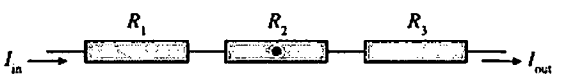
32 Fundamentals of Circuits

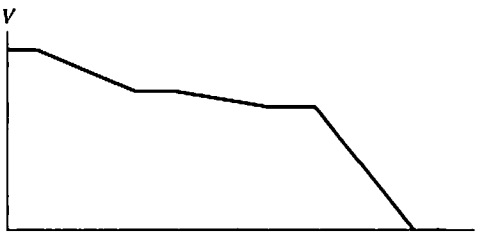
32.1 Circuit Elements and Diagrams

32.2 Kirchhoff's Laws and the Basic Circuit

1. The tip of a flashlight bulb is touching the top of a 3 V battery. Does the bulb light? Why or why not?

2. Current I_{in} flows into three resistors connected together one after the other. The graph shows the value of the potential as a function of distance.





   a. Is I_{out} greater than, less than, or equal to I_{in}? Explain.

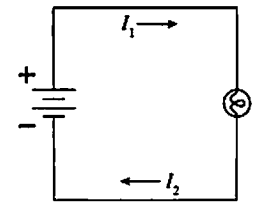
   b. Rank in order, from largest to smallest, the three resistances R_1, R_2, and R_3.

   Order:

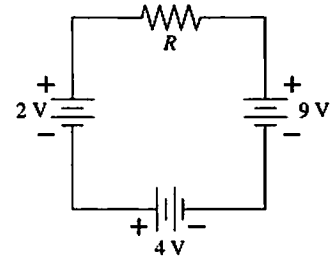
   Explanation:

   c. Is there an electric field at the point inside R_2 that is marked with a dot? If so, in which direction does it point? If not, why not?

3. A flashlight bulb is connected to a battery and is glowing. Is current I_2 greater than, less than, or equal to current I_1? Explain.



4. a. In which direction does current flow through resistor R?

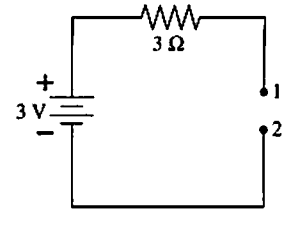


b. Which end of R is more positive? Explain.

c. If this circuit were analyzed in a clockwise direction, what numerical value would you assign to ΔV_R? Why?

d. What value would ΔV_R have if the circuit were analyzed in a counterclockwise direction?

5. The wire is broken on the right side of this circuit. What is the potential difference ΔV_{12} between points 1 and 2? Explain.

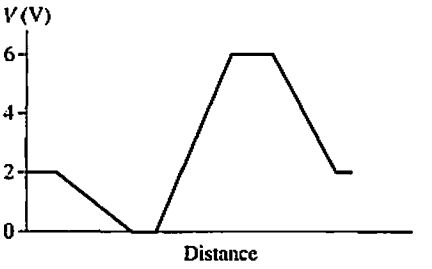


6. Draw a circuit for which the Kirchhoff loop law equation is

$$6\text{V} - I \cdot 2\Omega + 3\text{V} - I \cdot 4\Omega = 0$$

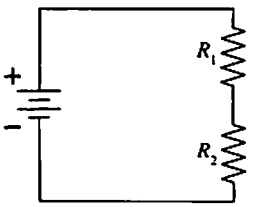
Assume that the analysis is done in a clockwise direction.

7. The current in a circuit is 2.0 A. The graph shows how the potential changes when going around the circuit in a clockwise direction, starting from the lower left corner. Draw the circuit diagram.

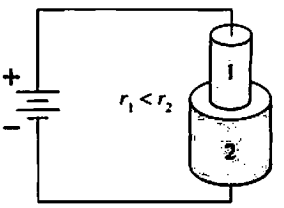


32.3 Energy and Power

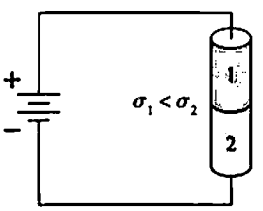
8. This circuit has two resistors, with $R_1 > R_2$. Which of the two resistors dissipates the larger amount of power? Explain.



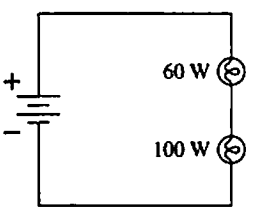
9. Two conductors of equal lengths are connected to a battery by ideal wires. The conductors are made of the same material but have different radii. Which of the two conductors dissipates the larger amount of power? Explain.



10. Two conductors of equal lengths are connected to a battery by ideal wires. The conductors have the same radii but are made of different materials and have different conductivities σ. Which of the two conductors dissipates the larger amount of power? Explain.



11. A 60 W lightbulb and a 100 W lightbulb are placed one after the other in a circuit. The battery's emf is large enough that both bulbs are glowing. Which one glows more brightly? Explain.

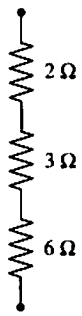


32.4 Series Resistors

32.5 Real Batteries

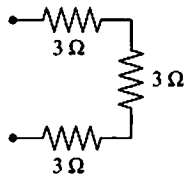
12. What is the equivalent resistance of each group of resistors?

a.



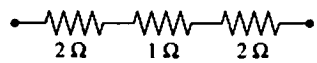
R_{eq} = _____

b.



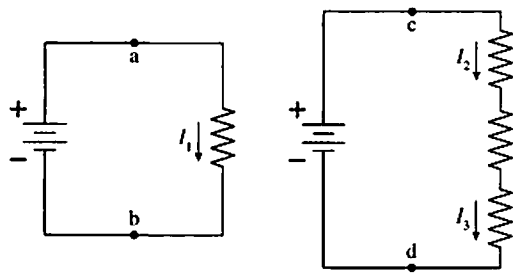
R_{eq} = _____

c.



R_{eq} = _____

13. The figure shows two circuits. The two batteries are identical and the four resistors all have exactly the same resistance.



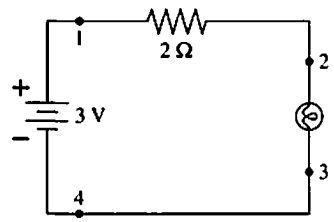
a. Is ΔV_{ab} larger than, smaller than, or equal to ΔV_{cd}? Explain.

b. Rank in order, from largest to smallest, the currents I_1, I_2, and I_3.

Order:

Explanation:

14. The lightbulb in this circuit has a resistance of 1 Ω.



a. What are the values of:

ΔV_{12} _____

ΔV_{23} _____

ΔV_{34} _____

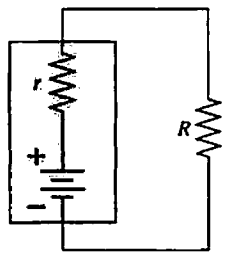
b. Suppose the bulb is now removed from its socket. Then what are the values of:

ΔV_{12} _____

ΔV_{23} _____

ΔV_{34} _____

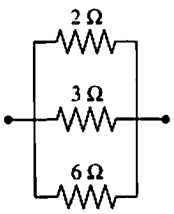
15. If the value of R is increased, does ΔV_{bat} increase, decrease, or stay the same? Explain.



32.6 Parallel Resistors

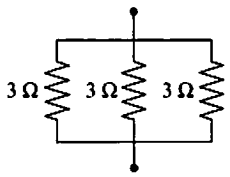
16. What is the equivalent resistance of each group of resistors?

a.



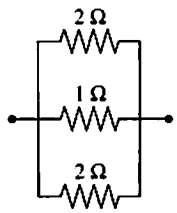
R_{eq} = _____

b.



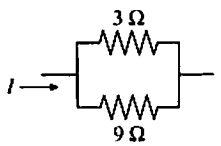
R_{eq} = _____

c.



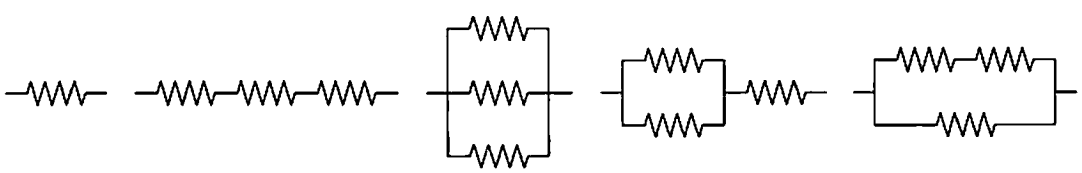
R_{eq} = _____

17. a. What fraction of current I goes through the 3 Ω resistor?



b. If the 9 Ω resistor is replaced with a larger resistor, will the fraction of current going through the 3 Ω resistor increase, decrease, or stay the same?

18. The figure shows five combinations of identical resistors. Rank in order, from largest to smallest, the equivalent resistances $(R_{eq})_1$ to $(R_{eq})_5$.



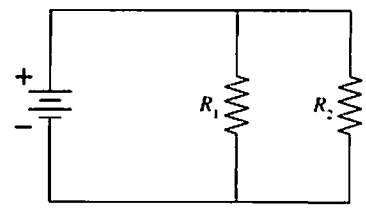
Order: _____

Explanation: _____

32.7 Resistor Circuits

32.8 Getting Grounded

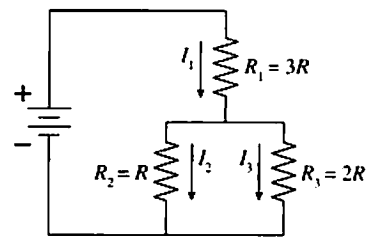
19. The circuit shown has a battery and two resistors, with $R_1 > R_2$. Which of the two resistors dissipates the larger amount of power? Explain your reasoning.



20. Rank in order, from largest to smallest, the three currents I_1 to I_3.

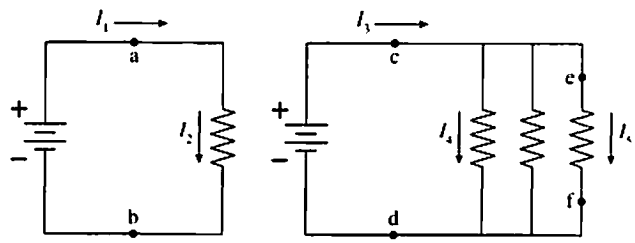
Order:

Explanation:



21. The two batteries are identical and the four resistors all have exactly the same resistance.

a. Compare ΔV_{ab}, ΔV_{cd}, and ΔV_{ef}. Are they all the same? If not, rank them in decreasing order. Explain your reasoning.



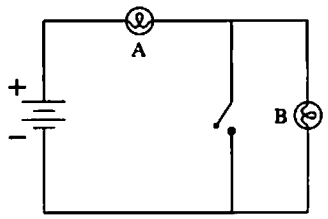
b. Rank in order, from largest to smallest, the five currents I_1 to I_5.

Order:

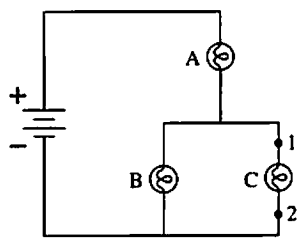
Explanation:

Exercises 22–28: Assume that all wires are ideal (zero resistance) and that all batteries are ideal (constant potential difference).

22. Initially bulbs A and B are glowing. Then the switch is closed. What happens to each bulb? Does it get brighter, stay the same, get dimmer, or go out? Explain your reasoning.



23. a. Bulbs A, B, and C are identical. Rank in order, from most to least, the brightnesses of the three bulbs.

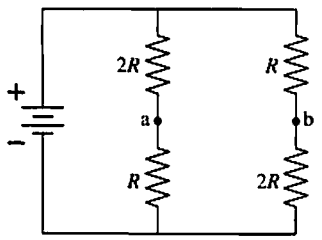


Order:

Explanation:

b. Suppose a wire is connected between points 1 and 2. What happens to each bulb? Does it get brighter, stay the same, get dimmer, or go out? Explain.

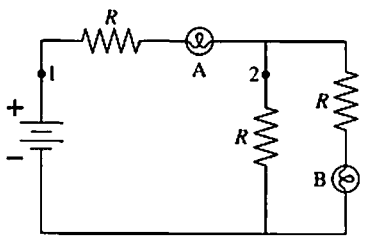
24. a. Consider the points a and b. Is the potential difference $\Delta V_{ab} = 0$? If so, why? If not, which point is more positive?



b. If a wire is connected between points a and b, does a current flow through it? If so, in which direction—to the right or to the left? Explain.

25. Bulbs A and B are identical. Initially both are glowing.

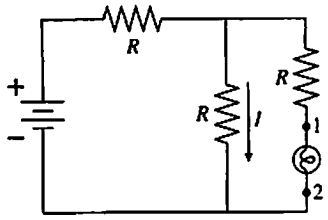
a. Bulb A is removed from its socket. What happens to bulb B? Does it get brighter, stay the same, get dimmer, or go out? Explain.



b. Bulb A is replaced. Bulb B is then removed from its socket. What happens to bulb A? Does it get brighter, stay the same, get dimmer, or go out? Explain.

c. The circuit is restored to its initial condition. A wire is then connected between points 1 and 2. What happens to the brightness of each bulb?

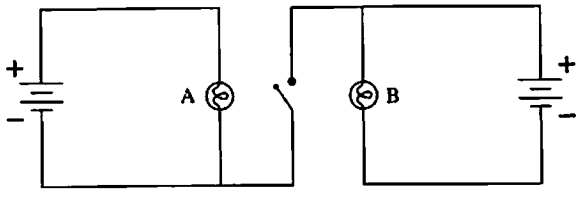
26. Initially the lightbulb is glowing. It is then removed from its socket.



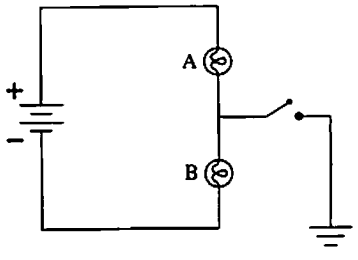
a. What happens to the current I when the bulb is removed? Does it increase, stay the same, or decrease? Explain.

b. What happens to the potential difference ΔV_{12} between points 1 and 2? Does it increase, stay the same, decrease, or become zero? Explain.

27. Bulbs A and B are identical and initially both are glowing. Then the switch is closed. What happens to each bulb? Does its brightness increase, stay the same, decrease, or go out? Explain.

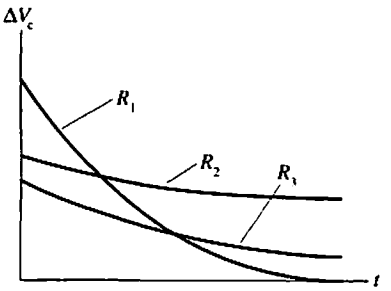


28. Bulbs A and B are identical and initially both are glowing. Then the switch is closed. What happens to each bulb? Does its brightness increase, stay the same, decrease, or go out? Explain.



32.9 *RC* Circuits

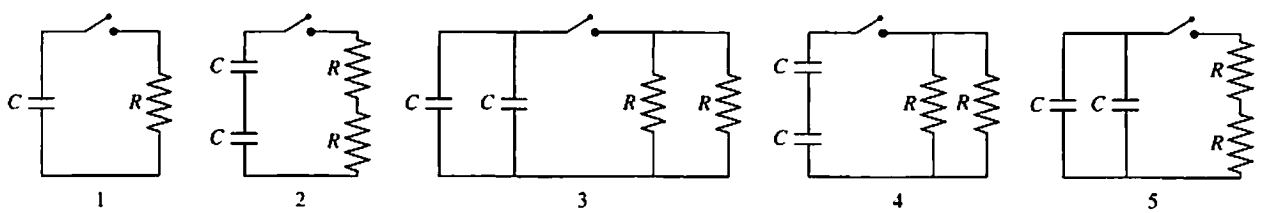
29. The graph shows the voltage as a function of time on a capacitor as it is discharged (separately) through three different resistors. Rank in order, from largest to smallest, the values of the resistances R_1 to R_3.



Order:

Explanation:

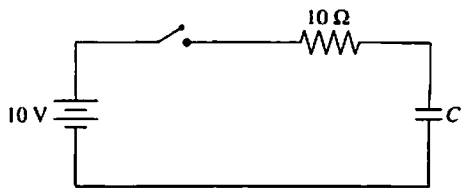
30. The capacitors in each circuit are discharged when the switch closes at $t = 0$ s. Rank in order, from largest to smallest, the time constants τ_1 to τ_5 with which each circuit will discharge.



Order:

Explanation:

31. The charge on the capacitor is zero when the switch closes at $t = 0$ s.



a. What will be the current in the circuit after the switch has been closed for a long time? Explain.

b. Immediately after the switch closes, before the capacitor has had time to charge, the potential difference across the capacitor is zero. What must be the potential difference across the resistor in order to satisfy Kirchhoff's loop law? Explain.

c. Based on your answer to part b, what is the current in the circuit immediately after the switch closes?

d. Sketch a graph of current versus time, starting from just before $t = 0$ s and continuing until the switch has been closed a long time. There are no numerical values for the horizontal axis, so you should think about the *shape* of the graph.