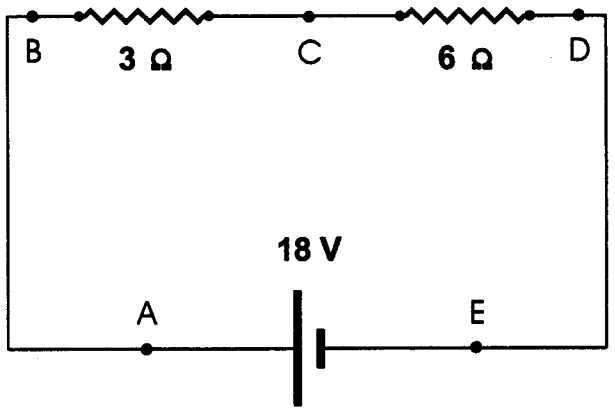
Chapter 6 Series Circuits

In-Class Questions

Prerequisite Concepts:

- **In a series circuit, there is only one path for current to flow**
- **Battery "voltage" is the potential difference between the battery terminals**
- **Potential *increases* as current moves through battery from negative to positive terminal**
- **Sum of potential changes (increases minus decreases) in a current loop equals zero**

Questions #1–13 all refer to this circuit:



1. Compared to the amount of current flowing through the 6-ohm resistor, the amount of current flowing through the 3-ohm resistor is:

   A. half as much

   B. the same

   C. twice as much

   D. Not enough information to determine.

2. Let us call the total amount of current flowing ***out*** of the battery "I_{tot}." How does this quantity, I_{tot}, compare to the total amount of current flowing ***into*** the battery?

   A. I_{tot} is larger than the amount of current flowing into the battery.

   B. I_{tot} is equal to the amount of current flowing into the battery.

   C. I_{tot} is less than the amount of current flowing into the battery.

   D. There is not enough information given to answer this question.

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3. Let us represent the amount of current flowing through the 6-ohm resistor by I_6, and that through the 3-ohm resistor by I_3. Which of the following numbered statements (*I, II,* and *III*) is true:

   I. $I_{tot} = I_3$

   II. $I_{tot} = I_6$

   III. $I_{tot} = I_3 + I_6$

   IV. $I_{tot} > I_3 + I_6$

   A. I only

   B. II only

   C. III only

   D. IV only

   E. I and II

   F. None of the above.

4. What is the magnitude of the potential difference between points A and E? (Let us symbolize this quantity by ΔV_{AE}.) *Remember that we assume all wires are ideal conductors.*

   A. $\Delta V_{AE} = 0$ V

   B. $0 \text{ V} < \Delta V_{AE} < 18 \text{ V}$

   C. $\Delta V_{AE} = 18$ V

   D. $\Delta V_{AE} > 18$ V

   E. There is not enough information to determine ΔV_{AE}.

5. Which of the following is true:

   A. The potential at B is the same as at D.

   B. The potential at B is higher than that at D.

   C. The potential at B is lower than that at D.

   D. There is not enough information to determine how the potentials at B and D compare.

6. Which of the following is true:

   A. A current of positive charges will flow through the resistors from point B to point D.

   B. A current of positive charges will flow through the resistors from point D to point B.

   C. There is not enough information to determine the direction in which a current of positive charges would flow through resistors.

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7. Which of the following is true:

   A. The potential at B is the same as at C.

   B. The potential at B is higher than that at C.

   C. The potential at B is lower than that at C.

   D. There is not enough information to determine how the potentials at B and C compare.

8. Which of the following is true:

   A. The potential at C is the same as at D.

   B. The potential at C is higher than that at D.

   C. The potential at C is lower than that at D.

   D. There is not enough information to determine how the potentials at C and D compare.

9. Which of the following is true:

   A. A current of positive charges will move through the battery from point E to point A.

   B. A current of positive charges will move through the battery from point A to point E.

   C. There is not enough information to determine the direction in which a current of positive charges would move through the battery.

10. Let $\Delta V_{BC} = | V_B - V_C |$, that is, it is the *magnitude* of the potential difference between points B and C. Then, $\Delta V_3 = \Delta V_{BC}$, and is the *magnitude* of the potential change across the 3-ohm resistor. Similarly, let $\Delta V_{CD} = | V_C - V_D |$; then, $\Delta V_6 = \Delta V_{CD}$.
    Which of the following relationships is true?

    A. $\Delta V_3 = 0.5\ \Delta V_6$

    B. $\Delta V_3 = \Delta V_6$

    C. $\Delta V_3 = 2\ \Delta V_6$

    D. none of the above

    E. not enough information available to determine the relative magnitude of ΔV_3 and ΔV_6.

11. Let $\Delta V_{AB} = | V_A - V_B |$, and $\Delta V_{DE} = | V_D - V_E |$; which of the following relationships is correct:

    A. $\Delta V_{AE} > [\Delta V_{AB} + \Delta V_3 + \Delta V_6 + \Delta V_{DE}]$

    B. $\Delta V_{AE} = [\Delta V_{AB} + \Delta V_3 + \Delta V_6 + \Delta V_{DE}]$

    C. $\Delta V_{AE} < [\Delta V_{AB} + \Delta V_3 + \Delta V_6 + \Delta V_{DE}]$

    D. Not enough information to determine the answer.

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12. *Assuming* that the wires in the circuit are ideal conductors, which of the following relationships is correct:

    A. $\Delta V_{AB} > \Delta V_{DE}$
    B. $\Delta V_{AB} < \Delta V_{DE}$
    C. $\Delta V_{AB} = \Delta V_{DE} \neq 0$
    D. $\Delta V_{AB} = \Delta V_{DE} = 0$
    E. Not enough information to decide

13. Assuming that the wires in the circuit are ideal conductors, which of the following relationships is correct:

    A. $\Delta V_{AE} > [\Delta V_3 + \Delta V_6]$
    B. $\Delta V_{AE} = [\Delta V_3 + \Delta V_6]$
    C. $\Delta V_{AE} < [\Delta V_3 + \Delta V_6]$
    D. Not enough information to determine the answer.

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14. A battery is connected to a resistor; the current through the resistor is I. Which of these actions will result in the current increasing by a factor of *four*? (That is, $I \rightarrow 4I$)

    A. double the battery voltage and double the resistance
    B. double the battery voltage and cut the resistance in half
    C. cut the battery voltage in half and double the resistance
    D. cut the battery voltage in half and cut the resistance in half

15. A battery is connected to a resistor with resistance R; the current through the resistor is I. If this ***same*** battery is connected to a different resistor with resistance 2R, what will be the current through this new resistor?

    A. I/4
    B. I/2
    C. I
    D. 2I
    E. 4I
    F. not enough information to answer

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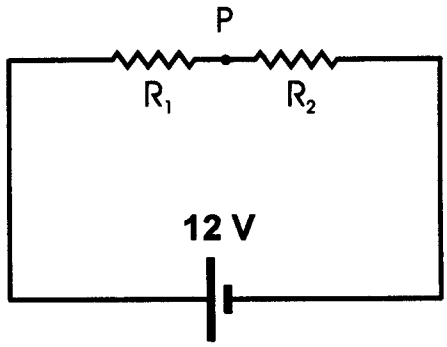
In-Class Exercises

Questions #1–3 refer to this figure:



Let ΔV_{R_1} and ΔV_{R_2} represent the magnitudes of the potential changes across resistors R_1 and R_2, respectively. (These are also called the "voltage drops" across these resistors.) Assume that the potential at the negative terminal of the battery is 0 V, and let V_P represent the potential at point P.

1. If $R_2 = R_1$, find the following values:

   ΔV_{R_1} = _____

   ΔV_{R_2} = _____

   V_P = _____

2. If $R_2 = 2R_1$, find the following values:

   ΔV_{R_1} = _____

   ΔV_{R_2} = _____

   V_P = _____

3. If $R_2 = 3R_1$, find the following values:

   ΔV_{R_1} = _____

   ΔV_{R_2} = _____

   V_P = _____

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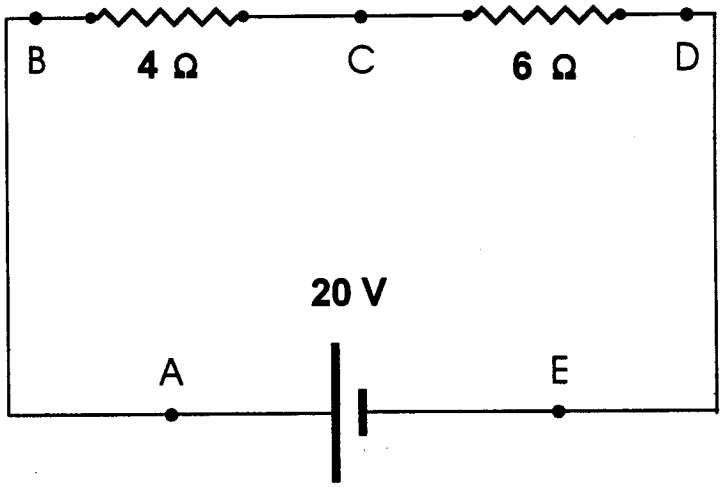
Questions #4–13 all refer to this figure:



4. Rank, in order, the following current magnitudes:

   A. I_4: the amount of current flowing through the 4-ohm resistor
   B. I_6: the amount of current flowing through the 6-ohm resistor
   C. I_{tot}: the total amount of current flowing ***out*** of the battery
   D. I_{in}: the total amount of current flowing ***into*** the battery

   Rank A, B, C, and D, starting with largest magnitude; if two or more are the same, put an "equals" sign ["="] between them; e.g., [A, B=C, D] means: A is largest, D is smallest, and B is equal to C.]:

   Ranking: (largest)_____(smallest)

5. Rank, in order, the following magnitudes:

   A. ΔV_4: the potential change across the 4-ohm resistor
   B. ΔV_6: the potential change across the 6-ohm resistor
   C. ΔV_{bat}: the potential difference between the battery terminals
   D. ΔV_{AB}: the potential difference between point A and point B
   E. ΔV_{DE}: the potential difference between point D and point E

   Rank A, B, C, D, and E, starting with largest magnitude; if two or more are the same, put an "equals" sign ["="] between them; e.g., [A, B=C, D, E] means: A is largest, E is smallest, and B is equal to C, but is larger than D]:

   Ranking: (largest)_____(smallest)

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6. Find the values of ΔV_4 and ΔV_6 in the following way:

   A. Write down the algebraic equation that relates the quantitites ΔV_4, ΔV_6, and ΔV_{bat}.

   B. Write down the algebraic equation that relates the quantitites ΔV_4 and ΔV_6.

   C. What is the value of ΔV_{bat}?

   ΔV_{bat} = _____

   D. Substitute the answers to B and C in the equation in A, in order to solve for ΔV_4 and V_6.

   ΔV_4 = _____

   ΔV_6 = _____

7. Write down the magnitudes of the following potential differences:

   A. ΔV_{AB} = _____

   B. ΔV_{BC} = _____

   C. ΔV_{CD} = _____

   D. ΔV_{DE} = _____

   E. ΔV_{AE} = _____

8. Assume that the potential at the negative terminal of the battery is 0 volts. Indicate the potential at the following points:

   A: _____

   B: _____

   C: _____

   D: _____

   E: _____

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9. Write down the magnitude of the following potential differences:

   A. ΔV_{AC} = _____

   B. ΔV_{BE} = _____

   C. ΔV_{CE} = _____

   D. ΔV_{DA} = _____

   E. ΔV_{BD} = _____

10. What is the amount of current flowing through the 4-ohm resistor? I_4 = _____

    What is the amount of current flowing through the 6-ohm resistor? I_6 = _____

    Write down the amount of current flowing past the following points in the circuit:

    A: _____

    B: _____

    C: _____

    D: _____

    E: _____

11.

    A. What is the amount of current ***coming out of*** the battery? (This is also called the "total current," or I_{tot})

       I_{tot} = _____

    B. What is the amount of current ***going into*** the battery?

       Amount of current going into battery = _____

12. What is the ratio $\Delta V_{bat}/I_{tot}$? (This is the "equivalent resistance" [R_{equiv}] of this circuit.)

    R_{equiv} = _____

13. Let us represent the resistance of the 4-ohm resistor as R_1, and that of the 6-ohm resistor as R_2. What is a simple algebraic relationship among R_1, R_2 and R_{equiv}?

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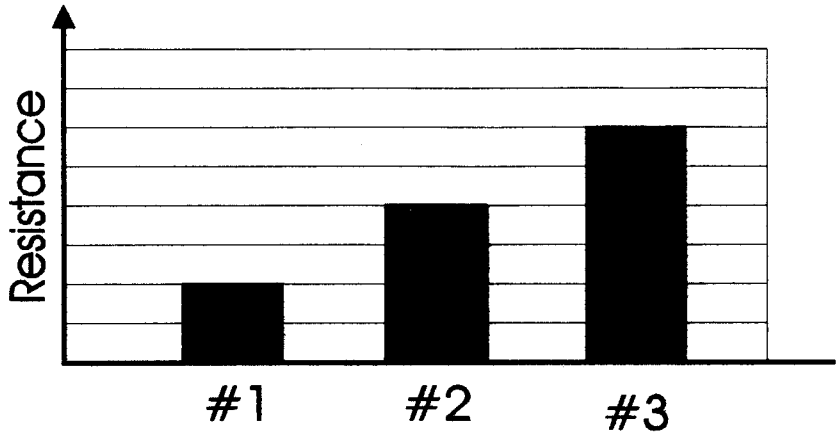
Homework Exercises

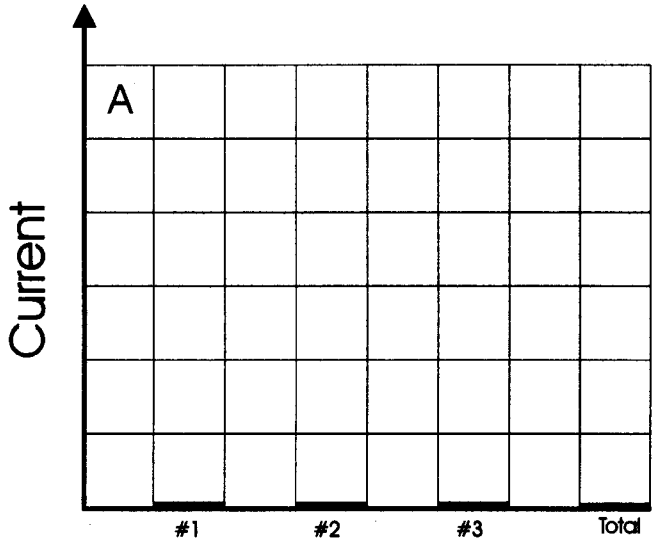
1. Three resistors are connected in series to a battery. The bar graph below shows the relative magnitudes of the three resistances.

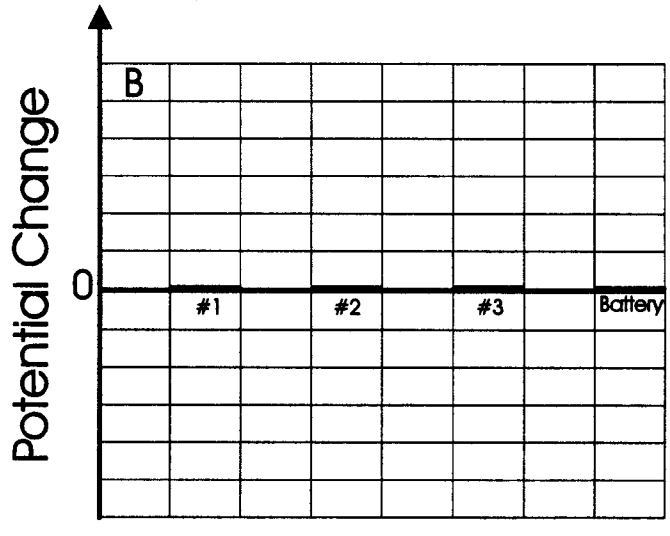


On the bar graphs below, draw:

A. three bars, representing the relative magnitudes of the current passing through each resistor, and a fourth bar indicating the relative magnitude of the current flowing through the battery (this is the "total current in the circuit").

B. three bars, representing the relative sizes of the potential changes experienced by the current as it flows across each resistor, and a fourth bar indicating the relative size of the potential change experienced by the current as it flows between the terminals of the battery. Indicate increasing potential as a *positive* change, and decreasing potential as a *negative* change.





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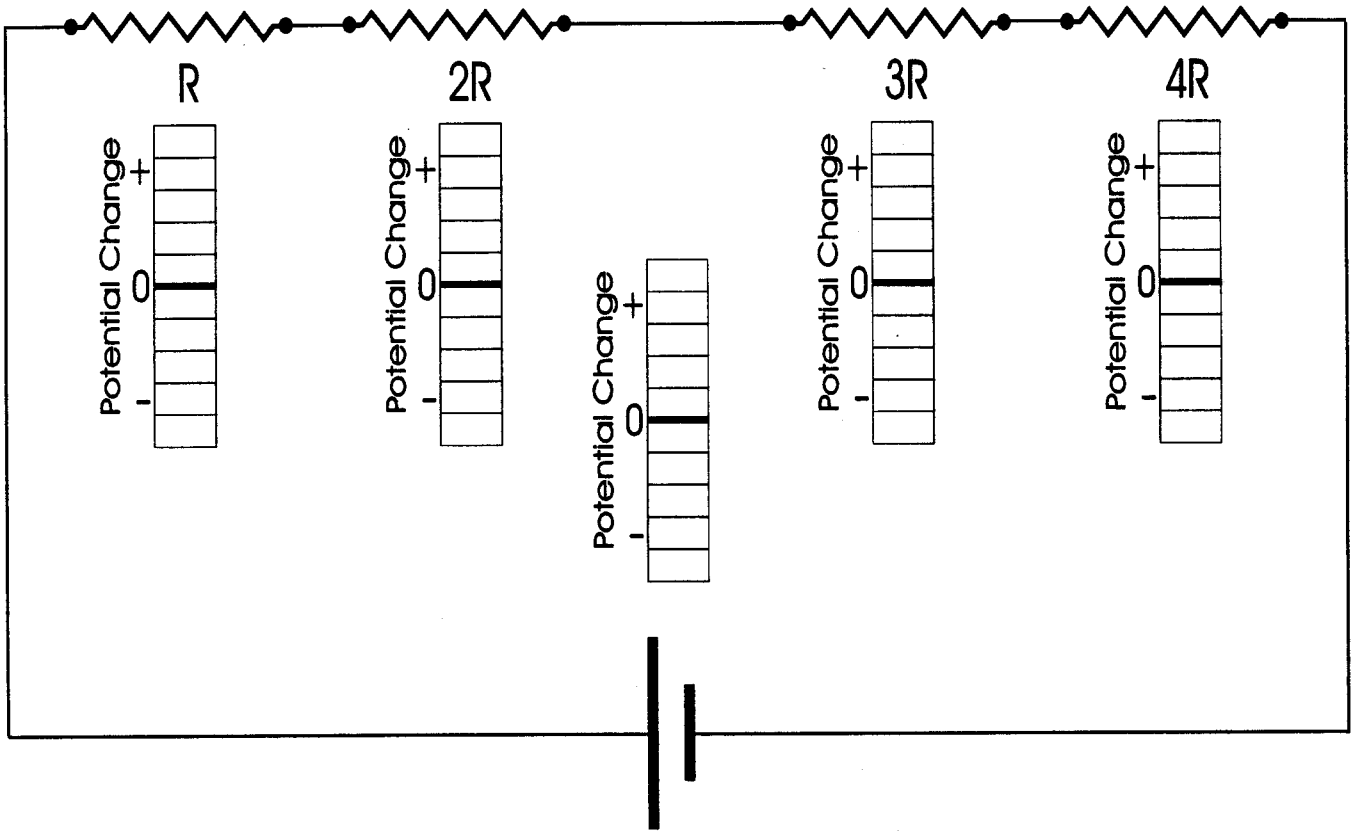
2. Four resistors are connected in series with a battery, as shown. The smallest resistance has a magnitude R, while the other three are 2R, 3R, and 4R respectively. On the circuit diagram, draw an arrow above each resistor, and one below the battery, indicating the direction of current flow. Make the length of each arrow proportional to the amount of current flowing through that particular part of the circuit. Below each resistor, and above the battery, a bar chart is drawn. Make the size of each bar proportional to the potential change experienced by the current as it moves across that particular circuit element (positive for increasing potential, negative for decreasing potential).



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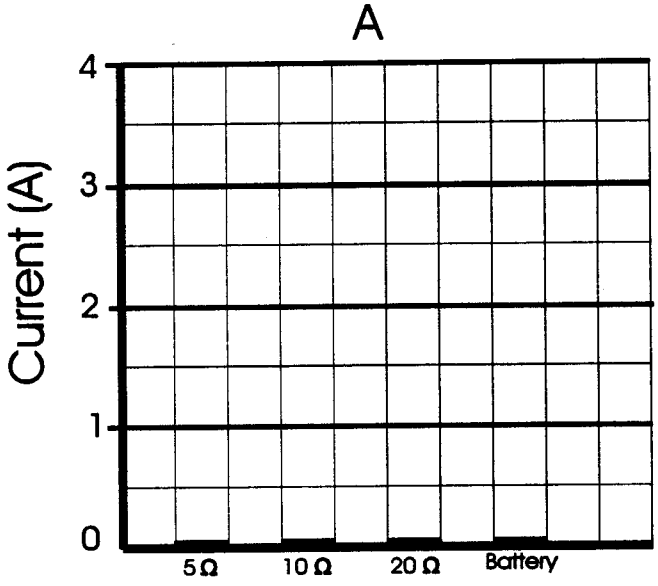
3. A 5-ohm resistor, a 10-ohm resistor and a 20-ohm resistor are connected in series with a 35-V battery. (Each of the following bar graphs should have four bars.)

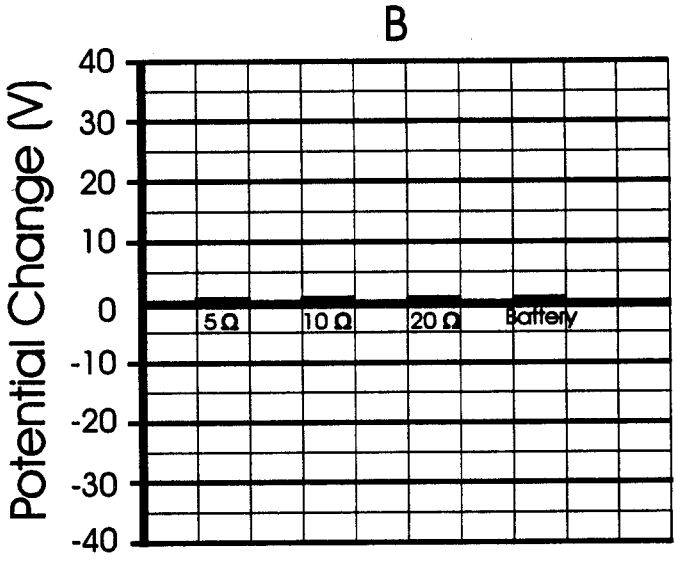
   A. Draw a bar graph showing the current flowing through the 5-ohm resistor, the 10-ohm resistor, the 20-ohm resistor, and the battery.

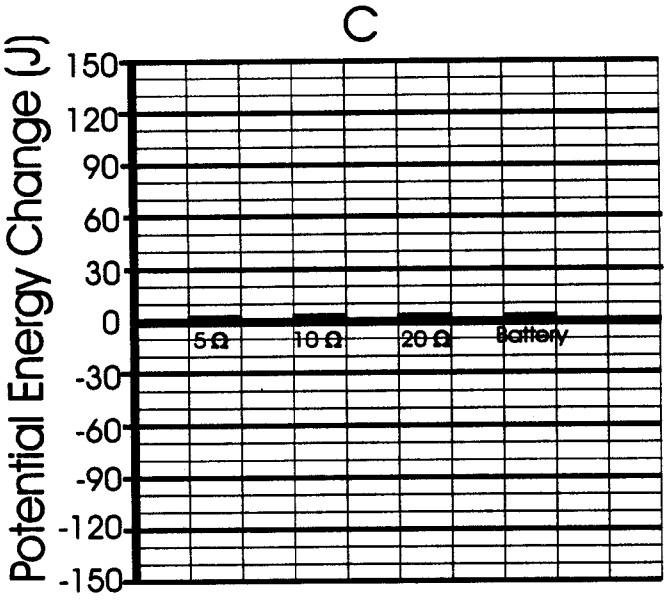
   B. Draw a bar graph showing the potential changes experienced by the current as it flows around the circuit. Indicate the potential increase (positive) or decrease (negative) across the 5-ohm resistor, the 10-ohm resistor, and the 20-ohm resistor, and between the terminals of the battery.

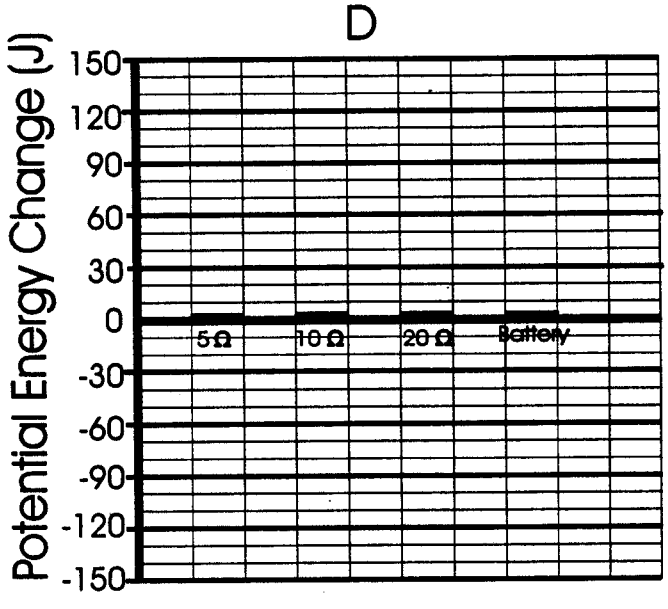
   C. Draw a bar graph showing the amount of potential energy gained (positive change) or lost (negative change) by a 2-C charge as it goes through the 5-ohm resistor, the 10-ohm resistor, the 20-ohm resistor, and the battery.

   D. Repeat C, this time assuming the battery is 70 V.









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4. Show algebraically that if three resistors R_1, R_2, and R_3 are connected in series, the equivalent resistance of the circuit is given by $R_{equiv} = R_1 + R_2 + R_3$. Follow these steps:

   a. Write down the definition of equivalent resistance R_{equiv} in terms of ΔV_{bat} and I_{tot}.

   b. Write an expression for ΔV_{bat} in terms of ΔV_{R_1}, ΔV_{R_2}, and ΔV_{R_3}, and substitute it in the equation in (a).

   c. Express ΔV_{R_1} in terms of I_{tot} and R_1, and write similar expressions for ΔV_{R_2} in terms of R_2, and ΔV_{R_3} in terms of R_3; substitute these in the equation in (b).

   d. Simplify the expression for R_{equiv} in (c) to eliminate I_{tot}.

5. A 2-Ω and a 4-Ω resistor are connected in series to a battery. $\Delta V_4 = 12$ V. $\Delta V_{bat} = ?$ Explain your answer.

6. A 3-Ω and a 5-Ω resistor are connected in series to a battery. $I_3 = 6$ A. $\Delta V_{bat} = ?$ Explain your answer.

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