A SELF-PACED PROGRAM

dealing with

BATTERIES AND BULBS

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The enclosed self-paced program was developed using an article from the Physics Teacher Magazine, January 1978, pages 15-22, titled: Teaching Electricity with Batteries and Bulbs" by James Evans. The enclosed program is the latest draft. Most errors have been corrected, however, if you find any, please contact the author. The author grants to anyone to whom he has given the materials permission to make copies for use in their classroom.

Other sources the author found valuable were:

Batteries and Bulbs - Book 1

"The Various Language, An Inquiry Approach to the Physical Sciences"
Author - ARNOLD Arons
Publisher - Oxford University Press

The author would welcome any comments and ideas that would correct any errors and enhance the program.

MATERIALS NEEDED FOR SELF PACED BATTERIES AND BULBS

by

Dick Heckathorn

Part A - The Development of a Model

1. 1 #14 bulb, 2 or 3 batteries, wire
4. 1 D-cell cut in half, Modern Physics book by Holt, 1 socket
5. 3 sockets, 3 #14 bulbs
8. resistance wires of various lengths and diameters
9. 5 sockets, 5 #14 bulbs
11. 1 #13 bulb

Part B - Resistance

1. 1 meter resistance wire fastened to meter stick (#28 Nichrome wire
2. Block of 9 resistor spools of various resistance
6. 4 equal lengths of same resistance wire such as nichrome

Part D - And Now to Reality

1. Resistors of known resistance
2. Ammeter
5. Voltmeter

Tools

1. screw driver
2. plyers
3. hookup wire

1. Obtain a #14 light bulb, one D-cell battery and a piece of wire.

   a. How many ways can you make the bulb light?

   b. Draw diagrams of all hook-ups tried as you try them.

   c. What is needed before the bulb will light? complete circuit

   d. Keep track of whether any of the three objects become warm or hot. If this happens, note circumstance(s).

   e. Describe in your own words the arrangements that do result in lighting the bulbs. What do they have in common? How do these arrangements differ from those that don't light a bulb?

2. Place pencils, coins, fingers, and other objects in one of the arrangements in which the bulb was made to light.

   a. Separate the objects into classes according to their behavior. Describe the pattern that emerges.

   b. What does each class have in common?

3. Examine the many parts of the #14 bulb.

   a. How many different parts do you find?

   b. Which parts would be assigned to which class of objects identified in item 2?

   c. Predict the purpose of each part.

4. Obtain a D-cell that has been cut in half.

   a. Keeping paper towels under the battery parts at all times, take the battery apart.

   b. Make a sketch of what was found. Then predict the purpose of each part.

   c. Page 418 of Modern Physics text may be of help.

   d. Put the parts back together when you are finished.

   e. Obtain a socket. Trace through the connections by inserting different parts of the socket into your circuit while observing whether the bulb lights or not.

5. Using two D-cell batteries, make first two and then three bulbs light at the same time.

   a. Draw diagrams of all hook-ups tried separating the successful from the non-successful trials.

   b. What was observed as to the brightness of the bulbs?

   c. What factor(s) affects the brightness? (Share with instructor your findings when finished.)

   d. Prepare a written summary of why you think the brightness of the bulbs vary.

   e. Now repeat the above investigations using a 3rd battery.

   f. Are there any similar situations that you have encountered which would parallel what has been observed here? What are they?

6. Examine Figure 1.

   a. Predict which bulbs will be brighter? (A)

   b. How much brighter?

   c. What will happen if you were to unscrew B which would remove it from the circuit?

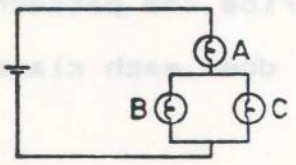


Fig. 1

   d. Construct the circuit using two batteries to see if your predictions were correct.

   Note...If two battery will not make all bulbs light, try a third <u>if</u> necessary. Do not use more than three.

7. Examine Figure 2.

   a. Predict which bulb will be brighter?

   b. How will the brightness of each bulb compare to the brightness of the others?

   c. Why do the brightness differ? Inform your instructor when you have formulated an answer.

   d. Construct (as needed) the circuits to verify any predictions.

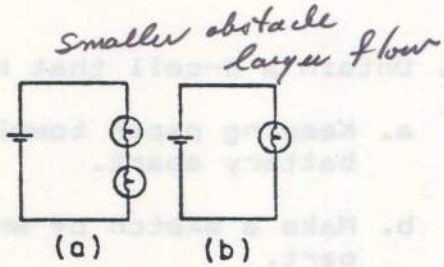


Fig. 2

8. We will now use the circuit shown in Figure 3 to compare the obstacles presented by two objects C and D. Bulbs A and B are similar bulbs.

   a. Place equal lengths of a similar wire at C and D. How does the brightness of the bulbs compare? Which has a greater obstacle? (Use only 1 battery.)

   b. Examine how the length of the wire affects the obstacle moving the lower fastner up one of the wires making the part in the circuit shorter. Results?

   c. Place two wires made of the same material but of different diameter at C and D. How does the diameter of the wire affect the brightness of the bulb? Which has the greater obstacle?

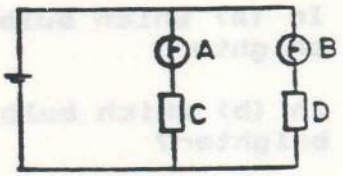


Fig. 3

9. Refer now to Figure 4. The bulbs at C and D are similar.

   a. How and why will the brightness of bulb A compare to bulb B? A>B

   b. Construct the circuit. What does one find?

   c. What conclusion(s) can one draw? bulbs in parallel - smaller obstacle

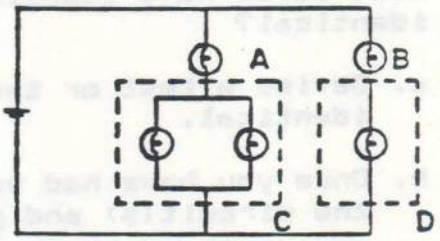


Fig. 4

10. Refer now to Figure 5. Here as in item 9 the bulbs C and D are the same.

   a. How and why will the brightness of bulb A compare to bulb B?

   b. Construct the circuit and compare what you see with what you predicted.

   c. Conclusion(s)?

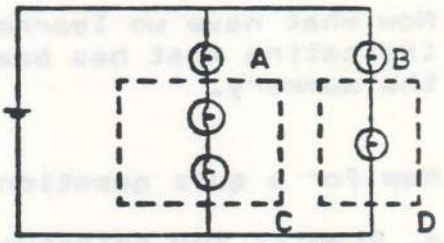


Fig. 5

11. In Figure 6, we will examine the effect of a #13 bulb at C to a #14 bulb at D by comparing the brightness of Bulbs A and B.

   a. Construct the circuit.

   b. How does the brightness of bulbs A and B compare? (If one or more of the bulbs do not light with one battery, use two or if <u>necessary</u> three batteries to make all bulbs light.)

   c. Which bulb presents the greatest obstacle?

#13 larger obstacle

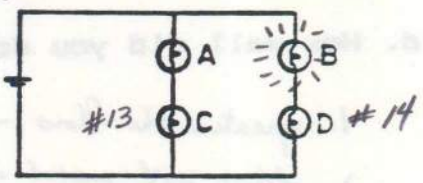


Fig. 6

12. Examine Figure 7.

larger obstacle glows brighter

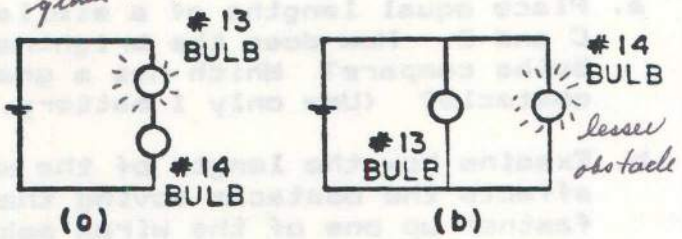


Fig. 7

a. In (a) which bulb will glow brighter?

b. In (b) which bulb will glow brighter?

c. Construct first one circuit and then the other. Use two batteries rather than one.

d. Results? Conclusion(s)?

13. So far we have had to assume bulbs A and B used in various circuits as test bulbs were identical. But how can we be sure that they are identical?

a. Devise a test or tests that prove beyond a doubt that two bulbs are identical.

b. Once you have had your idea(s) checked by your instructor, construct the circuit(s) and perform the tests.

c. Were bulbs A and B (the one you used previously for testing) identical?

14. Now what have we learned? Prepare in written form, a summary indicating what has been learned. Then have your instructor evaluate the summary.

15. Now for a quiz question. In Figure 8 we find five identical bulbs.

a. Predict the relative brightness of the five bulbs.

b. Inform your instructor of your predictions and your reasoning for the predictions.

c. Construct the circuit and check your predictions.

d. How well did you do?

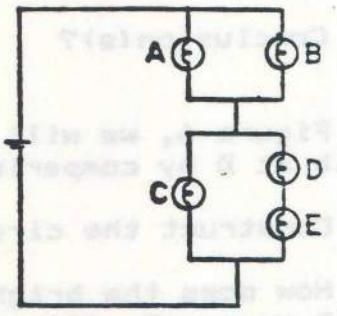


Fig. 8

1. greater the flow - greater the glow
2. flow not used up
3. size of flow determined by size of obstacle
4. 2 obstacles in series > obstacle than 1 alone
5. 2 " " parallel " " 1 "

1. We are now ready to make some quantitative measurements of obstacles (resistance). To do this we will use a circuit as shown in Figure 9. Bulbs A and B need to be identical bulbs. At D there is a length of #28 nichrome wire.

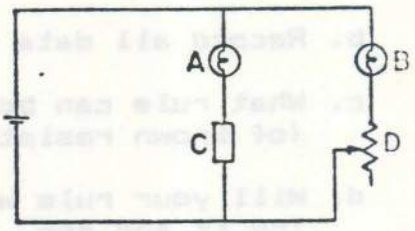


Fig. 9

   a. If we adjust the length of wire (at D) until the bulbs (A and B) are of equal brightness, what can be concluded about the resistance of C and D?

   b. How can the resistance of an object at C be measured?

   c. What units will be assigned to the measurement?

2. We will now use the circuit in Figure 9 to measure the resistance of various objects.

   a. Measure the resistance of the following objects placing the results in table form.

move 2 →

   (1) Resistance spool - 40 cm of #30 nickel silver
   (2) Resistance spool - 80 cm of #30 nickel silver
   (3) Resistance spool - 120 cm of #30 nickel silver
   (4) Resistance spool - 160 cm of #30 nickel silver
   (5) Resistance spool - 200 cm of #30 nickel silver
   (6) Resistance spool - 200 cm of #28 nickel silver
   (7) Resistance spool - 2000 cm of copper
   (8) a #13 bulb
   (9) a #14 bulb

   b. Repeat the measurements with first two and then three batteries (connected in series) in place of one battery used in (a).

   c. What conclusion(s) can one make?

batteries not affect

3. Again using the circuit in Figure 9:

   a. Measure the total resistance of two or more resistance spools connected in series. (Use ones from 2a.)

   b. As before record all data in table form.

   c. What rule can be developed that can be used to find the total resistance of objects (of known resistance) connected in series?

4. Once again using the circuit in Figure 9:

   a. Measure the total resistance of two resistance spools of equal resistance when they are connected in parallel. Repeat for other objects of equal resistance. (Be sure that you have good connections.

   b. Record all data in table form.

   c. What rule can be used to find the total resistance of two objects (of known resistance) when they are connected in parallel?

   d. Will your rule work for three equal resistors connected in parallel? Try it and see.

5. As further test. (The circuit in Figure 9 will again be used.)

   a. Predict the total resistance of two unequal resistances connected in parallel using the rule developed.

   b. Construct the circuit and check your prediction.

   c. How well did you do?

6. How does the resistance of a piece of #_____ nichrome wire depend on the flow through it?

   a. Construct the circuit shown in Figure 10. All resistors are the same length of #_____ nichrome wire. Bulbs A and B are identical.

   b. Compare the brightness of the two bulbs.

   c. Conclusion(s)?

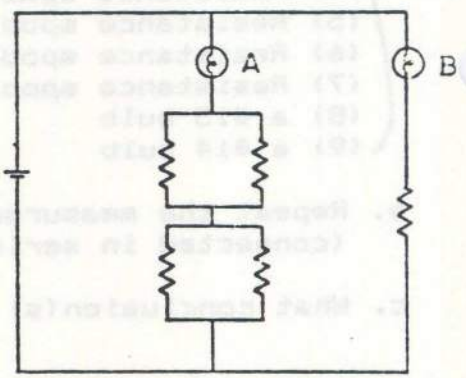


Fig. 10

7. Does the situation change if the resistors in Figure 10 are replaced by five identical bulbs as in Figure 11?

   a. Construct the circuit as shown in Figure 11.

   b. How does the brightness of the bulbs compare?

   c. Conclusion(s)?

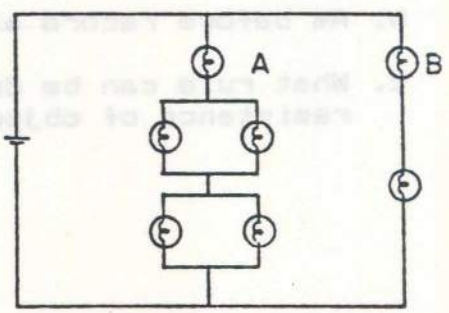


Fig. 11

1. We will now make some measurements of flow (current). Our unit of current will be that current which just causes a #14 bulb to barely glow. We will call this unit of current a GLOW. It will be up to each one of us to establish precisely what BARELY GLOWS represents.

   a. Examine Figure 12. We will use this circuit to measure the resistance of light bulb C when it barely glows. E insures that bulb C is barely glowing while D insures that bulbs A and B glow with equal brightness.

   b. Construct the circuit. Then adjust D and E alternately until both conditions are fulfilled. (i.e., both C barely glows and bulbs A and B are of equal brightness.) You are to use large batteries for this investigation.

   c. What does D represent?

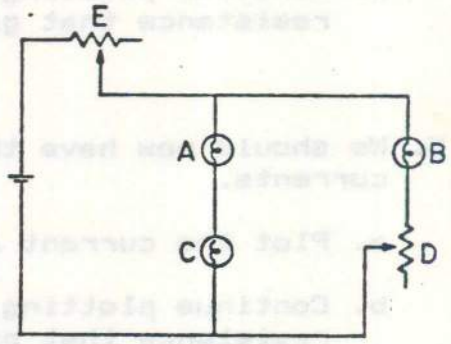


Fig. 12

2. Consider now the circuit shown in Figure 13.

   a. Construct the circuit.

   b. Adjust the sliding resistor until the bulb barely glows.

   c. What is the current through the bulb?

   d. What is the total resistance of this circuit?

   e. Record the resistance and the current.

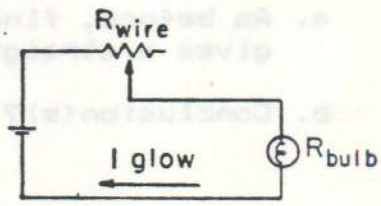


Fig. 13

3. Consider the circuit shown in Figure 14 which shows two bulbs connected in parallel.

   a. Construct the circuit.

   b. Adjust the sliding resistor until the bulbs barely glow.

   c. Again record the total resistance and the current.

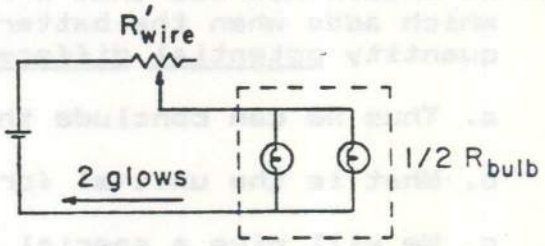


Fig. 14

4. Repeat the above investigation with three bulbs connected in parallel.

   a. Plot the current as a function of resistance.

   b. Continue plotting to see if there is a function of current vs resistance that gives a straight line through the origin.

5. We should now have three comparative measurements of resistance and currents.

   a. Plot the current as a function of resistance.

   b. Continue plotting to see if there is a function of current vs resistance that gives a straight line through the origin.

6. Repeat the measurements for current vs resistance for one, two, and three bulbs connected in parallel using first two and then three batteries connected in series.

   a. As before, find the current as a function of resistance graph that gives a straight line through the origin.

   b. Conclusion(s)?

7. By now we should see that the current (I) is inversely proportional to the resistance (R). Thus we can write: $I = k/R$.

   a. What does k represent?

   b. To what is k related?

8. We should now see that k represents some quantity due to the battery(s) which adds when the batteries are connected in series. We call this quantity potential difference and will represent it using symbol V.

   a. Thus we can conclude that V = _____.

   b. What is the unit(s) for V ? _____

   c. We will give a special name for the unit(s). It is a shove.

D. AND NOW TO REALITY

1. Before we progress further, we need to see what the measurements we made using our own units have in common with everyday units.

   a. Obtain some resistors of known resistance measured in ohms.

   b. Use the circuit in Figure 9 to determine the resistance (in ohms) of one centimeter of wire.

2. Connect an ammeter in series with a standard bulb and a variable resistor as shown in Figure 15.

   a. Adjust the resistor until the bulb barely glows.

   b. Record the current.

   c. Define the glow of a #14 bulb in terms of the current.

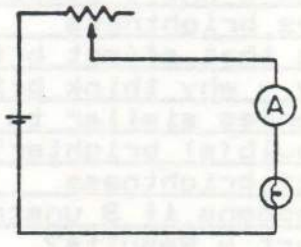


Fig. 15

3. Since V = IR:

   a. 1 shove = (1cm) x (1 glow)

   b. 1 shove = (_____ ohm) x (_____ amp)

   c. 1 shove = (_____ ohm amp)

4. One (ohm amp) is known as a volt.

   a. Thus one shove = _____ volt.

5. Check your calculations by connecting a voltmeter across a bulb which is connected to a dry cell.

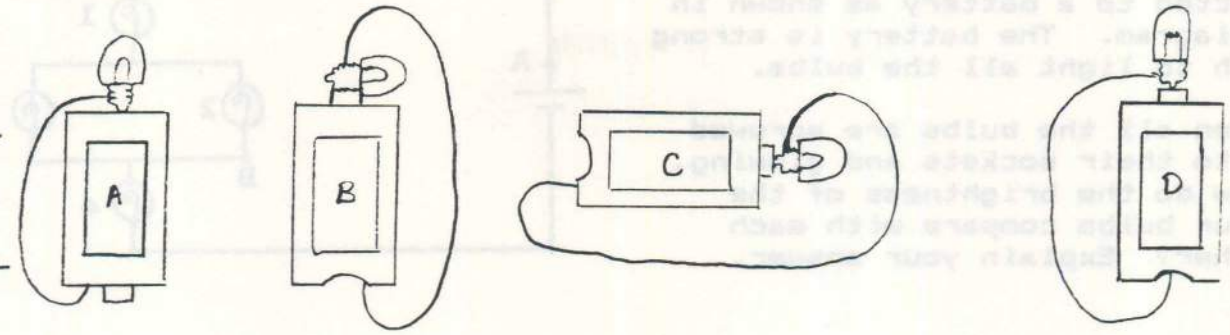
EVALUATION - BATTERIES AND BULBS A Name_____

1.a. # ways make bulb light
b. all diagrams drawn
c. What needed to make bulb light
d. Evidence of heat
e. Describe-what makes bulb light
2.a. Separate objects into groups
b. What common to each group?
##########
3.a. # parts of bulb found
b. parts separated into groups
c. predict purpose of each part
4.b. sketch parts - predict purpose of parts
##########
5.a. Diagrams 2 and 3 bulbs
b. Describe brightness
c. Factors that affect brightness
d. Summary - why think brightness varies
f. Experiences similar to this
6.a. Which bulb(s) brighter?
b. Contrast brightness
c. What happens if B unscrewed?
d. Construct - Results?
##########
7.a. Which bulb(s) will be brighter?
b. Contrast brightness
c. Reasons for answers in 'b'
d. Construct - Results?
8.a. Brightness, = length, same
b. Brightness, not = length, same
c. Brightness, not same wire
##########
9.a. Prediction A or B brighter?
b. Construct - Results?
c. Conclusion - Parallel
10.a. Prediction A or B brighter?
b. Construct - Results
c. Conclusion - Series
##########
11.a. Construct
b. #13 or #14 brighter?
c. Which bulb has greatest obstacle?
12.a. Which brighter-series
b. Which brighter-parallel
c. Construct
d. Results
##########
13.a. Devise test to compare bulbs brightness
b. Construct after instructor checks
c. Results
14. Summary of work to date
##########
15.a. Contrast brightness of all 5
b. Reasons - instructor informed
c. Construct
d. Results

BATTERIES AND BULBS TEST -1- NAME_____

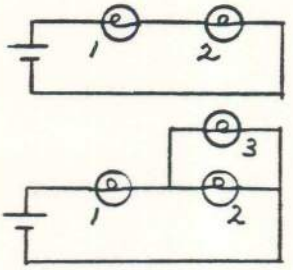
1. In each of the diagrams below, will the bulb light? (yes or no)

A _____
B _____
C _____
D _____



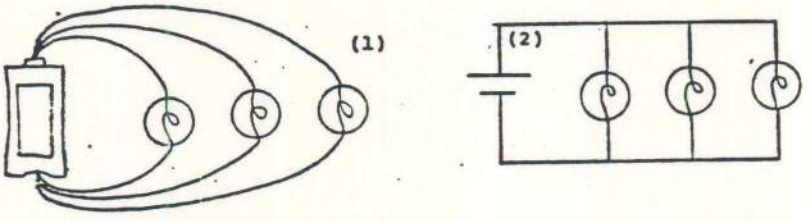
2. Suppose you start with two identical bulbs connected to the battery in series as shown in diagram A.

What will happen to the brightness of the first bulb if a third identical bulb is hooked in parallel to the second bulb, as shown in diagram B. Explain your answer.

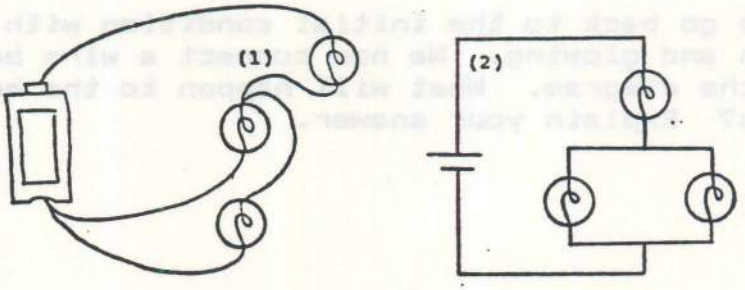


3. In the following pairs of diagrams (A), (B), and (C), do the two drawings (1) and (2) represent equivalent circuits in each case? (yes or no) By equivalent circuits we mean that all effects such as brightness of the bulbs and drain on the battery are the same in the two drawings regardless of how the wires are hooked up.

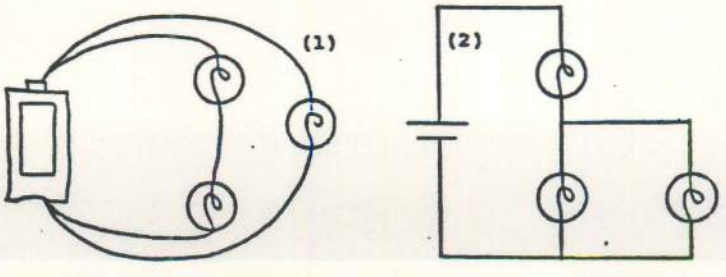
_____ A.



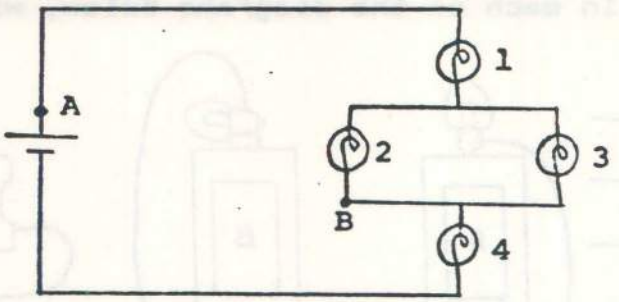
_____ B.



_____ C.



4. We start with four identical bulbs connected to a battery as shown in the diagram. The battery is strong enough to light all the bulbs.

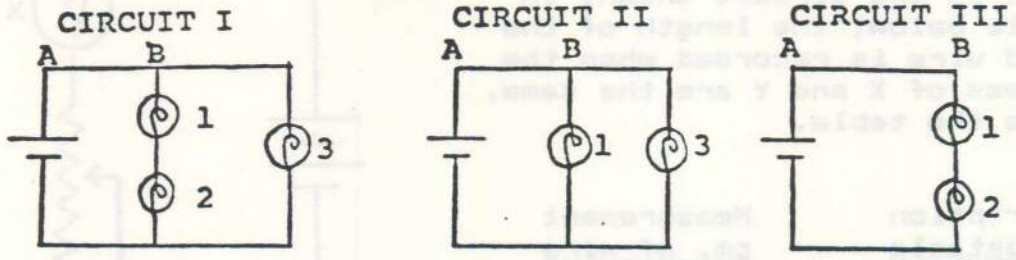


   a. When all the bulbs are screwed into their sockets and glowing, how do the brightness of the four bulbs compare with each other? Explain your answer.

   b. When bulb 3 is unscrewed so that it no longer lights in the above situation, what will happen to the brightness of bulbs 1, 2, and 4? Be sure to compare the final brightness with each other and also with the condition of part A. Explain your answer.

   c. Suppose we go back to the initial condition with all four bulbs screwed in and glowing. We now connect a wire between the points A and B on the diagram. What will happen to the brightness of the four bulbs? Explain your answer.

5. Three identical light bulbs are connected as shown in the circuit diagrams.



a. How does the brightness of bulb 1 compare in each of the three circuits? (i.e., mentioning circuits by number, indicate were bulb 1 glows with the greatest, least, or intermediate brightness.) Explain your answer.

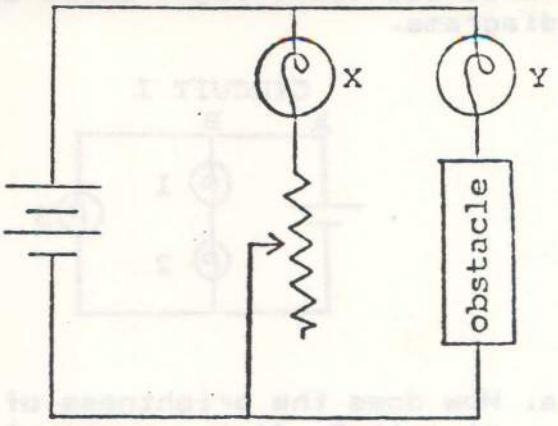
b. How does the brightness of bulb 3 compare in Circuit I and Circuit II? Explain your answer.

c. Compare the strength of the current in the wire between points A and B in each of the three circuits shown. (i.e., in which of the three circuits is there the most flow through the battery? the least flow? etc.?) Explain your answer.

d. In Circuit I, what happens to the brightness of bulbs 2 and 3 when bulb 1 is removed from its socket? Explain your answer.

BATTERIES AND BULBS TEST -4- NAME_____

6. Using bulbs X and Y to compare the length of a standard wire to an obstacle in the circuit shown, in the table below, the length of the standard wire is recorded when the brightness of X and Y are the same. Complete the table.



Description of Obstacle	Measurement cm. of wire
30 cm of #30 wire	15
60 cm of #30 wire	_____
90 cm of #30 wire	_____
200 cm of #30 wire	_____

A	60
B	10
C	20

2 C's in series	_____
A & B in series	_____
2 C's in parallel	_____
3 A's in parallel	_____

7. If 30 cm of #30 wire measures 15 cm of standard wire and #24 wire is larger in diameter, the resistance of 30 cm of #24 wire would measure

_____ a. 15 cm of standard wire
b. less than 15 cm of standard wire
c. more than 15 cm of standard wire

8. If 30 cm of #30 wire is the obstacle in the above circuit and the measuring wire is set at 10 cm of standard wire, then the bulb X will appear

_____ a. brighter than Y
b. dimmer than Y
c. the same brightness

9. If there is a lamp on in the room and you plug a second lamp into a wall outlet and turn it on, the the second lamp is added to the circuit in

_____ a. series
b. parallel
c. unknown

EVALUATION - BATTERIES AND BULBS B Name_____

1.a. What if A and B same brightness?
b. How measure resistance?
c. What units used?
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
2.a. objects - 1 battery
#13 bulb - 1 battery
#14 bulb - 1 battery
b. With 2 batteries
With 3 batteries
c. Conclusion
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
3.a. Data-2 objects-series
b. Data in table
c. Rule-Series Resistance
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
4.a. Data-2 equal objects-parallel
b. Data in table
c. Rule-2 equal objects-parallel
d. Did it work for 3 = in parallel?
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
5.a. Predict if parallel, not =
b. Construct
c. Results
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
6.a. Construct - 5 wires
b. Compare brightness A and B
c. Conclusion
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
7.a. Construct - 5 bulbs
b. Compare brightness A and B
c. Conclusion

EVALUATION - BATTERIES AND BULBS C Name_____

1.a. Examine circuit
b. Construct circuit
c. D represent ?
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
2.a. Construct-1 bulb-1 battery
b. Make proper adjustment
c. Current is? Record
d. Resistance is? Recorded
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
3.a. Construct-2 parallel-1 battery
b. Make proper adjustments
c. Resistance & Current recorded
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
4.a. Construct-3 parallel-1 battery
b. Make proper adjustments
c. Resistance & Current recorded
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
5.a. Plot Current vs Resistance
b. Results
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
6.a. Construct-1 bulb-2 battery
Construct-2 parallel-2 battery
Construct-3 parallel-2 battery
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
Construct-1 bulb-3 battery
Construct-2 parallel-3 battery
Construct-3 parallel-3 battery
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
b. Conclusion from Graph
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
7.a. k represents?
b. k related to?
xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx
8.a. V = ?
b. unit of V?
c. information (shove is?)

IN A COMPLETE CIRCUIT OF A BATTERY, BULB AND WIRE, AN ELECTRIC FLOW EXISTS. THE BRIGHTNESS OF THE BULB DEPENDS ON THIS FLOW THROUGH THE BULB.

WHAT ARE CHARACTERISTICS OF A FLOW?

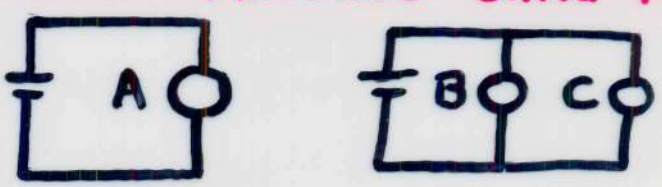
WHAT GOES IN MUST COME OUT.

∴ A CONSERVATION LAW

∴ FLOW "NOT" USED UP

DOES A BATTERY ALWAYS PRODUCE SAME FLOW?

CONTRAST BRIGHTNESS



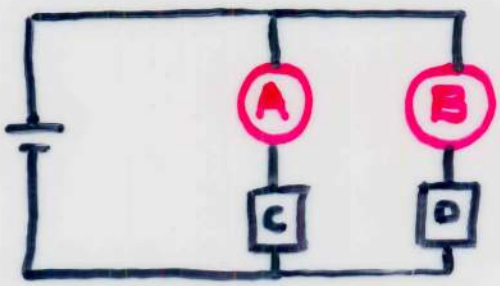
IS FLOW SHARED?

IS FLOW USED UP?

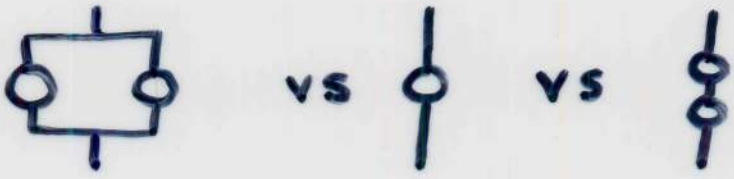
WHY IS A COMPLETE CIRCUIT NEEDED?

WHAT EFFECT DOES OBSTACLE HAVE?

COMPARER



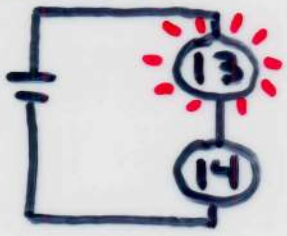
RESULTS:

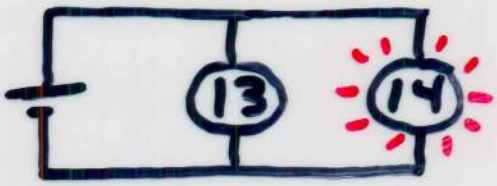


COMPARED: #13 BULB VS #14 BULB

RESULT $R_{13} > R_{14}$

OBSERVED:





IF SAME FLOW THEN WHY?

GREATER OBSTACLE

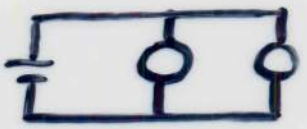
IS BRIGHTER

WERE THE 2 TEST BULBS IDENTICAL?

WHAT DOES "IDENTICAL" MEAN?

SAME NUMBER DOES IT?

WHAT IF TWO BULBS IN PARALLEL?



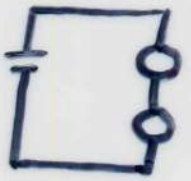
IF BRIGHTNESS IS THE SAME, THEN....

OBSTACLE IS THE SAME

BUT...

IS THE FLOW THROUGH EACH BULB THE SAME?

THUS MUST CHECK WHEN FLOW THE SAME.



THEREFORE

1ST : CHECK BRIGHTNESS WHEN SAME FLOW

2ND : " " WHEN OBSTACLE IS SAME

Rules

1. Greater Flow ⇒ Greater Glow
2. Flow not used up
3. Size of flow determined by size of obstacle
4. 2 objects in series have greater obstacle than either alone
5. 2 objects in parallel have lesser obstacle than either alone.