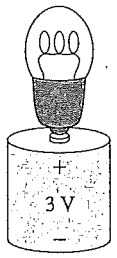
32 Fundamentals of Circuits

32.1 Circuit Elements and Diagrams

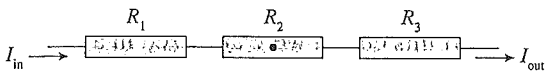
32.2 Kirchhoff's Laws and the Basic Circuit

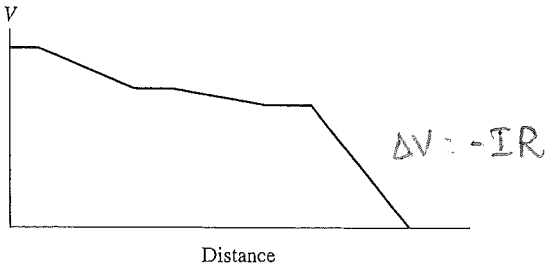
1. The tip of a flashlight bulb is touching the top of a 3 V battery. Does the bulb light? Why or why not?



No. Need a circuit (loop) for current to flow.

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.

$I_{out} = I_{in}$

at steady state charge must not be building up anywhere.

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

Order: $R_3 > R_1 > R_2$

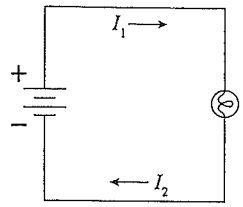
Explanation:

$\Delta V = -IR$ (left to right) all I's same.

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?

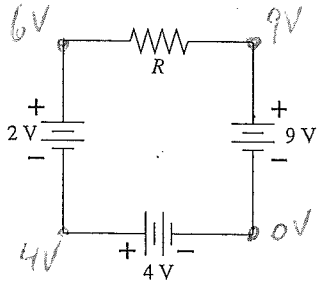
Yes. $I = JA$ $J = E/\rho$. to the right, the direction of current

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.



Same See 2a above.

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



From 9V → 6V

R to Left.

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

Right side (Write voltage at each corner to see this)

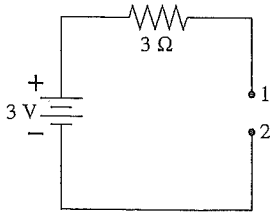
c. If this circuit were analyzed in a clockwise direction, what numerical value would you assign to ΔV_R? Why?

$\Delta V = V_f - V_i = 9v - 6v = 3V$

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

$-3V$.

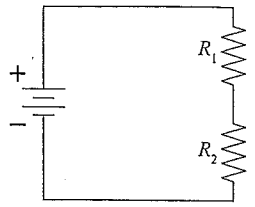
5. The wire is broken on the right side of this circuit. What is the potential difference ΔV_{12} between points 1 and 2? Explain.



3V. Voltage Drop through R = 0. because I = 0.

32.3 Energy and Power

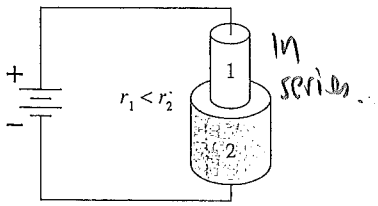
8. This circuit has two resistors, with $R_1 > R_2$. Which of the two resistors dissipates the larger amount of power? Explain.



I same:

$P = I^2R$ $\quad P_1 > P_2$.

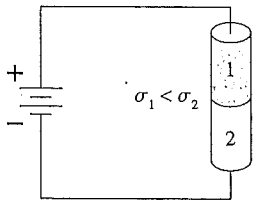
9. Two conductors of equal lengths are connected to a battery by ideal wires. The conductors are made of the same material but have different radii. Which of the two conductors dissipates the larger amount of power? Explain.



$R = \rho\frac{L}{A} = \frac{\rho L}{\pi r^2}$ $\quad r_1 < r_2 \Rightarrow R_1 > R_2$.

$P_1 > P_2$.

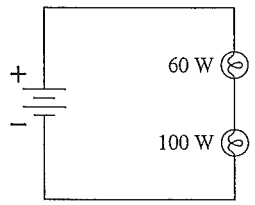
10. Two conductors of equal lengths are connected to a battery by ideal wires. The conductors have the same radii but are made of different materials and have different conductivities σ. Which of the two conductors dissipates the larger amount of power? Explain.



$\rho = \frac{1}{\sigma}$ $\quad \sigma_1 < \sigma_2$

$\rho_1 > \rho_2$. $\quad P_1 > P_2$.

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.



Which has higher resistance?

Since $P = \frac{V^2}{R}$, $R_{60} > R_{100}$ 60 W means "60W at 120V"!

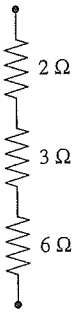
So IN SERIES, $P_{60} > P_{100}$!

32.4 Series Resistors

32.5 Real Batteries

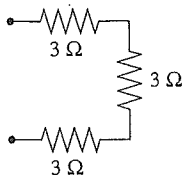
12. What is the equivalent resistance of each group of resistors?

a.



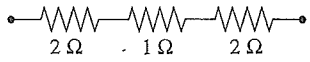
$R_{eq} =$ 11 Ω

b.



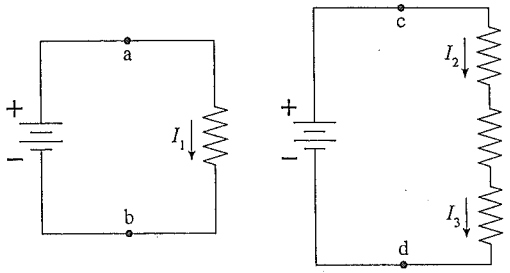
$R_{eq} =$ 9 Ω

c.



$R_{eq} =$ 5 Ω

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.

Same = $\mathcal{E}$.

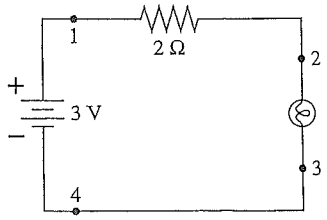
b. Rank in order, from largest to smallest, the currents I_1, I_2, and I_3.

Order: I_1 , I_2 & I_3 tie.

Explanation:

$\mathcal{E} = V = IR_{eq}$

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



a. What are the values of:

ΔV_{12} 2V

ΔV_{23} 1V

ΔV_{34} 0V

Use V=IR to find ΔV across each element

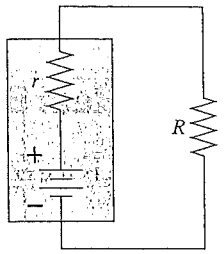
b. Suppose the bulb is now removed from its socket. Then what are the values of:

ΔV_{12} 0V

ΔV_{23} 3V

ΔV_{34} 0V

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



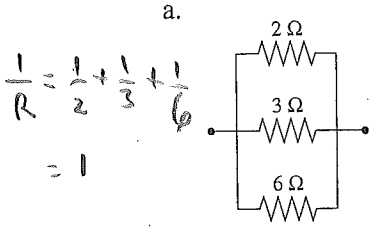
R↑ I↓ $\Delta V_{batt} = \mathcal{E} - Ir_{int}$

ΔV_{batt} ↑

32.6 Parallel Resistors

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

a.

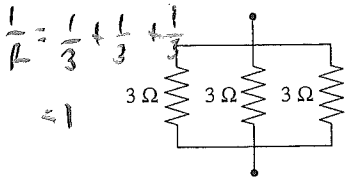


$\frac{1}{R} = \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$

$= 1$

$R_{eq} =$ 1 Ω

b.

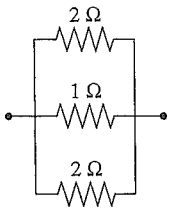


$\frac{1}{R} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$

$= 1$

$R_{eq} =$ 1 Ω

c.

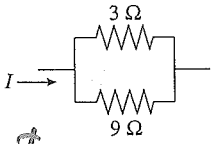


$\frac{1}{R} = \frac{1}{2} + \frac{1}{1} + \frac{1}{2}$

$= 2$

$R_{eq} =$ 0.5 Ω

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



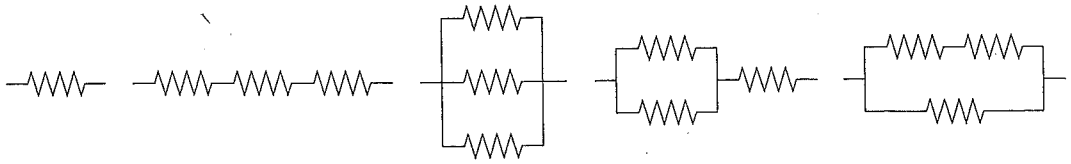
$V = I_1 R_{eq} = 1/R_{eq} = 1/3 + 1/9 = 4/9$ $R_{eff} = 9/4$

$V = \frac{9}{4} I_1$ V also $= I_3 3\Omega$ so $3I_3 = \frac{9}{4} I_1$ $I_3 = \frac{3}{4} I_1$

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?

Fraction of current will increase.
Amount of current is UNCHANGED!!!!

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



1 2 3 4 5

Order: 2 4 1 5 3

Explanation:

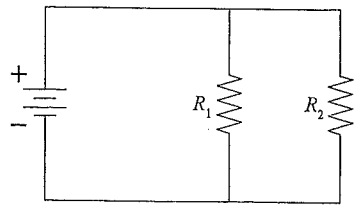
$R_4 > R_1$

BUT $R_5 < R_1$

32.7 Resistor Circuits

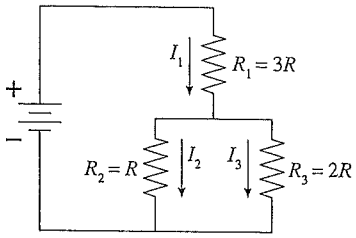
32.8 Getting Grounded

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.



$P = V^2/R$ $\quad P_2 > P_1$

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



Order: I_1, I_2, I_3.

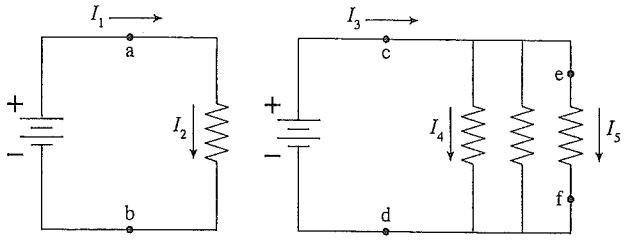
Explanation:

$I_1 = I_2 + I_3$ so largest

a larger fraction of current goes through smaller resistor in parallel

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.



Same, all = $\mathcal{E}$.

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

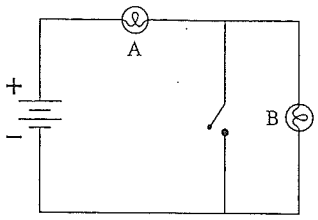
Order: I_3; I_1, I_2, I_4, I_5 all tie

Explanation:

$V = IR$.

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

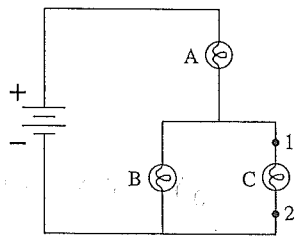
22. Initially bulbs A and B are glowing. Then the switch is closed. What happens to each bulb? Does it get brighter, stay the same, get dimmer, or go out? Explain your reasoning.



(B) goes out. All current flows through switch

(A) gets brighter. $V_A \uparrow$ $P = V^2/R$.

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



Order: A; B & C tie

Explanation:

$P = I^2R$. $I_A = I_B + I_C$.

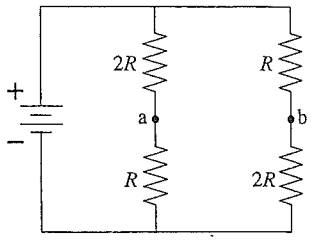
(A) gets twice the current.

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.

(B) & (C) BOTH GO OUT.

(A) gets brighter.

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?



No. $V_a = \frac{1}{3}\mathcal{E}$ $V_b = \frac{2}{3}\mathcal{E}$.

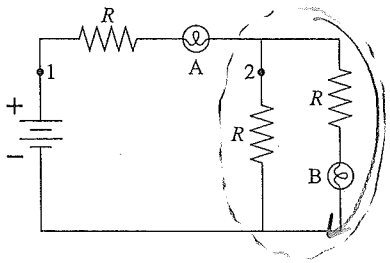
$V_b > V_a$

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.

Right to Left. See above.

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) goes out! No current flows.

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.

(A) gets DIMMER.
Removing right path INCREASES effective resistance in dotted oval. This decreases I.

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?

(A) goes out.
(B) gets brighter