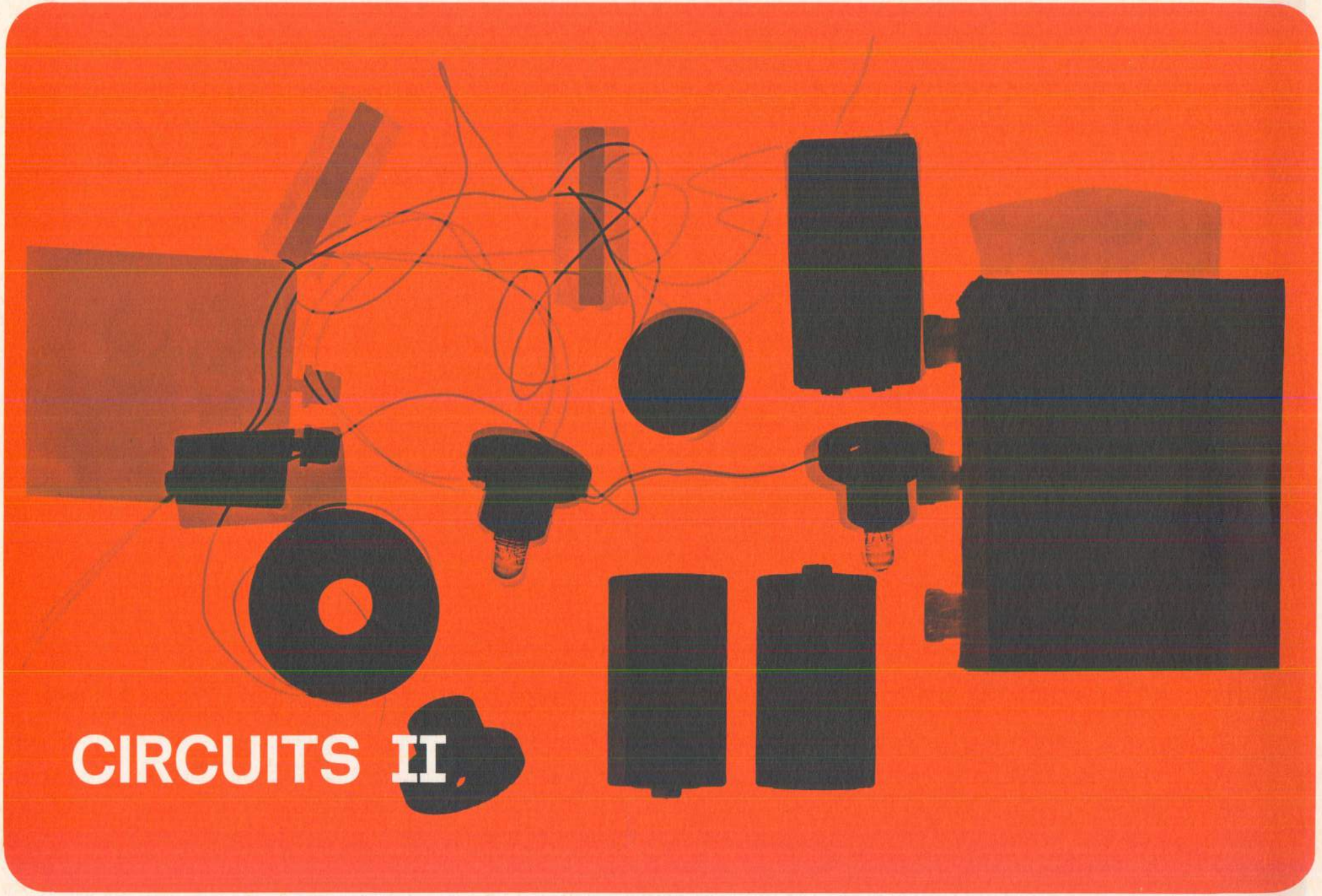
BATTERIES AND BULBS

Book 3



CIRCUITS II

BATTERIES AND BULBS

Teacher's Guide

Trial Teaching Edition

Book 3

CIRCUITS II

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CONTENTS OF CIRCUITS II

INTRODUCTION

Circuits II

Circuits II deals in greater depth with the batteries, bulbs, and wires first encountered in *Circuits I*. 6th, 7th and 8th grade children often get into some of these problems not long after they have started *Circuits I* simply through pooling their equipment to make more elaborate circuits. For them, some of these more analytical experiments are of interest. In this case, *Circuits I* and *Circuits II* can be presented more or less together.

For the earlier grades, *Circuits I* is ample challenge by itself, and *Circuits II* might then become a second course, to be taught later in the year, or in another year.

A great deal of *Circuits I* was characterized by zestful free exploration, where one result was as intriguing as another. In *Circuits II,* the joy comes more and more from making predictions and drawing conclusions. If the prediction turns out to be wrong, it is a challenge; if right, a satisfaction, but it is always helpful for the children to attempt to make predictions.

In experimental activities prediction is an excellent evaluation of understanding. Correctly predicting how bright a bulb will be or how long a battery will last in a given circuit calls upon the children's thorough knowledge of the phenomena involved.

Circuits II includes work with more complex circuits, Nichrome wire and other batteries. Investigations by individuals or by the class as a whole may lead from one area to another and back again; the problems are interrelated. Proceeding in the order given may be helpful the first time you teach this, but by the time you are familiar enough with what batteries and bulbs can do and what children can do with them, attempting to maintain this order will be a limitation rather than a help.

There are quite a few prediction sheets included in *Circuits II*. You may want to add other examples to these selections.

Special investigations are also included for some topics to give additional viewpoints on a particular experiment. If these special investigations are handed out for individual exploration, they should be used only with children who have a great interest in *Batteries and Bulbs*. However, they can also be used as class activity where you can ask everyone, or individuals, to do certain experiments, and then discuss the results together.

There are no teacher workshop sections in *Circuits II*. You will definitely need to read the introduction to *Batteries and Bulbs* and work through the materials in *Circuits I* if you have not previously taught the unit. We suggest that before undertaking to teach a particular section in *Circuits II* you become familiar with some of the activities by doing the experiments and trying out some of the prediction sheets and special investigations. After working with *Circuits I* you should have a feeling for how much advanced investigation you will want to make into the subject matter of this unit.

If your class did *Circuits I* and *Circuits and Magnets* a year or two ago, a couple of review lessons may be needed.

You may need to refer back to *Circuits I* for additional activities.

REVIEW OF CIRCUITS I AND CIRCUITS AND MAGNETS

NEW MATERIALS FOR REVIEW

for the class —

Rolls of #32 (thin) Nichrome wire, #26 (thick) Nichrome wire and #24 Formvar (enameled copper wire)

Have available more of everything on list below.

for each child —

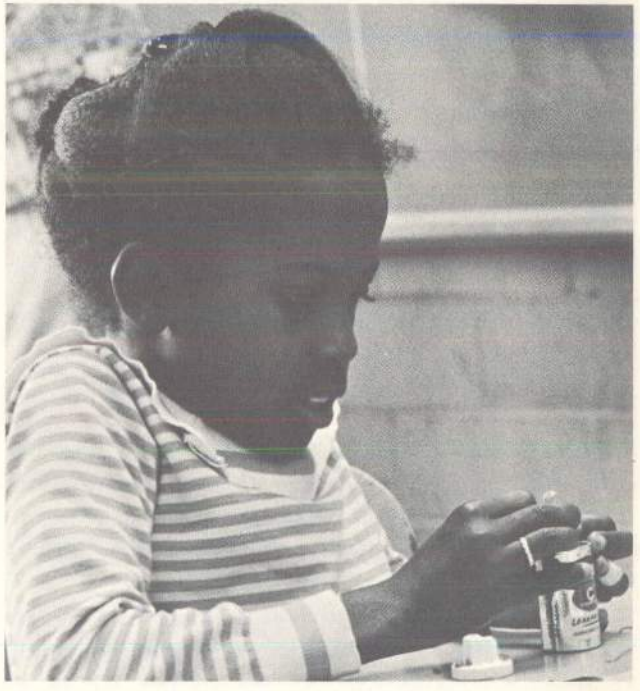
2 "D" batteries with holders
2 #41 bulbs (WBs)
2 #48 bulbs (PBs)
2 bulb holders
2 eight-inch pieces #22 copper wire (plastic-insulated)
Box to keep materials in
4 eight-inch pieces #20 (thick) bare copper wire

Activities Children May Try

Light a bulb without battery holder or bulb holder.
Light a bulb using both types of holders.
Short-circuit a bulb.
Short-circuit a battery.
Light two bulbs at once.
Dim a bulb with Nichrome wire.
Make Nichrome wire hot.
Make circuit diagrams for other children.
Set up circuits from someone else's circuit diagrams.
See how many different-looking arrangements can be made from only one circuit diagram.
Use a galvanometer* to test what is happening in several paths of a circuit.

NOTE: Suggest some more of the earlier activities and discuss some of the conclusions that were made in previous work until you feel the children are ready to go on to the new material.

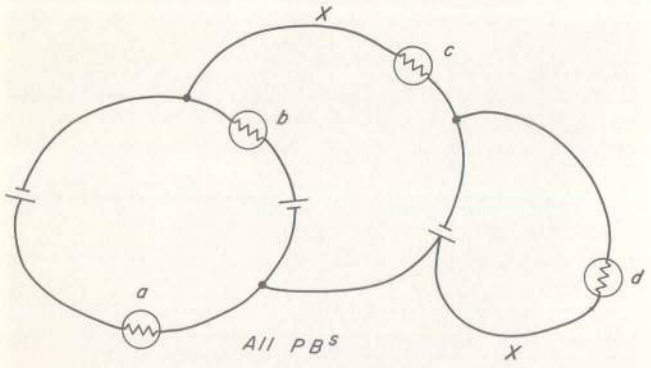
*If you have not previously done **Circuits and Magnets,** disregard any mention or use of galvanometers in this material.



COMPLEX CIRCUITS

General Comments

One group of 8th graders pooled their equipment and came up with this circuit:



Bulb *d* was standard (the light from one PB connected to a "D" battery); *b* was brighter and *c* could barely be seen. When they put a wire between the two X marks, all the bulbs became standard!

They were enthralled and mystified by it. So were both the teachers who were present — one of them spent the rest of the period trying to understand it. (He tried to predict what would happen if a bulb were unscrewed, or if a battery added to another wire were introduced.)

Such circuits are intriguing, and it is certainly worth allowing scope for their invention. It is also worth looking at much more simple circuits, where some basis for predictions can be developed. For instance, the children should become thoroughly familiar with circuits involving only one battery and several bulbs and with circuits involving one bulb with two, three, or four batteries.

This section poses some ways to look at these complex but manageable circuits. In general, children may study circuits involving:

two batteries and two bulbs
several batteries and one bulb
one battery and several bulbs
several batteries and several bulbs.

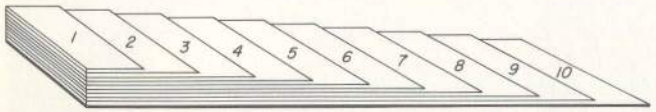
In each case, let the children explore freely ways they can put the batteries, bulbs and wires together. It may be a good idea to have the children put drawings and diagrams on the blackboard so that they can compare the various combinations.

After at least two classes of work on their own with each type of circuit, the children can be given prediction sheets with ten or twelve diagrams for study. For some children this crystalizes what they know. For others, it is a way to make sure that they do make a variety of circuits. They can start by making a prediction of brightness of the bulb in each case and then check the predictions with their equipment. It should be made clear to the children that the sheets are not a teacher's test but a way for them to check their own predictions. The children should keep the prediction sheets for their own records. It will probably be necessary to help the children individually so that they will develop their own ideas of how and why the circuits behave as they do.

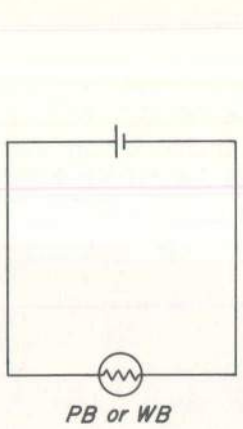
The focus of attention in this section is on the brightness of bulbs, and clearly some agreement

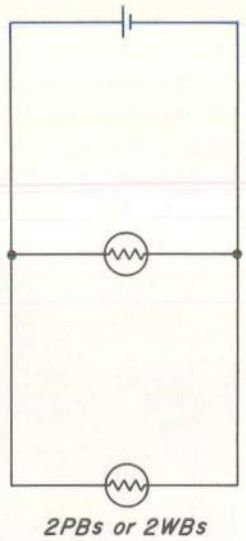
will have to be reached in judgments of brightness. It is useful to establish the brightness of one bulb (usually PB) attached to one new "D" battery as "standard brightness." Bulbs can then be judged as "very dim," "dim," "standard," "bright," "very bright."

An alternative is to construct a brightness "meter" from about ten two-inch by ten-inch strips of white paper. The strips are put in a pile and pasted together at one of the two-inch edges. The bottom strip should be the full ten inches long, the one on top of it should be nine inches, the one on top of that, eight inches, etc. Therefore, the finished meter has one-inch sections of different thickness of paper. The different sections can be numbered from one to ten.



If a child can first see a lighted bulb through the third section, then he may say it has a "three" brightness. The children should all use the same type of paper if any meaningful comparison is to be made. Where the meter is placed in relation to the bulb as well as background lighting (bright room, dark closet) are both factors in getting consistent results. One class found that putting the circuit to be tested in a shoe box and placing the meter directly on the bulb maintained the most nearly identical experimental conditions. Your children may also want to mark their meter to correspond to very dim, dim, standard, bright, and very bright. For the PB, a "one" on the scale may be very dim while a "six" may be standard. A different scale would be made for the WB. To begin with, the children should try out their brightness meters on these circuits to see if a PB or a WB is brighter.





The compass galvanometer or the other meter your class might have made, if they have already done *Circuits and Magnets,* will be useful to use with the brightness meter or as an alternative to it. Any galvanometer can be put in a path of a circuit that is being studied to give a more exact and numerical idea of what is happening in that path. We have found that only a few children in each class (the higher the grade, the more children) wish to spend the extra time needed to use the galvanometer in the experiments in *Circuits II.* However, those who do feel it is time well spent.

There are a few techniques of experimentation which will almost always contribute something throughout this study of more complex circuits, and the children should be urged to do them often. These techniques are the following:

1. From a circuit containing several bulbs, remove one bulb at a time and see what happens to the remaining ones.
2. Use a piece of thick copper wire to short-circuit a bulb, a battery, or any combination and see what happens to the remaining bulbs.
3. Do lifetime tests with batteries in various circuits. Compare how long the battery lasts in each case. (How many of these the children can do, of course, depends on your budget for extra batteries.)

NOTE: Generally, when a bulb is mentioned, and no reference is made to type, either can be used. However, if two or more bulbs are indicated, all should be of the same type (either WB or PB) unless specifically stated otherwise.

A. Two Batteries — Two Bulbs

MATERIALS FOR TWO BATTERIES — TWO BULBS

No new materials needed

Activities Children May Try

Connect two batteries to two bulbs so each bulb is standard brightness.

Connect two batteries to two bulbs so each bulb is brighter than standard.

Connect two batteries to two bulbs so each bulb is less than standard brightness.

Make diagrams of other circuits.

Notice that the same diagram may represent different-looking circuits.

Unscrew bulbs in circuits to see what happens.

Touch a wire from one part of a circuit to other parts to see what happens.

Set up a lifetime test for the batteries in two bulb — two battery circuits.

Compare these results to those found when a combination of WBs and PBs is used.

Predict the result and then test the prediction by constructing the circuits on **Prediction Sheet A.**

Comments on Prediction Sheet A

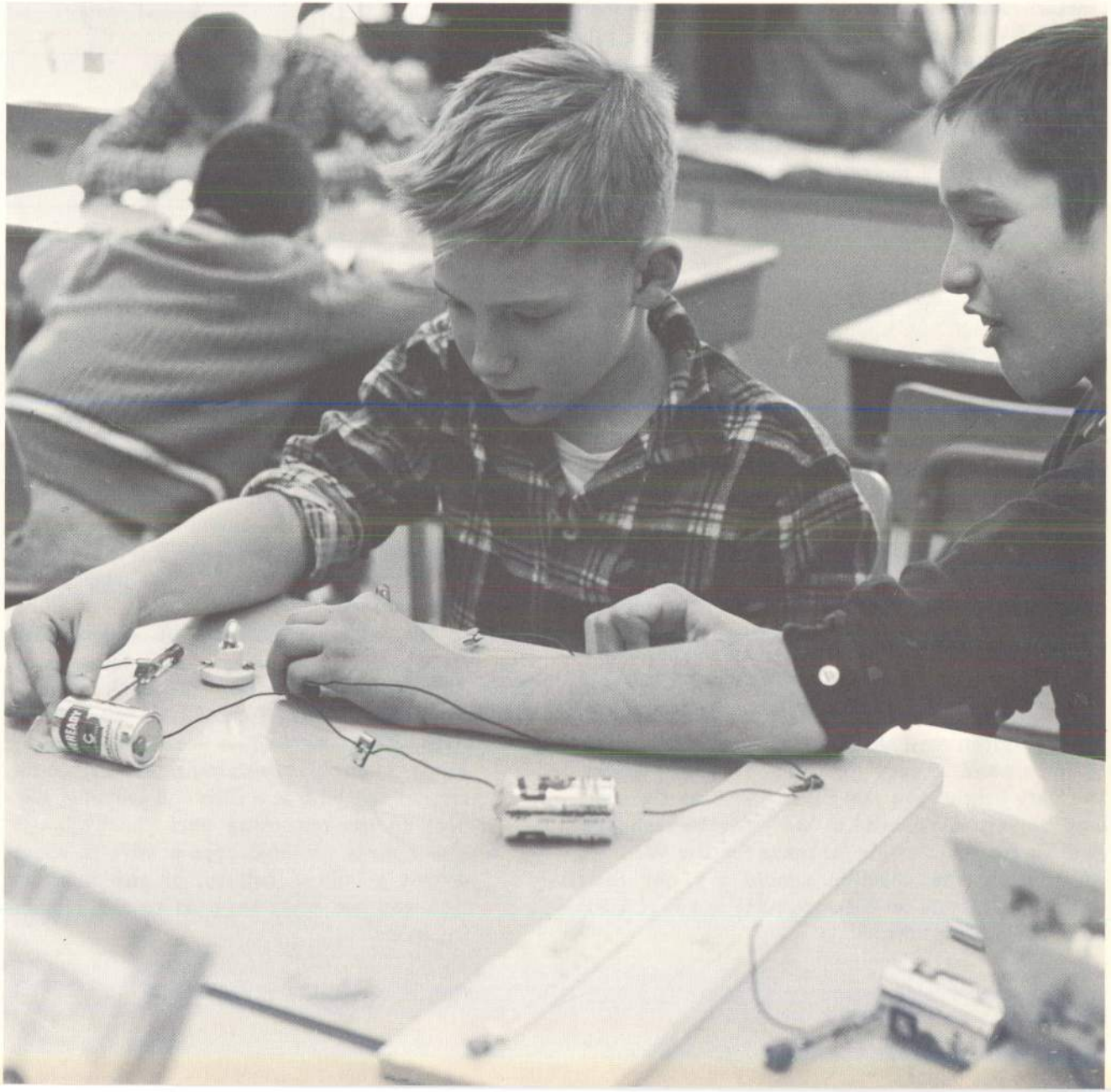
Circuits **7** and **5** raise the most significant and puzzling questions in **Prediction Sheet A.** Note that in each case, two batteries are lighting two identical bulbs. Why are the bulbs the same brightness in each case? The same number of batteries (one) are "across" **each** bulb in both cases.

The galvanometer can be put to good use in comparing circuits 5, 6 and 9 to see what differences, if any, are elicited by changing the **position** of some item. Also 7, 8 and 12 should be compared with the same ideas in mind.

With "D" batteries and PBs, battery lifetime tests will run from three to ten days, depending on the circuit.

Be sure the children decide on some criterion for determining that a battery is "dead." When a battery will no longer light two bulbs, it may still be able to light one bulb or move the galvanometer needle. This means that every once in a while batteries should be tested with a bulb. A battery is not "dead" if it will still light one bulb.

Circuit 11 is of special interest. If the wire is not connected midway between the batteries and bulbs, it is like circuit 9 where the bulbs do not light. With this new path the bulbs light with standard brightness.

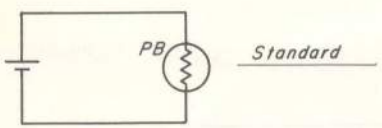


CIRCUITS II

Prediction Sheet A

In the circuit diagrams below, write beside each bulb how bright you think it will be: very bright, bright, standard, dim, very dim.

1



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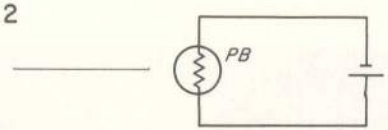

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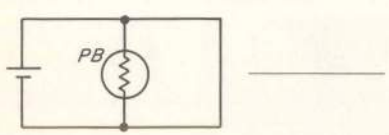

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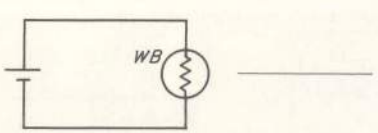

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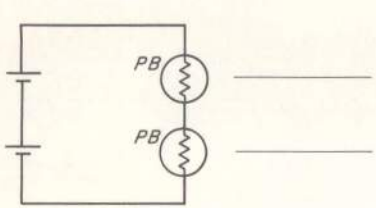

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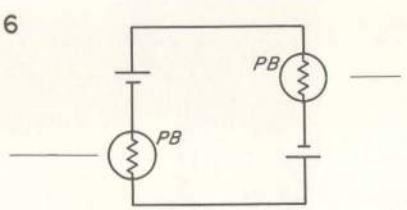

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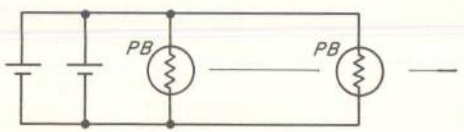

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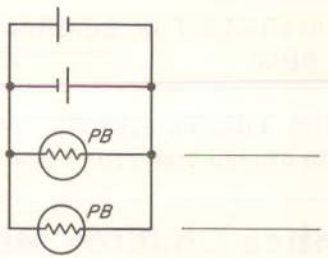

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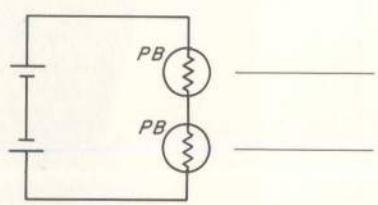

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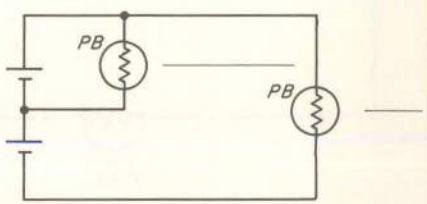

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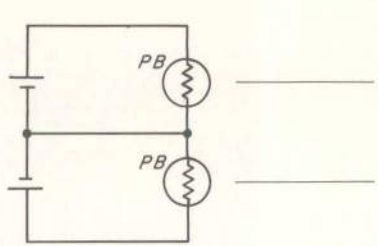

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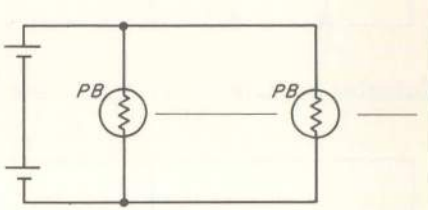


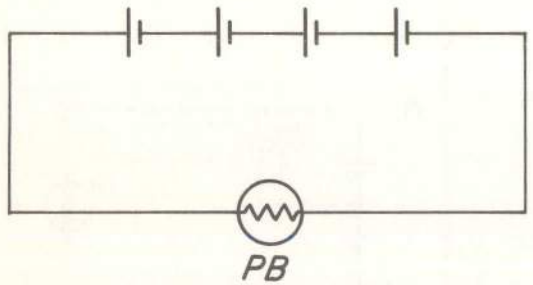
B. Several Batteries — One Bulb

NEW MATERIALS FOR SEVERAL BATTERIES — ONE BULB

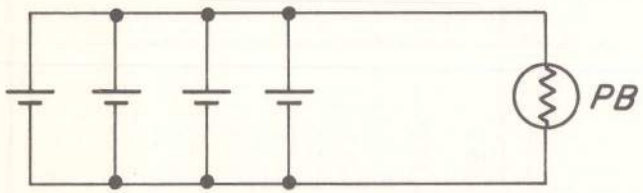
Have extra batteries accessible to children who want to expand their experiments.

Activities Children May Try

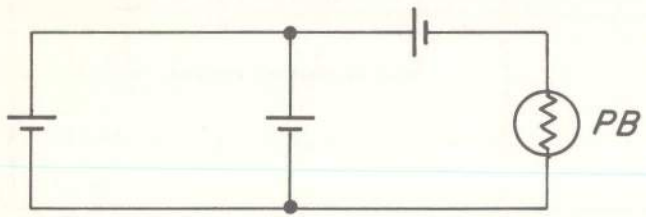
Connect several batteries to one bulb to light at standard brightness, brighter than standard. Try batteries end to end.



Try batteries side by side.



Combine batteries both ways in one circuit.



See if batteries must all be lined up in one direction, or if the bulb will light when one battery is turned around.

Discover the **smallest** number of batteries necessary to light a bulb with the same brightness as some bulb in a more complicated circuit, such as one where a wire can be added to a circuit without putting out the bulb. (See Diagram on page 4.)

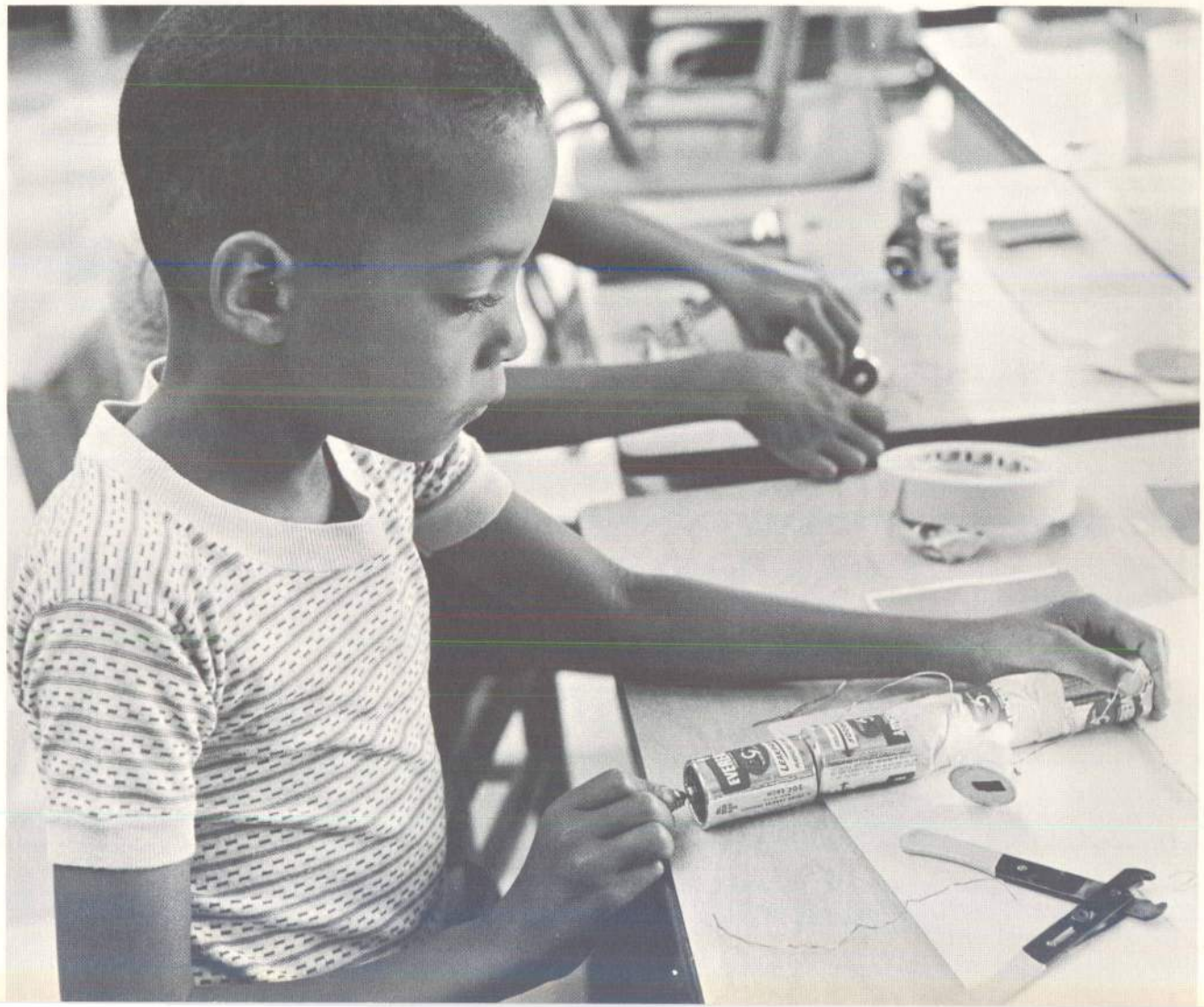
Dim a bulb by adding a wire.

Put batteries together in a way to make a bulb **not** light.

Predict the result and then test the prediction by constructing the circuits on **Prediction Sheet B.**

Comments on Prediction Sheet B

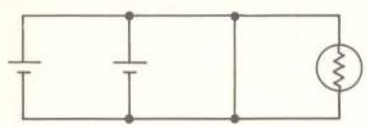
By this time most of the class should have a fairly good idea of how to go about trying various circuits. There are many more alternative circuits that you may wish to put on this prediction sheet. Some children may make up their own prediction sheets to try on other members of the class.

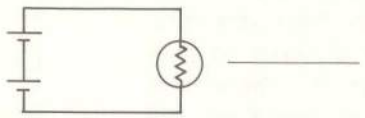


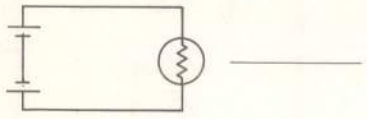
CIRCUITS II

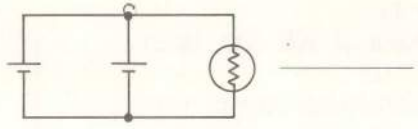
Prediction Sheet B

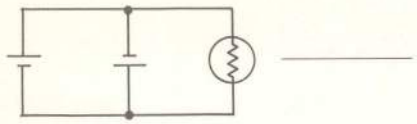
In the circuit diagrams below, write beside each bulb how bright you think it would be: very dim, dim, standard, bright, very bright. (All PBs)

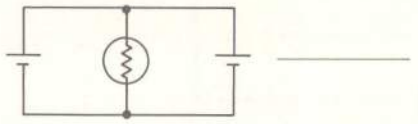
1  _____

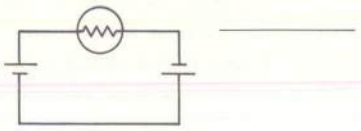
2  _____

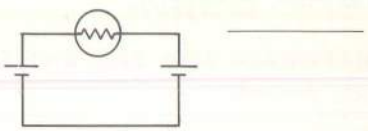
3  _____

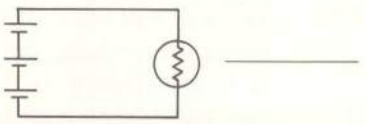
4  _____

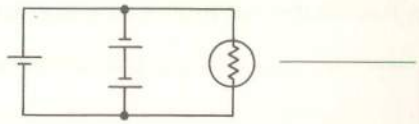
5  _____

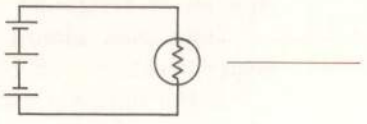
6  _____

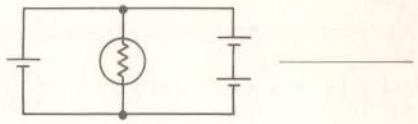
7  _____

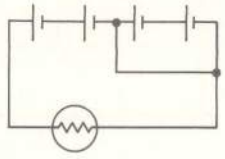
8  _____

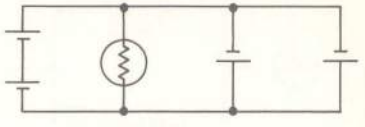
9  _____

10  _____

11  _____

12  _____

13  _____

14  _____

C. One Battery — Several Bulbs

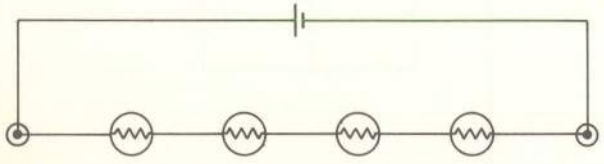
NEW MATERIALS FOR ONE BATTERY — SEVERAL BULBS

Have additional batteries and bulbs available.

Activities Children May Try

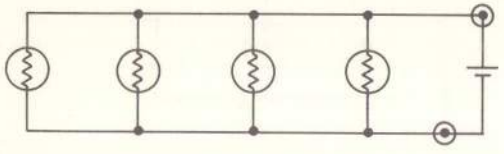
Connect several bulbs to a battery so that the bulbs will light to standard brightness, less than standard, brighter than standard.

See how many bulbs in a row one battery will light.



See if it is the same for WBs and PBs.

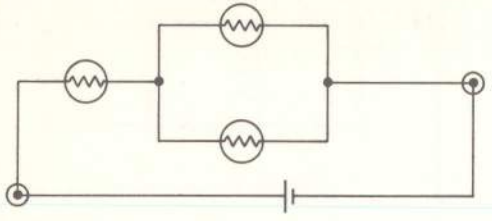
See how many bulbs in separate paths a battery will light before the bulbs start getting dimmer.



See if it is the same for WBs and for PBs.

Do a battery lifetime test with a WB.

Try combinations of paths to one battery — some bulbs in a row, some on separate paths.



Try combinations of WBs and PBs to one battery.

Predict what will happen in any circuit before you attach a battery.

Predict what will happen to the other bulbs in a circuit when one or more are unscrewed.

Use a piece of wire to put a bulb out.

Use a piece of wire to make a bulb brighter.

Predict the result and then test the prediction by constructing the circuits on **Prediction Sheet C.**

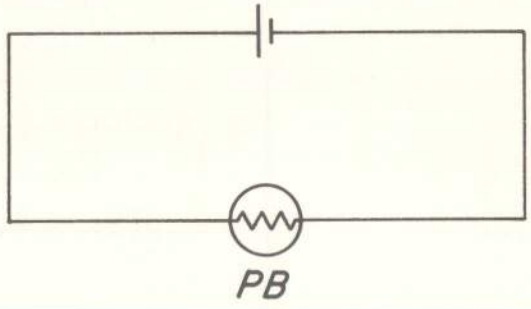
Comments on Prediction Sheet C

It is striking and perplexing that a WB does not light when it is in a single path with a PB (**Prediction Sheet C** — example 10). Children are likely to say that the PB is "stronger" and "takes the electricity away" from the WB. Some children do their own experiments to try to explain this more fully. One child kept adding batteries to see if the WB would ever start to glow. The PB kept getting brighter and blew out before the WB lit.

If any children in your class are really intrigued by this PB-WB comparison, there is an exciting series of experiments using Nichrome wire that they can do. These experiments are outlined in **Special Investigation I,** page 12.

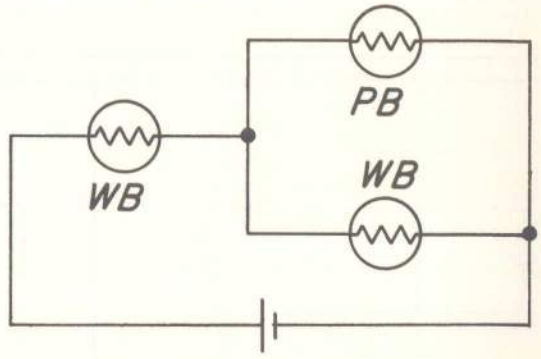
Note also circuit 12 where a WB has been added across the PB of circuit 10.

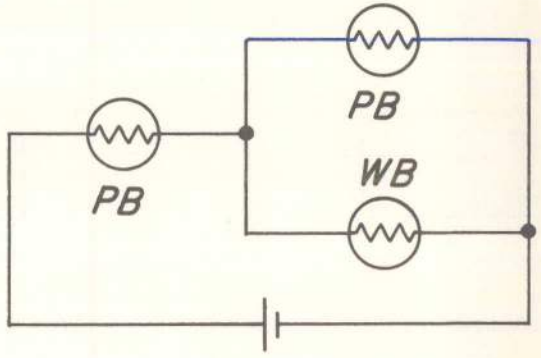
If the children put a galvanometer in the path of circuit 10 and compare that reading with the reading in this circuit:



they find that the PB limits the path to the battery in circuit 10.

As a special project they can make similar measurements in comparing these two circuits.



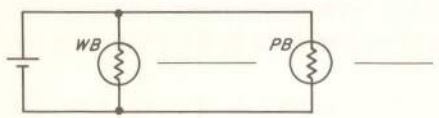


CIRCUITS II

Prediction Sheet C

In the circuit diagrams below, write beside each bulb how bright you think it would be: very dim, dim, standard, bright, very bright.

1



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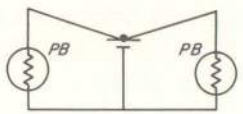
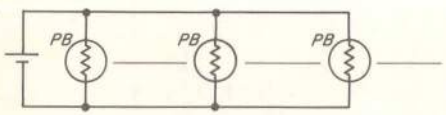


3



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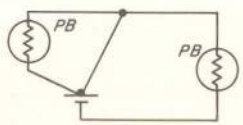

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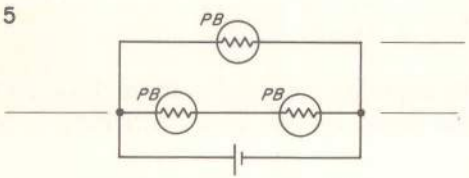

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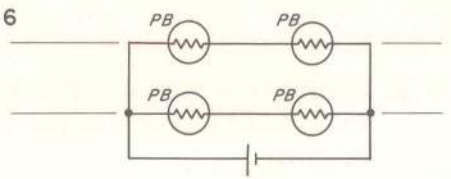

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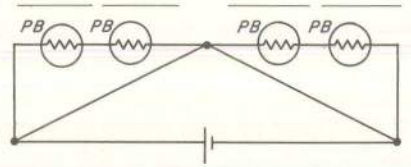
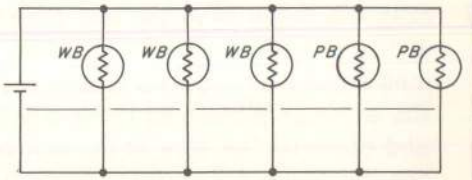
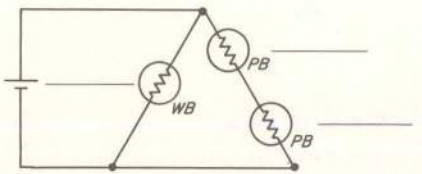


8



9



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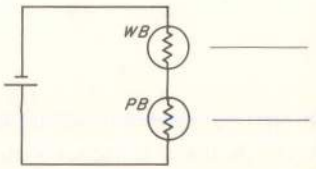
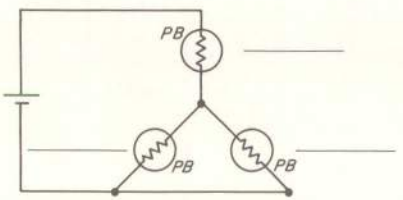
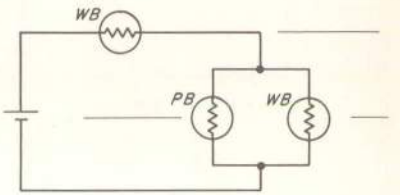


11

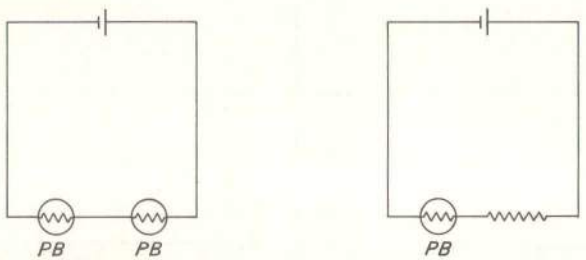


12



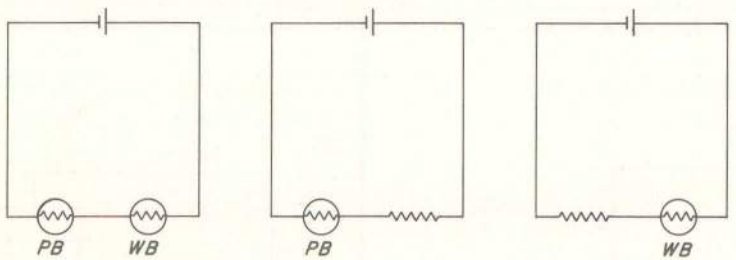
Special Investigation I

1. Both the bulbs in **A** are less than standard brightness. Set up circuit **B** with one bulb removed and some thin Nichrome wire in its place. How long a piece of this wire is necessary to dim the remaining bulb until it is the same brightness as the two in Circuit **A**? Cover up one of the **A** bulbs, and cover up the wire in **B**. Is it possible for someone else to tell which one has two bulbs and which one has one bulb and one piece of wire?



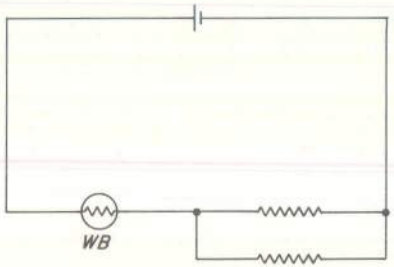
A **B**

2. Repeat the same experiment with WBs instead of PBs.
3. In Circuit **A** the PB lights and the WB does not. In circuit **B** insert the piece of wire you used in problem 1; then replace it with the piece you used in problem 2. How bright is the bulb in each case? Do the same in circuit **C**. Can you predict what will happen?



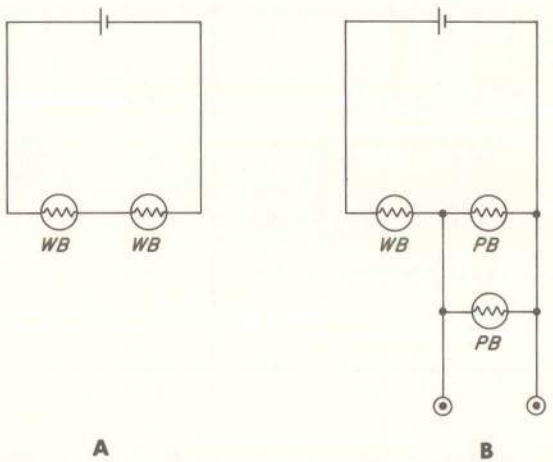
A **B** **C**

4. In circuit **B** use a WB and the piece of thin Nichrome wire you used in problem 1. (That's the long piece.) Now, cut another piece of thin Nichrome wire, the same length, and put it beside the first piece, so it makes a double path, like in the diagram at the top of the next page.



Does this make any change in the brightness of the WB? What if you add another piece? And another? How many pieces do you have to have side by side before it makes a difference? How many pieces do you have to have before the WB in **B** is as bright as the WBs in **A**? (You may have to try up to ten.)

5. Activity 5 is like activity 4. Instead of adding Nichrome wire side by side, keep adding PBs side by side. How many do you think you will need before the WB in **B** is as bright as the WBs in **A**? (And how bright are the PBs?)



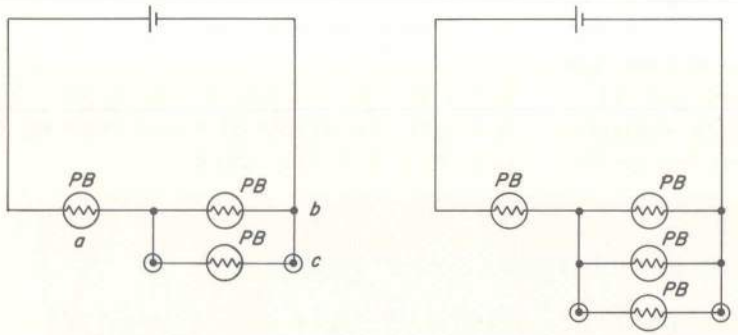
A **B**

6. Combine activities 4 and 5. That is, combine pieces of Nichrome wire and PBs, side by side. Do you get the same results as in activities 4 and 5? Why?

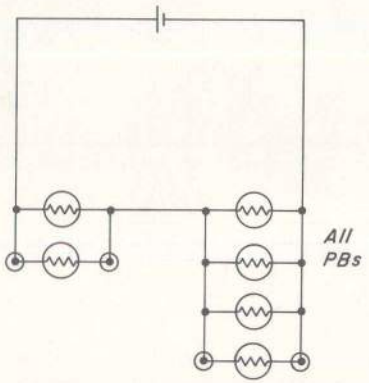
CIRCUITS II

Special Investigation II

1. How does the brightness of bulb **a** compare with the brightness of bulbs **b** and **c**?



2. What if you add another bulb across bulb **c**? How many do you have to add before bulb **a** is standard brightness? How bright are the others then?
3. Add one more bulb to side **a**:



Now one at a time add and subtract bulbs to and from both sides. Can you predict when any of the bulbs will glow? What results do you get when only WBs are used?

D. Several Batteries — Several Bulbs

NEW MATERIALS FOR SEVERAL BATTERIES — SEVERAL BULBS

No new materials should be needed, but more batteries, bulbs and wires should be available.

Activities Children May Try

Use three batteries and three bulbs to light all the bulbs at standard brightness.

Use three batteries and two bulbs to light the bulbs at standard brightness.

Use four batteries and two bulbs to light the bulbs at standard brightness.

Use two batteries and three bulbs to light the bulbs at standard brightness.

Use three batteries and two bulbs to light the bulbs at **less** than standard brightness.

Use two batteries and three bulbs to light the bulbs at **more** than standard brightness.

Add a battery to a circuit already connected so the brightness of the bulb is changed.

Add a bulb to a circuit already connected without changing the brightness of the other bulbs.

Predict what will happen to the other bulbs in a circuit if you unscrew any one bulb.

Add wires to make bulbs brighter or dimmer.

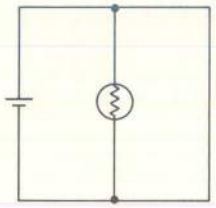
See if several batteries lined up can light a WB that is in a path with a PB.

Predict the result and then test the prediction by constructing the circuits on **Prediction Sheet D.**

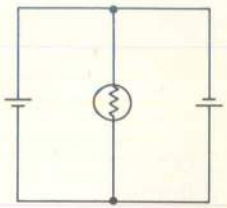
Comments on Prediction Sheet D

After much familiarity with complex circuits like the ones in this study, the children may be ready to state some of the rules they use to make their own predictions.

In one class one of the first rules for prediction came to be known as Debbie's rule. It was this: **Whenever a bulb has its own path through a battery, the bulb will be standard brightness.** Children should be made aware that many rules are true under certain conditions, but they are not **always** true. For example, two circuits in which the rule stated above does not hold are shown to the right.



A



B

In both cases, the battery is short-circuited, the bulb will not light, and the battery will get hot.

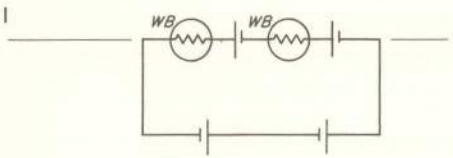
Some children may want to make measurements with their galvanometers. Even though the bulbs in the circuits in the above diagrams do not light, the needle of a galvanometer put in the path to a bulb may move.

CIRCUITS II

Prediction Sheet D

In the circuit diagrams below, write beside each bulb how bright you think it would be: very dim, dim, standard, bright, very bright.

1



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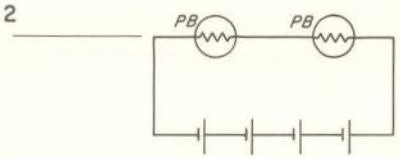

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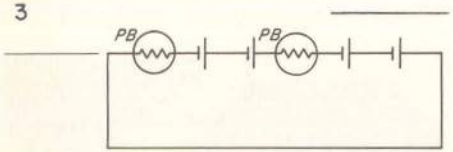

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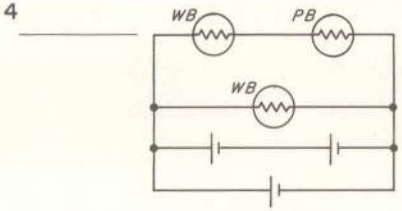

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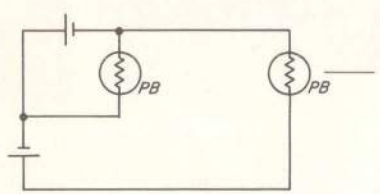

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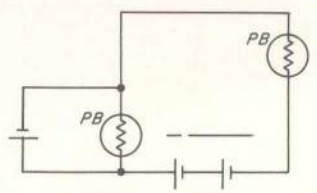

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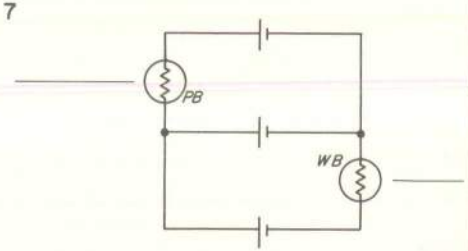
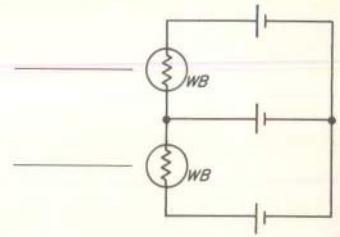


8



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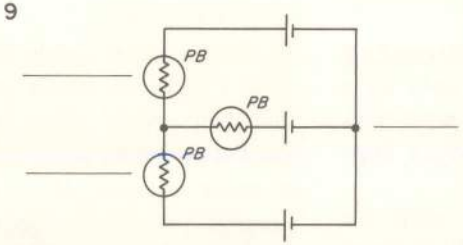

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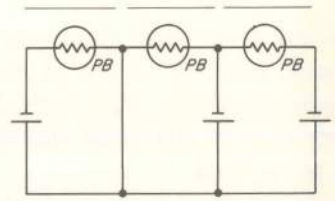
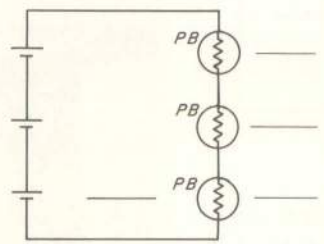
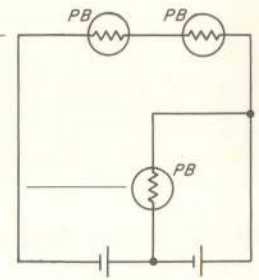


11



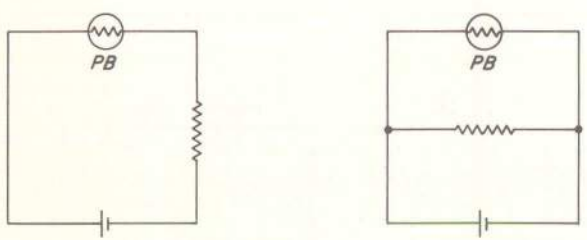
12



Nichrome Wire

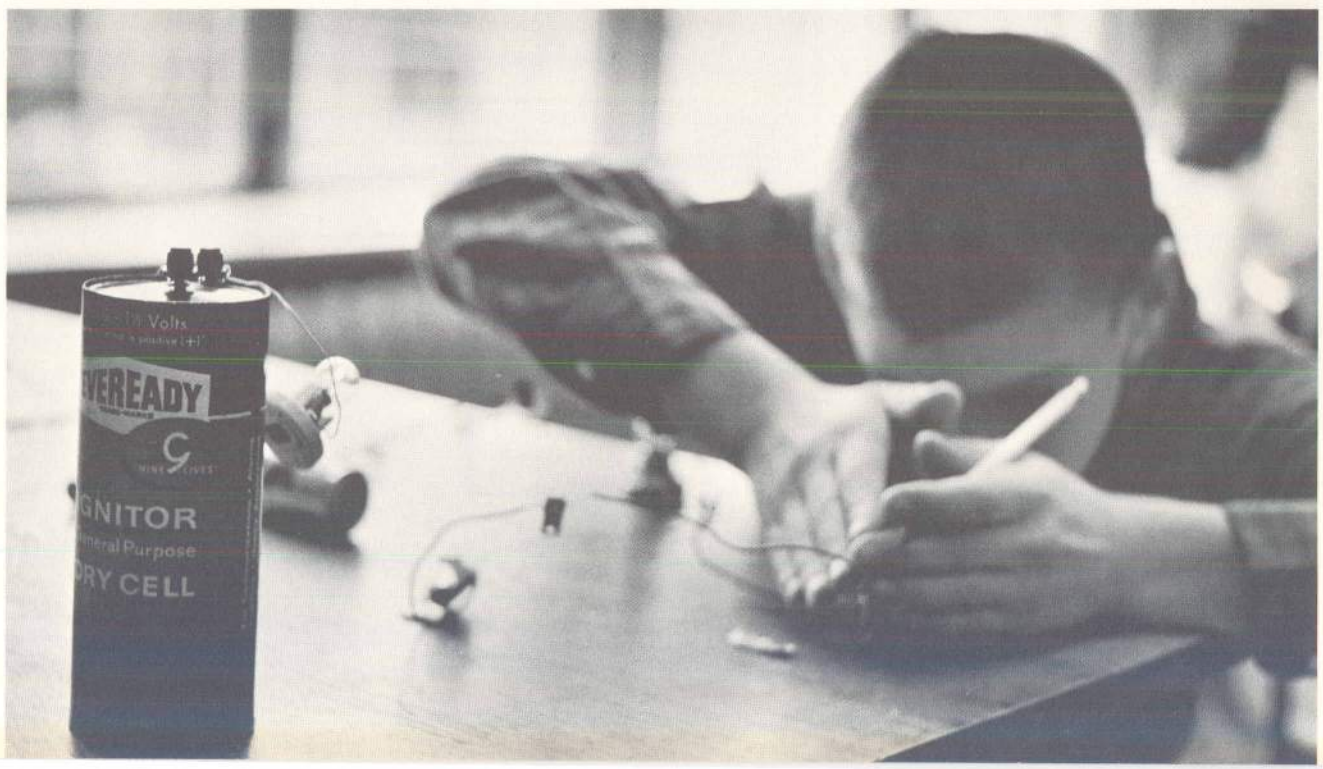
Every child can have a certain understanding of Nichrome wire. *It is not as good a path to a bulb as copper wire is. The bulbs in its path may be dimmer than if the same size and length copper wire were used.*

Some questions raised by Nichrome wire are not easy to answer. A fifth grader stumbled upon this one:



A B

In circuit A, the longer the Nichrome wire, the dimmer the bulb. In circuit B, the shorter the Nichrome wire, the dimmer the bulb. Not every child gets to the point where he understands this. The above fifth grader did not. Other questions, such as "How much thick Nichrome wire is needed to dim a bulb as much as a certain length of thin Nichrome wire dims it?" and "How much thin Nichrome wire inserted in one circuit will make a bulb as dim as a given bulb inserted in a comparable circuit?" can be readily answered. For children who want to look more closely at what Nichrome wire does, additional examples have been outlined in *Activities Children May Try* and in *Special Investigations II and IV*.



Courtesy, Cornell Alumni News

NEW MATERIALS FOR NICHROME WIRE

for each group —

3′ #32 (thin) Nichrome wire
4′ #26 (thick) Nichrome wire

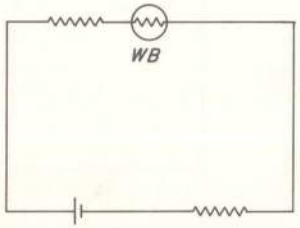
Activities Children May Try

(The first two investigations below review the work done on Nichrome wire in **Circuits I.**)

See how much thin Nichrome wire is needed to put out a PB, a WB.

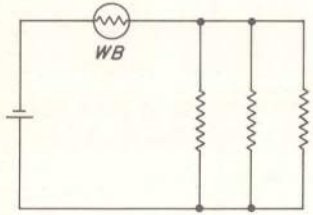
See how much thick Nichrome wire is needed to put out a PB (two groups may have to pool their wire for this one), a WB.

Cut a piece of thin Nichrome wire into several pieces. Put the pieces in different places in this circuit:

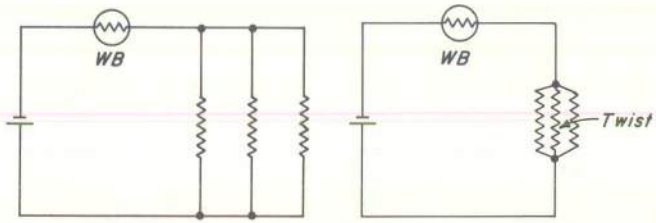


See if the brightness of the bulb is the same as when **one** piece of the original length is placed in one place in the circuit.

Lay six-inch pieces of this Nichrome wire side by side to see if it makes any difference to the brightness of the bulb in this circuit:



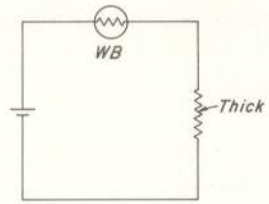
Twist together the pieces of thin Nichrome wire to see how the brightness with the twisted strands compares with the brightness in a circuit with the same number (and length) of pieces side by side:



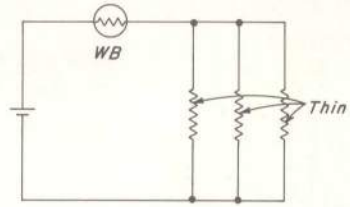
Try an experiment with a PB or with thick Nichrome wire. Start with a piece of thin Nichrome wire long enough to put out a WB; add more pieces the same length, side by side, to see how many are needed to make the bulb glow and how many are needed to make the bulb standard brightness.

Repeat this experiment with pieces eight inches long, ten inches long, twelve inches long.

Use a piece of thick Nichrome wire which is long enough to dim a WB noticeably, and then find out how many thin pieces (circuit **B**), **the same length as the thick** (circuit **A**), side by side, will make the bulb glow to the same brightness.

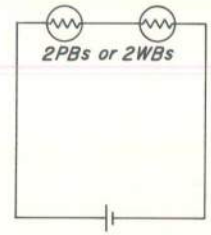


A

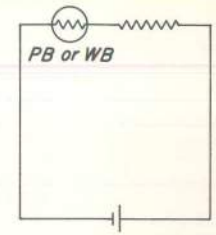


B

Set up two circuits, **C** and **D**, one with two PBs, one with one PB and some Nichrome wire, and make all the bulbs the same brightness.



C



D

Set up the same thing with WBs and compare the length of wire that is needed.

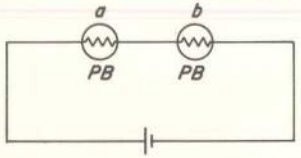
NOTE: In all these activities which compare the brightness of two bulbs, children find the paper brightness meter of great help.

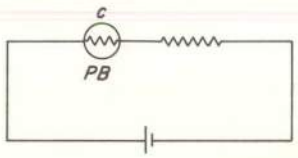
Special Comments

1. There are essentially two comparisons being made in this section. One is between thick and thin Nichrome wire. The other is between WBs and PBs. An excellent way to make these comparisons is to record measurements by cutting strips of paper as long as the wire. These lengths of paper are much easier to compare than numbers of inches. It is easily seen that in a particular situation it takes three to four times as much thick wire as thin wire to achieve the same effect. (Refer back to the wire chart P. 43 in **Circuits I.**) The PB is easily seen to be equivalent to about eight to ten times as much Nichrome wire as the WB.
2. The use of a galvanometer ought to help the children understand the example in the introduction to **Nichrome Wire** as well as some of the other circuits using Nichrome wire.

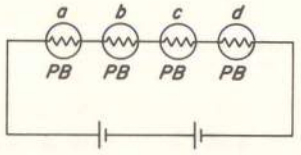
CIRCUITS II

Special Investigation III

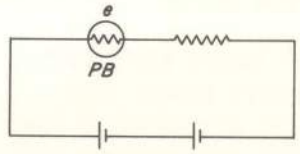




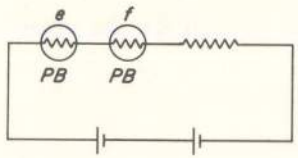
1. Using PBs, you already know how much thin Nichrome wire is needed to make bulb **c** as bright as bulbs **a** and **b**.
   Can you predict in (1), (2), and (3) how much Nichrome wire you will need to replace the bulbs, so that **e** is the same brightness as **a, b, c** and **d**? Verify your prediction by trying each case.



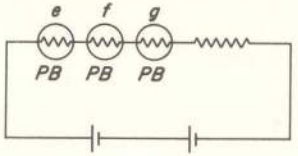
1



2

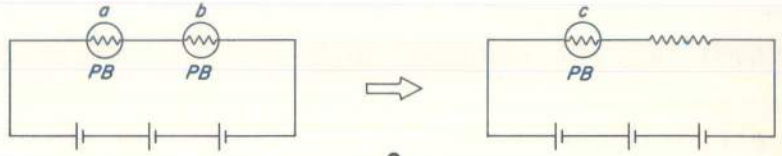


3



2. Now try these circuits with PBs. How much Nichrome wire will make bulb **c** as bright as **a** and **b** in each case? (Continued in next column.)

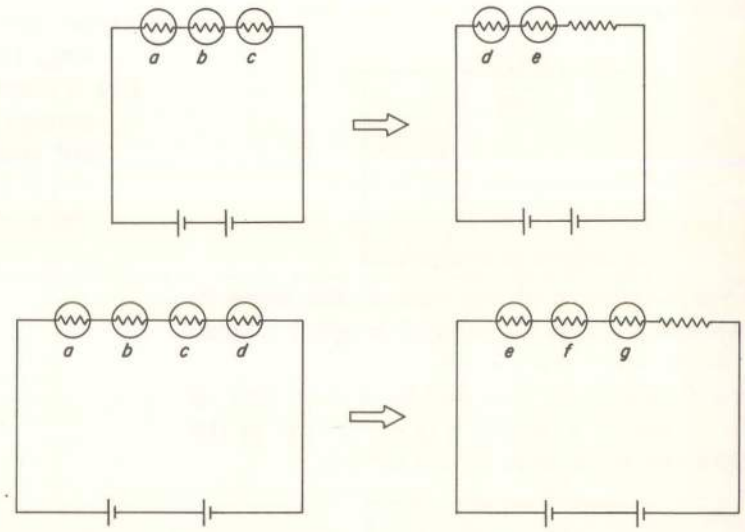
1



2

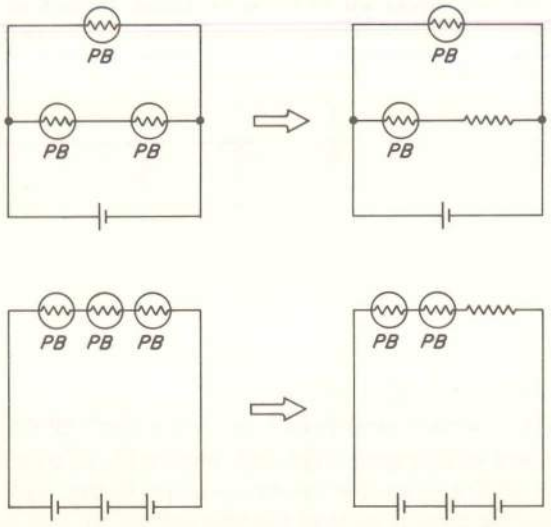
3

3. This time, try to predict, again using PBs.

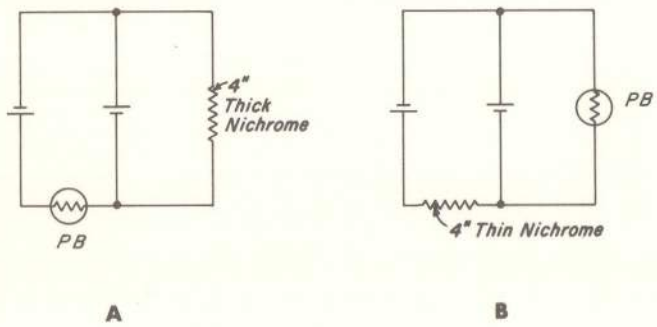


Will you need more, less, or the same amount of wire here as you did in the very first situation to make **d** and **e** light the same as **a, b** and **c**? To make **e, f** and **g** light the same as **a, b, c** and **d**?

4. Now try any circuits you want to that have more than one bulb. Every time, try to replace one bulb with the amount of thin Nichrome wire that will keep the remaining bulbs at the same brightness they had. Here are some possible examples.



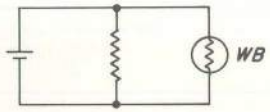
5. What kind of bulb or bulbs can you put in place of the Nichrome wire in circuits **A** and **B** to keep the bulbs in each circuit the same brightness?



A **B**

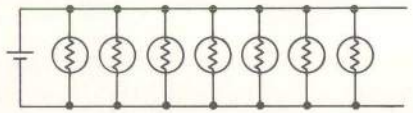
Special Investigation IV

1. Have you ever done this?

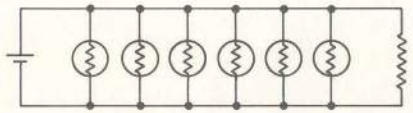


What happens if you use a longer piece of Nichrome wire?
What happens if you use a shorter piece of Nichrome wire?

2. If that surprised you, try these experiments.
Add WBs side by side until they start getting dim.

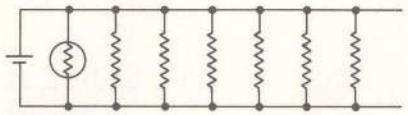


Now replace one bulb with a piece of Nichrome wire long enough so the others keep the same brightness.



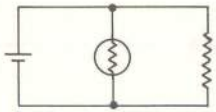
How long is the piece?

3. Replace all the bulbs except one with a piece of Nichrome wire as long as the piece you used in question 2 in this investigation.



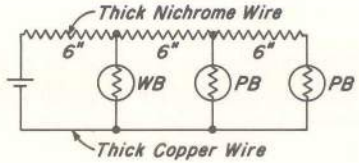
Is the remaining bulb as bright as it originally was?

4. If you were to take away all but one of those pieces of wire (leaving the bulb as bright as it is), will the remaining wire be longer or shorter than the others? (Use wire of the same thickness.)



Can you predict how long it will be?

5. Make the circuit below. How bright are the bulbs? What difference is seen if the bulbs are exchanged with one another? If thin Nichrome wire is used instead of the thick Nichrome, are the bulbs still as bright?
Can you make the circuit so that the WB will be lit, but not the PB?



OTHER BATTERIES

In almost every class the children become interested in different types of batteries. They usually bring in their own of various sizes and types. You can supplement their supply by adding some others, as outlined in the materials for this section. One of the first activities is to compare the brightness of bulbs using each battery. Another is to determine which places on these batteries corresponds to the special places on the "D" battery. (Refer to the precautions on batteries in *Circuits I*, page 7.)

Beyond these investigations there are a number of other experiments suggested by different types of batteries. Just when the children are beginning to feel some mastery of batteries and bulbs, they are confronted with perplexing phenomena. For instance, they may notice that an eight-inch-high, No. 6 dry cell lights a PB no brighter than the smallest flashlight battery does, but it heats Nichrome wire much more than that small battery does. The tiny transistor battery may even blow out a PB and yet a WB is scarcely any brighter on it than on a "D" battery. With some batteries, a short-circuiting wire heats up, but with others the battery itself gets hot.

Once again, not every child may want to follow these leads but a few Special Investigations are indicated for those who do.

Courtesy, Cornell Alumni News

NEW MATERIALS FOR OTHER BATTERIES

for the class —

Several (if possible) of each of the following types of batteries:
transistor radio (9-volt), No. 6 dry cell, "C", "AA", and 912, 914, lantern (6-volt)

NOTE: Do not use any batteries that are equivalent to more than twelve "D" batteries.

Activities Children May Try

Find out which battery lights a PB or a WB the brightest.

Find out which battery lights a WB or PB the dimmest.

See how many "D" batteries are equivalent to each of the other batteries.

Set up battery lifetime tests for each kind of battery.

See which battery makes a wire hottest.

Take apart a transistor battery.

See which battery is easiest to heat up when it is short-circuited.

Find out how many WBs can be attached in separate paths before they start getting dim.

Using each battery, one at a time, connect many bulbs in a single path to see how many can be put on and still give a visible glow.

Find out how good a path to a bulb some "dead" batteries of different kinds are.

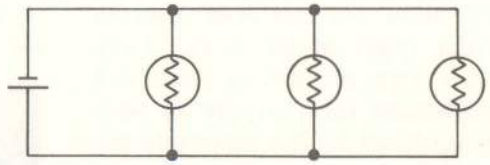
Figure out how much Nichrome wire each "dead" battery is equivalent to.

CIRCUITS II

Special Investigation V

You know how long a "D" battery will light a PB or a WB. Do you know how long a "C" battery will light a PB? A WB? Try it to find out.

1. How many days would it take to wear a "D" battery down to the point where it acts like a "C" battery?
   To check your prediction take a partly worn-out "D" battery, and see how many WBs it will light. How does this compare with a "C" battery?
   Is a "C" battery like a partly worn-out "D" battery?
   Is the 9-volt transistor battery like six partly worn-out "D" batteries?
2. Connect some WBs in separate paths to a "AA" battery, enough so they are all quite dim.
   Connect the same number of WBs to a "D" battery.



   Where in the path to the "D" battery could you put a single piece of Nichrome wire so the bulbs would be the same brightness in both circuits? How long is the wire?
3. Now use this "D" battery plus Nichrome in other circuits, and compare the way it acts with the way a "AA" battery above acts.
   How many PBs in the same path can the "AA" battery and the "D" battery plus Nichrome wire light?
   How hot does a six-inch piece of Nichrome wire that is short-circuiting the "AA" and "D" batteries get?
   Is a "AA" battery like a "D" battery plus Nichrome?
4. In a way similar to that in problem 3, above, see whether a "D" battery is like a large No. 6 battery plus Nichrome.
5. Also, find out if a 9-volt transistor battery is like six "D" batteries plus Nichrome.
6. How do five "D" batteries compare with a 6-volt lantern battery? Do the five "D" batteries act like the 6-volt lantern battery plus Nichrome?
7. Is a partly worn-out "D" battery like a new "D" battery plus Nichrome?
8. If you look inside a worn-out or partly worn-out battery, can you see what might be acting like Nichrome wire?

Special Project — Battery Box

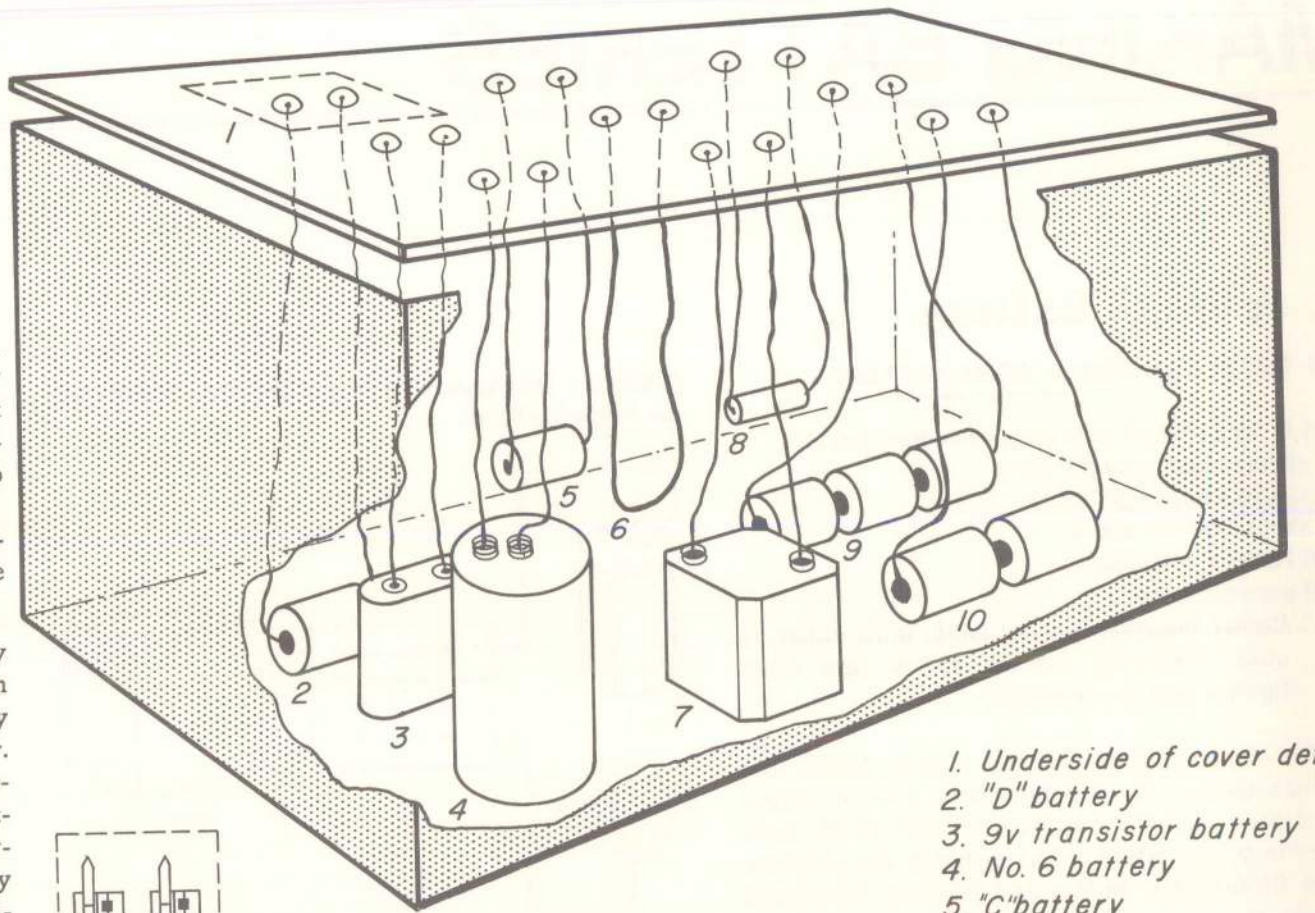
In this Battery Box are several different types of batteries. The child is to figure out what kind of battery is connected to each pair of paper fasteners.

Any cardboard box that can be sealed is wired with several types of batteries. Each battery is connected to two Fahnestock clips which are attached to the box with paper fasteners (in the same way as was done with Mystery Boxes in *Circuits I*).

The purpose of the Battery Box is for children to check on their knowledge of the batteries they have studied, find out how many "D" batteries act the same as each of these batteries and reformulate their theories about what any battery can do in a circuit.

After each battery has been identified, this information can then be used to determine the characteristics of an unknown battery.

NOTE: In one class a child insisted a battery he brought in was *one and one-half volts* even though there was no indication of the validity of that statement on the case of the battery. Clearly the child did not know what *one and one-half volts* meant or even why different sized batteries are necessary. This child was able to determine by studying a Battery Box that his battery was like two "D" batteries. He went on to investigate how PBs and WBs acted in a path to his battery *compared* to what happens when "D" batteries are in those circuits.



1. Underside of cover detail
2. "D" battery
3. 9v transistor battery
4. No. 6 battery
5. "C" battery
6. Thick copper wire
7. Lantern battery
8. "AA" battery
9. 3 "D" batteries
10. 2 "D" batteries

MAKING BATTERIES

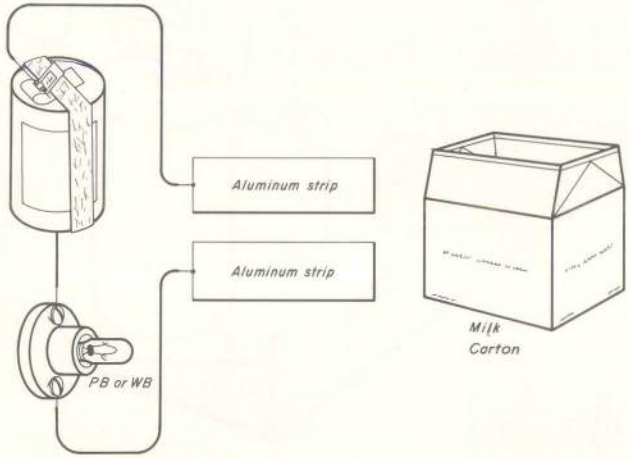
A. A Weak Battery

NEW MATERIALS FOR A WEAK BATTERY

15 to 20 half-pint milk cartons — tops cut off
2 sheets aluminum (5″ x 8″)
2 sheets copper (5″ x 8″)
1 sheet lead (4″ x 5″)
30 Fahnestock clips
30 paper fasteners
Comet cleanser, baking soda, milk, sugar, liquid detergent, instant coffee and other liquids and compounds

Cut two aluminum and two copper plates into one-inch strips. You will then have sixteen copper and sixteen aluminum strips each five inches long. Have the other materials accessible to the children.

In **Circuits I** a battery and PB may have been connected to two pieces of aluminum foil instead of Fahnestock clips. The wires and the foil were dipped into salt water to see if the water could be part of a path to the bulb. If your children have not tested any other solutions or have not used aluminum foil strips in a tester, they might want to see if these materials can be made part of the path to a bulb. Refer to **Circuits I** for some more suggestions. The apparatus below can be used for all the following tests.



Children may use different metals for the strips in testing liquids. They may try one of copper foil and one of aluminum foil.

When the children use two different metals and have, say, salt water in the path, you may suggest that they turn the "D" battery around so that the end that was connected to the bulb is connected to one of the metal plates, the other end being now connected to the bulb. A WB in the circuit will not light as brightly in one of these situations as in the other. Children may conclude that the path seems better one way the "D" battery is connected than the other.

If they do not bring it up themselves, you might ask them "What is the only thing that you have worked with that is different when it is turned one way rather than the other in a circuit?" Maybe they have made a battery out of these two different metals and the salt water!

Will this "battery" light a bulb? Move a galvanometer needle?

This first battery will probably not light a PB but it will move the needle of a galvanometer with a fifty-turn coil.

Many children may be interested in seeing if they can make a battery that will light a PB. Some suggestions they might make include: increasing the plate size, moving the plates closer to each other (but not touching), trying other solutions, connecting two or more of these batteries together.

The following section is for those children who wish to pursue **Making Batteries** further.

B. A Battery that Will Light a Bulb

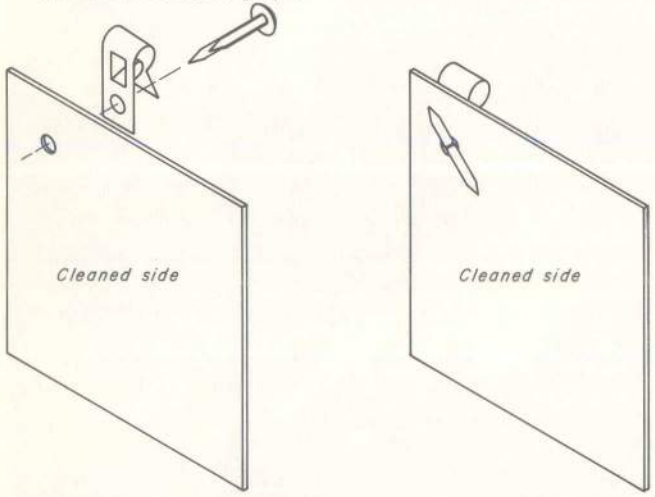
NEW MATERIALS FOR A BATTERY THAT WILL LIGHT A BULB

for the class —

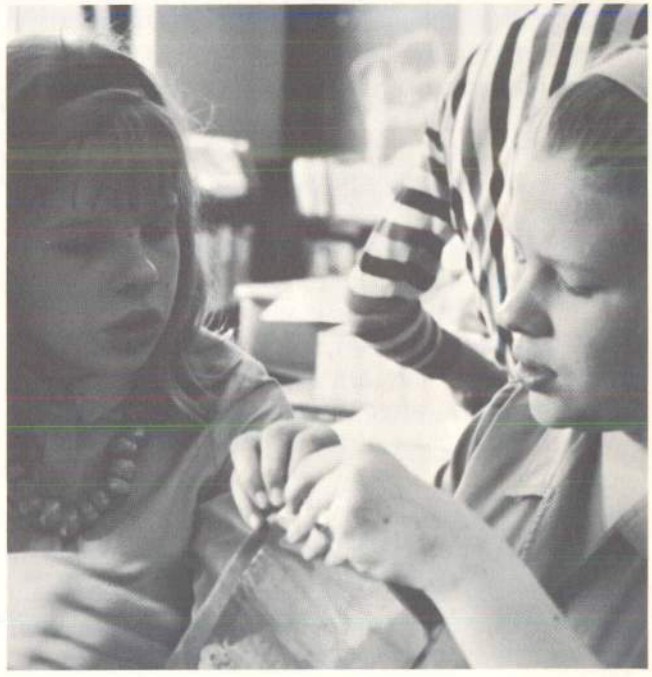
- **1 can of Comet cleanser**
- **3 steel wool balls made into 15 smaller balls**
- **1 bucket, or pan, of water**

for each group —

- **2 sheets aluminum (5″ x 8″)**
- **2 sheets copper (5″ x 8″)**
- **Several white absorbent paper towels**
- **4 Fahnestock clips**
- **4 paper fasteners**
- **2 sheets of newspaper**



Rub one side of each plate with steel wool to clean it and to make sure it is flat and smooth. Attach a Fahnestock clip to **opposite** top corners of each plate by passing the paper fastener through the clip and plate before folding the prongs back. The paper fasteners do not go through **both** plates together. Each fastener attaches a Fahnestock clip to **one** plate. The clip will be to the **outside** of the battery.



Put newspapers on the desks to absorb any excess water. Sprinkle Comet cleanser generously on both sides of one thickness of a **very** wet paper towel. The Comet and water should make a thick paste. The plates are placed on opposite sides of the towel, (cleaned side next to the towel) so no part of one plate touches the other plate. (The plates may have to be flattened further or pushed together by weights to make sure they are in contact with the solution.)

Activities Children May Try

Put a piece of wire into each Fahnestock clip and then connect it to a PB. Will it light a PB? Will it light a WB? Will a WB light if two of these batteries are used? Three? Reduce the size of the plates of one of these batteries, by cutting off a strip at a time, to find the surface area of the plates which will just light a PB.

Try other solutions in place of Comet cleanser and water for comparison. (From the knowledge gained in the preceding section, children should have a pretty good idea which will be best.)

See how bright the bulbs are.

Find out how long each bulb will light before it goes out.

Investigate ways you can make it light again once it has gone out.

See how the battery you made compares with the "D" battery, an "AA", or a 914 battery.

Check to see if there are any changes in the color of the plates after the cell has been used.

Find out if the color of the solution has changed.

Special Comments

The plates should be thoroughly washed and cleaned with steel wool between tries. New paper towels should also be used with every new try.

C. A Different Kind of Battery

NEW MATERIALS FOR A DIFFERENT KIND OF BATTERY

for the class —
- **1 box baking soda**

for each group —
- **4 lead plates (4″ x 5″)**
- **4 Fahnestock clips**
- **4 paper fasteners**
- **Several white absorbent paper towels**
- **2 newspapers**

The children can use a piece of the lead foil to see if it can be a good path from a battery to a bulb. They can use the lead foil also with the copper and aluminum foils to see if an even better battery might be made using the solutions already tried. (Put Fahnestock clips on these lead plates as with the previous plates. Clean one side of each plate with steel wool.)

Children can make a battery by placing a wet paper towel saturated with baking soda between two lead plates. Be sure the metal plates do not touch each other. If this combination does not light a PB, you can suggest they connect two "D" batteries to the lead plates for about two minutes.

When the children examine the sides of the plates that were touching the paper towel, they should see that one is brown and the other is a dull gray, signifying some change has taken place. This is now a battery like the other kinds the children have made: that is, two different metal plates placed in any solution that can be used as a path to a bulb.

If the children leave a PB attached to the lead battery it soon goes out. The lead battery is now almost "dead." The children can reconnect the two "D" batteries to the lead plates for about two minutes. When the "D" batteries are removed, the lead battery will again light the PB. They may want to compare what the inside faces of the plates look like when the battery will light a bulb and when it will not.

Activities Children May Try

Vary the length of time that the "D" batteries are connected to the lead battery. Change the number of "D" batteries used.

Find out the relation of the length of time the "D" batteries are attached to the lead battery to the length of time it takes the lead battery to go "dead" when connected to a PB.

Get the lead battery to light a WB. Increase and decrease the plate size to see if there is any difference in the action of the lead battery.

D. Some Differences Between the Lead Battery, a Copper-Aluminum Battery and a "D" Battery

1. The "dead" lead battery can be reactivated by connecting it to two or more "D" batteries. The "dead" "D" battery cannot be reactivated. The aluminum-copper battery cannot be reactivated without changing the liquid or plates.

2. The lead battery will light a PB longer with one half of the plate size needed for the copper-aluminum battery. If it is connected to "D" batteries for a long time and the plates are very smooth, the lead battery can light the same type bulb longer than one "D" battery can.

Batteries can be made from many other materials. The children can connect a fifty-turn galvanometer to a screwdriver blade and a copper wire that are dipped (not touching each other) into the same solution of Comet cleanser. They will see that the needle will move. They will want to try things made from other metals such as spoons, coins and scissors; and other liquids, such as water with baking soda or salt, vinegar, household ammonia. Two different kinds of clean coins, such as a penny and a nickel, placed on either side of the tongue, will make a small battery; two different metals stuck into a lemon will also be a battery. Children begin to see that any two different metals in one of these solutions is a battery. Some of these batteries are better than others because of the materials used, the size of the plates, or the closeness of the plates. It is easier to find materials and solutions which will *make* a battery than those which *will not*.