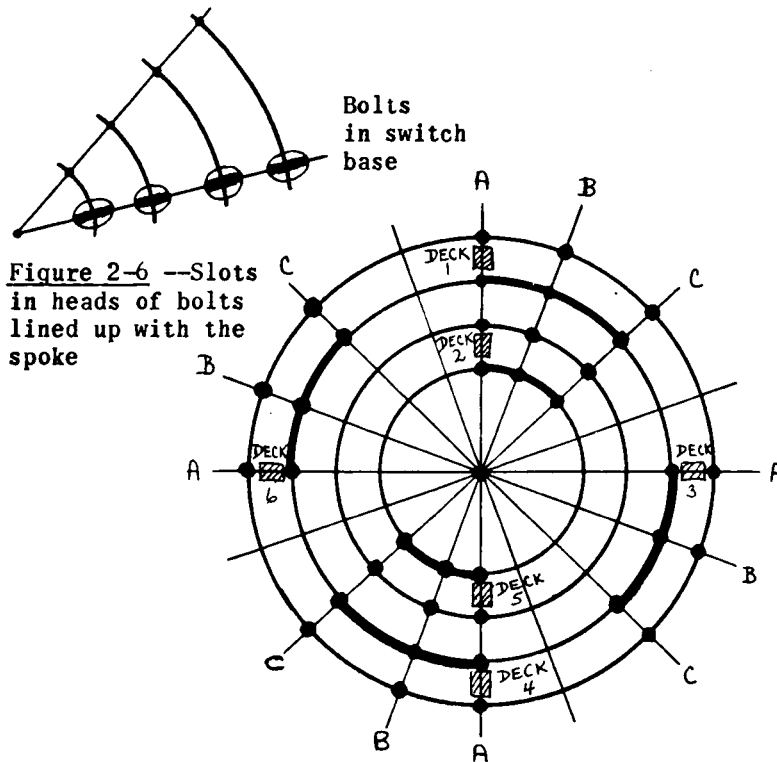



Figure 2-6 --Slots in heads of bolts lined up with the spoke

Figure 2-7 — Three Position Switch, Six Decks (or Poles or Levels).

Now suppose we wanted to assemble a switch which would have any one of three positions A, B, and C, and which would be capable of switching every one of six different circuits. A way in which that switch could be assembled is shown in Figure 2-7, in which both the top and the bottom of the switch are drawn over each other. Six jumpers are inserted in the top of the switch, shown as  in Figure 2-7. It is important that jumpers be inserted in pairs opposite each other, so that the top of the switch will stay parallel to the bottom of the switch. A total of six times six or 36 nuts and bolts are inserted in the bottom of the switch, in the spots marked ● in Figure 2-7. They are in groups of six called decks (also called poles, or levels); these decks are electrically independent, and they enable us to switch 6 different circuits. The holes belonging in any one deck in Ring 1 or Ring 3 are connected together by wire, as shown by the heavy line; they are connected with one of the short wires 1½ inches long. They are made electrically

common; in other words, they are commoned. Together they constitute what is called a transfer contact.

Let us now consider the layout of the spokes and the rings and the 64 holes which they produce. We can see that we can assemble a switch in a number of different ways. This is the advantage of the design of the multiple switch we have chosen (on which patent is being applied for). Here are the types of switches that can be made with these parts:

<u>Number of Positions</u>	<u>Maximum Number of Decks</u>
2	16
3	10
4	8
5	6
6 to 8	4
9 to 16	2

If nuts and bolts did not cost anything, we could insert 64 nuts and bolts into the base of each switch and leave them there -- ready for use in any switch. Actually, because the kit has a limited supply, it may be necessary to move nuts and bolts from one switch to another in order to make the different machines we want.

In the case of jumpers, we shall fairly often have to move them to different places, in order to make different switches for different machines.

14. Additional Material. You may obtain additional or replacement material for this kit by buying it at a local store, or by writing to us. Obviously, if your battery runs down, or if you want more wire, or if you want more nuts and bolts, the easy thing to do is to buy them in your neighborhood. But for more switch disks or for more jumpers, etc., you will probably need to write us. Prices for these items are listed on a price list which may be obtained on request.

15. Wiring Lists and Templates. In work with electrical circuits we need to lay out beforehand what we are going to do. We need to design on paper how we are to connect the different pieces of material. For this purpose, we use (1) circuit diagrams, (2) wiring lists, and (3) templates.

A circuit diagram, as mentioned before, shows the scheme of connection of batteries, switches, lights, etc., in order



to make the circuit. In a circuit diagram we pay little attention to the actual physical location of the material; we just show a diagram of its arrangement.

In a wiring list, we name the terminals, by words or letters or numbers, and we state, for every part of the circuit, what terminal is connected to what terminal. In a wiring list again we pay no attention to the actual spatial locations of the terminals.

In a template, the case is different; we show the wiring and for any difficult portions of the circuit, such as the multiple switches, we show the approximate relative spatial location of the different pieces of material used in the circuit. In other words, we draw a picture of where the terminals are, and then we indicate the wiring either by drawing lines for the connections or by writing notes showing the connections.

16. An Example. Suppose we have a circuit as shown in Figure 2-8. This circuit consists of two switches A and B, each having the positions 1, 2, 3, two lights marked E and O, and a battery. Only one deck of switch A is used but three decks of switch B are used.

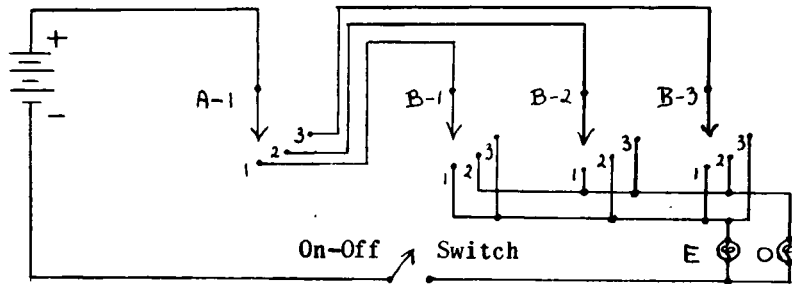


Figure 2-8 -- A Sample Circuit

What would the wiring list for this circuit be? It would be as follows:

<u>Wire From</u>	<u>To</u>
1. One side of battery, Battery Plus	Transfer of Switch A, Deck 1
2. Switch A, Deck 1, output 1	Transfer, Switch B, Deck 1
3. A-1, 2	B-2, T

<u>Wire From</u>	<u>To</u>
4. A-1, 3	B-3, T
5. B-1, 1	One side of light E, E 1
6. B-1, 2	One side of light O, O 1
7. B-1, 3	B-1, 1
8. B-2, 1	O 1
9. B-2, 2	E 1
10. B-2, 3	B-2, 1
11. B-3, 1	E 1
12. B-3, 2	O 1
13. B-3, 3	B-3, 1
14. E 2	O 2
15. E 2	One side of On-Off Switch
16. Other side of On-Off Switch	Other side of battery, Battery Minus

Here then is an example of how a list of wiring instructions for a circuit can be prepared. The list specifies where each wire comes from and where it goes. Furthermore, instead of running long wires from certain outputs of the decks of switch B over to one side of the lights, we take short cuts by hitching on at an early point to a wire already running to the desired destination.

Now some circuits are so simple that no wiring list is needed. In many complicated circuits (especially in circuits in computing machines and other kinds of large electric brains), the wiring is so complicated that a written-out wiring list is unavoidable.

What would be the template for this circuit?

The way the template would look is shown in Figure 2-9, although here we have simplified the picture of the switch base and the switch top so that we show only two rings instead of the four rings that it actually contains. We can see that there is a considerable difference between the circuit description of a multiple switch and the template description of a multiple switch; but we can also see the close relation between them.

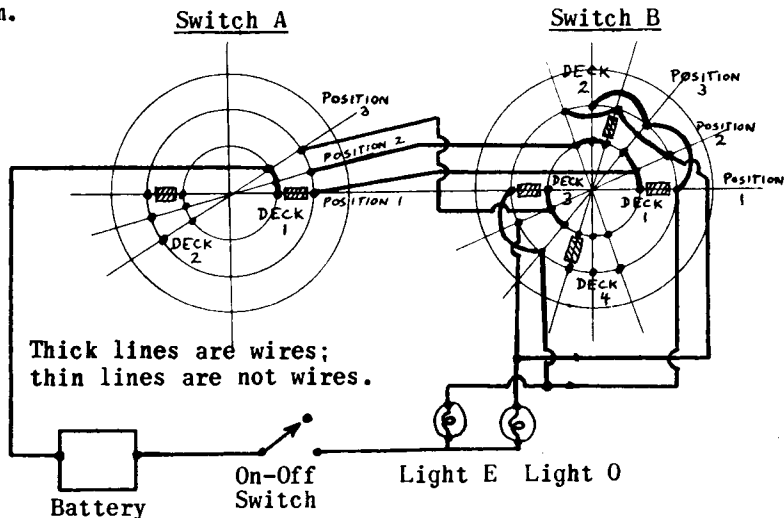
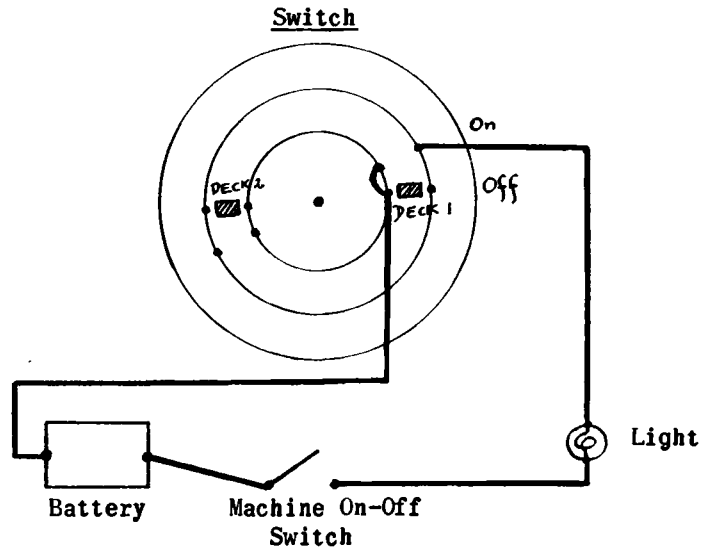


Figure 2-9 -- Template for the Sample Circuit

The question may be asked: Why in putting together the multiple switches, are jumpers, nuts and bolts inserted where they are not electrically necessary, as in Deck 2 of Switch A (in Figure 2-9) and in Deck 4 of Switch B? The answer is that the additional symmetrically placed hardware is needed for mechanical reasons; by putting it in, the central rubber washer which acts as a spring will pull the switch top at right angles instead of obliquely, which would result in poor electrical contact. The multiple switches should always be constructed symmetrically in this way for mechanical reasons. Since this mechanical aspect can from now on be deduced, we may omit this part of the assembly in the drawings of future templates.

17. Detailed Wiring for "The Flashlight". We shall now consider the details of the assembling and wiring of the kit materials so as to make the first machine, "The Flashlight". Following is the template for this circuit:

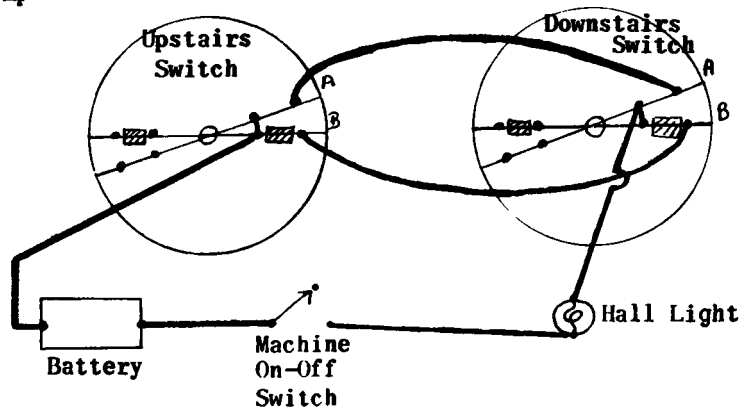


One multiple switch only is needed. The top is fitted with two opposite jumpers. The base is fitted with eight bolts in the pattern shown. The battery is mounted on the panel in the battery clamp; the machine "on-off switch" is also mounted; and a light in its light socket is mounted. Wires run: from one side of the battery to a common terminal of Deck 1; from the "on position" of the switch to one side of the light (light socket); from the other side of the light socket to one side of the machine on-off switch; and from the other side of the machine on-off switch to the other side of the battery.

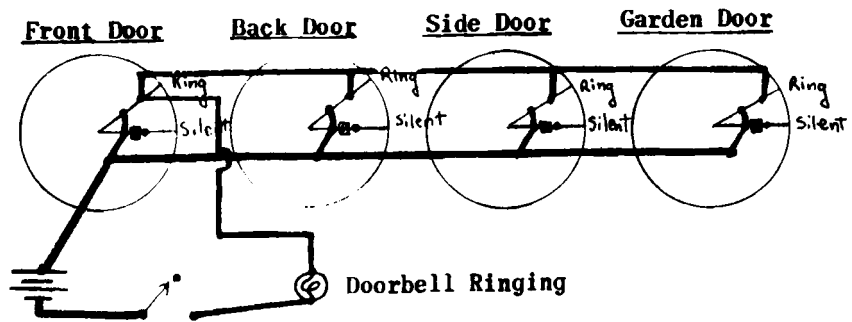
18. Detailed Wiring for "The Hall Light". Wiring list:

<u>From</u>	<u>To</u>
1. Battery, Plus	Upstairs Switch, Transfer
2. Upstairs Switch, Position B	Downstairs Switch, Position B
3. Upstairs Switch, Position A	Downstairs Switch, Position A
4. Downstairs Switch, Transfer	Hall Light, one side
5. Hall Light, Other side	On-Off Switch, one side
6. On-Off Switch, Other side	Battery, Minus

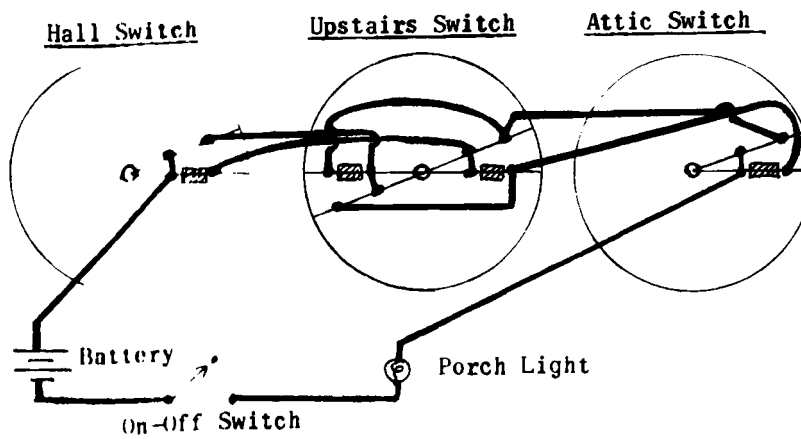
Template:



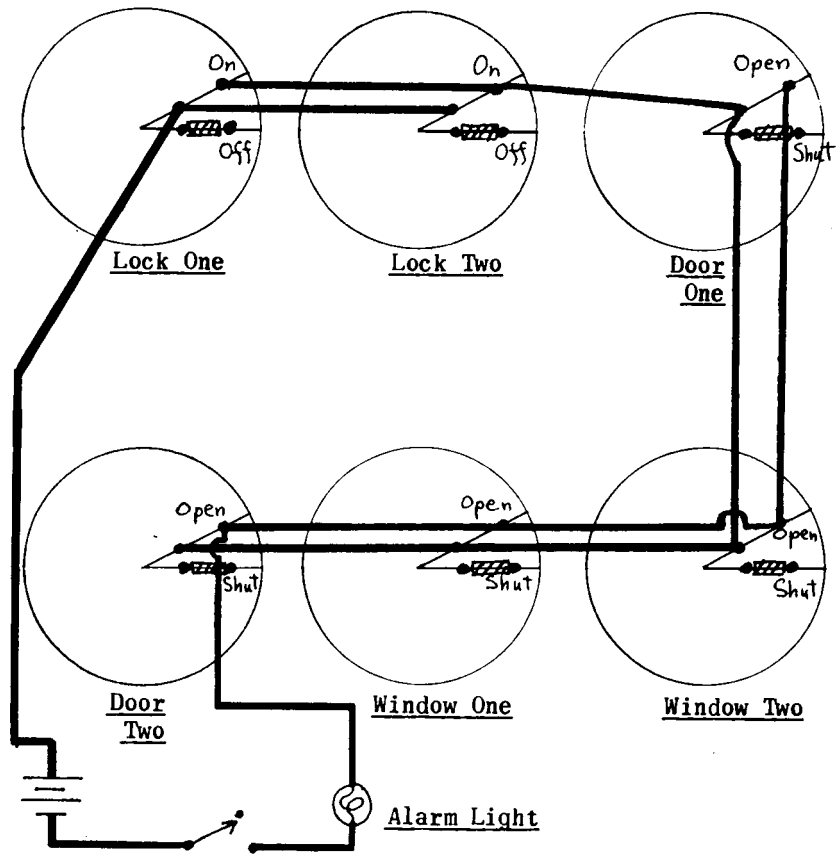
19. Detailed Wiring for "The Doorbell"



20. Detailed Wiring for "The Porch Light"



21. Detailed Wiring for "The Burglar Alarm"



**22 . Detailed Wiring for "The Two Jealous Wives". Wiring**

**Instructions:**

<u>From</u>	<u>To</u>
Minus end of battery	transfer, deck 1, switch H1 (H1-1:T)
H1-1: I	transfer, deck 1, switch H2 (H2-1:T)
H1-1: N	H2-2:T
H2-1: I	safety light, side 1
H2-1: N	W1-1: T
H2-2: I	W2-1: T
H2-2: N	safety light, side 1
W1-1: I	"
W1-1: N	W2-2: T
W2-1: I	safety light
W2-1: N	W1-2: T
W2-2: I	C-1: T
W2-2: N	C-2: T
W1-2: I	C-3: T
W1-2: N	C-4: T
C-1: I	safety light, side 1
C-1: N	danger light, side 1
C-2: I	"
C-2: N	safety light, side 1
C-3: I	"
C-3: N	danger light, side 1
C-4: I	danger light, side 1
C-4: N	safety light, side 1
danger light, side 2	plus end of battery
safety light, side 2	plus end of battery

In the above, T stands for "transfer contact"; I stands for contact "in canoe"; N stands for contact "not in canoe".

