Lecture (08)
DC Circuits

By:

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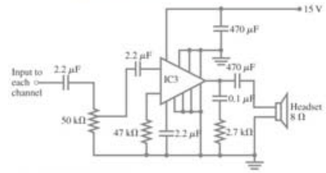
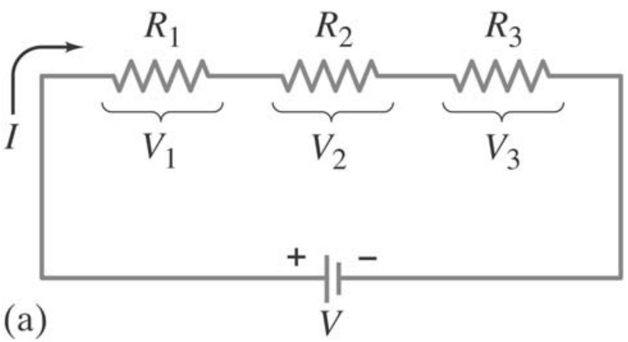
- MP3 players contain circuits that are dc, at least in part. (The audio signal is ac.)
- The circuit diagram below shows a possible amplifier circuit for each stereo channel.
- Although the large triangle is an amplifier chip containing transistors ,
- the other circuit elements are ones we have met, resistors and capacitors



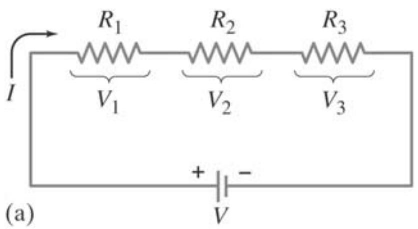
Resistors in Series and in Parallel

- **A series connection has a single path from the battery, through each circuit element in turn, then back to the battery.**



(a)

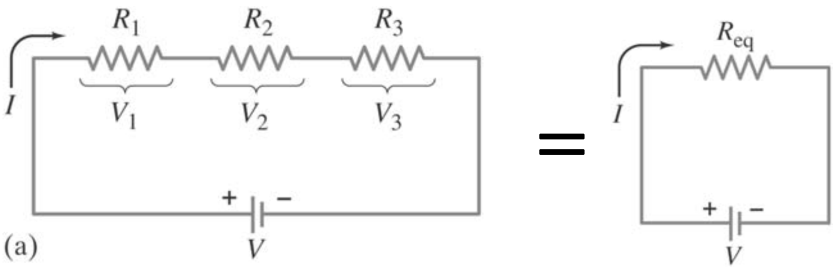
- **The current through each resistor is the same; the voltage depends on the resistance.**
- **The sum of the voltage drops across the resistors equals the battery voltage:**
- $\boldsymbol{V = V_1 + V_2 + V_3}$
- $\boldsymbol{V = I\,R_1 + I\,R_2 + I\,R_3}$
- $V = I\,(R_1 + R_2 + R_3)$
- $V = I\,Req$
- $\therefore R_{eq} = R_1 + R_2 + R_3$



(a)

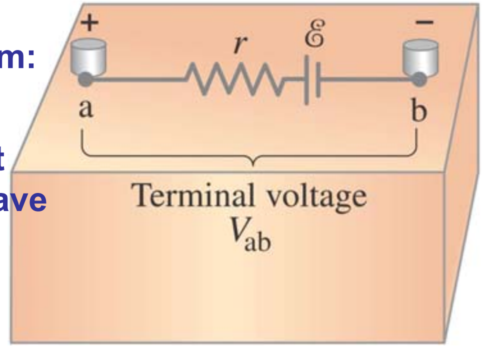
- From this we get the equivalent resistance (that single resistance that gives the same current in the circuit):

- $R_{eq} = R_1 + R_2 + R_3$ → series



EMF and Terminal Voltage

- Electric circuit needs battery or generator to produce current – these are called sources of emf (archaic term: electromotive force).
- Battery is a nearly constant voltage source, but does have a small internal resistance, which reduces the actual voltage from the ideal emf:

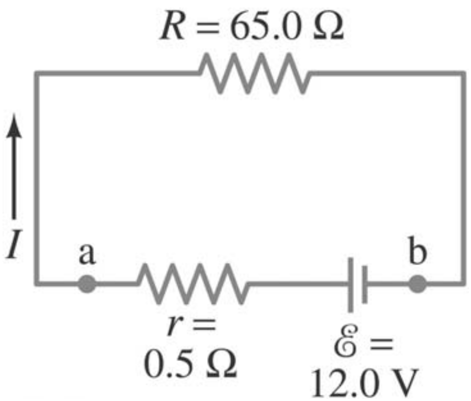


$$V_{terminal} = Vint_{ernal} - I\ Rinternal$$

$$V_{ab} = \varepsilon - I\ r$$

Example

- A 65.0-Ω resistor is connected to the terminals of a battery whose emf is 12.0 V and whose internal resistance is 0.5 Ω. Calculate (a) the current in the circuit, (b) the terminal voltage of the battery, V_{ab}, and (c) the power dissipated in the resistor R and in the battery's internal resistance r.

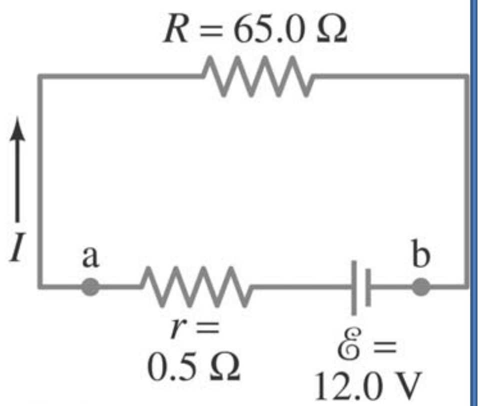


- $I = \frac{V}{Req} = \frac{\varepsilon}{R+r} = \frac{12}{65+0.5} = \frac{12}{65.5} = 0.183\ A$

- $V_{ab} = \varepsilon - I\ r = 12 - 0.5 \times 0.183 = 11.91\ V$

- $P_R = I^2\ R = (0.183)^2\ \times 65 = 2.8\ W$

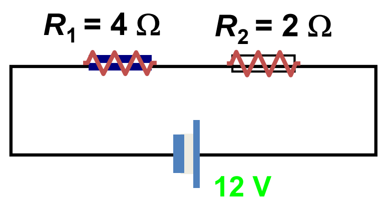
- $P_r = I^2\ R = (0.183)^2\ \times 0.5 = 0.0167\ W$



MCQ

In the circuit below, what is the voltage across R_1?

1) **12 V**
2) **zero**
3) **6 V**
4) **8 V**
5) **4 V**



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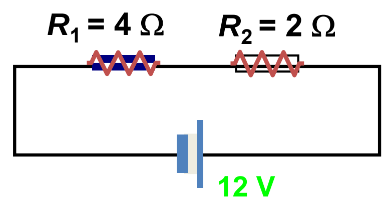
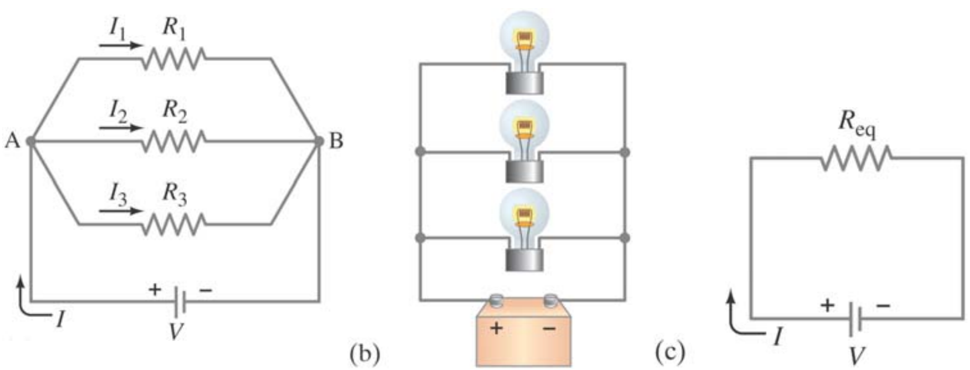


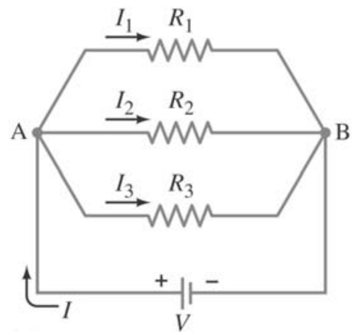
The voltage drop across R_1 has to be twice as big as the drop across R_2. This means that $V_1 = 8$ V and $V_2 = 4$ V. Or else you could find the current $I = V/R$ = (12 V)/(6 Ω) = 2 A, and then use Ohm's law to get voltages.

Resistors in Series and in Parallel

- **A parallel connection splits the current; the voltage across each resistor is the same:**



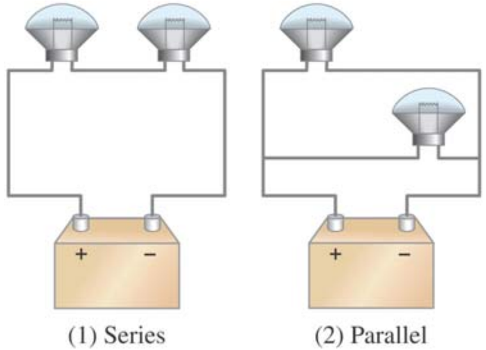
- **The total current is the sum of the currents across each resistor:**
- $I = I_1 + I_2 + I_3$
- $I = \frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$
- $\frac{V}{R_{eq}} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$
- $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$



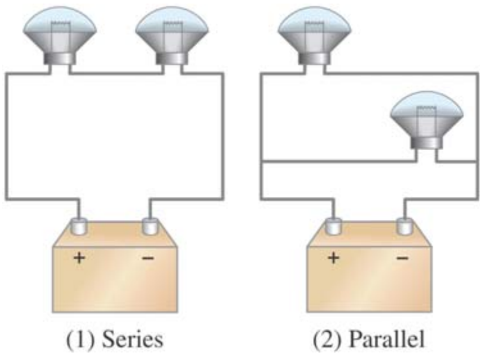
- **An analogy using water may be helpful in visualizing parallel circuits. The water (current) splits into two streams; each falls the same height, and the total current is the sum of the two currents. With two pipes open, the resistance to water flow is half what it is with one pipe open.**

Resistors in Series and in Parallel

- **Conceptual Example 26-2: Series or parallel?**
- **(a) The lightbulbs in the figure are identical. Which configuration produces more light?**
- **(b) Which way do you think the headlights of a car are wired? Ignore change of filament resistance *R* with current.**



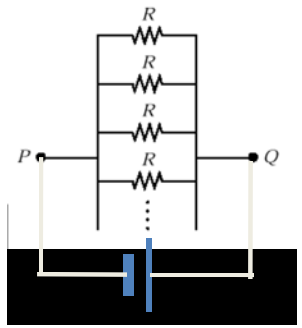
- a. In the parallel configuration, the equivalent resistance is less, so the current is higher and the lights will be brighter.
- b. They are wired in parallel, so that if one light burns out the other one still stays on.



MCQ

- Points P and Q are connected to a battery of fixed voltage. As more resistors *R* are added to the parallel circuit, what happens to the total current in the circuit?

1) increases
2) remains the same
3) decreases
4) drops to zero

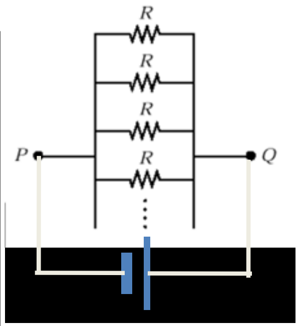


MCQ

- Points P and Q are connected to a battery of fixed voltage. As more resistors *R* are added to the parallel circuit, what happens to the total current in the circuit?

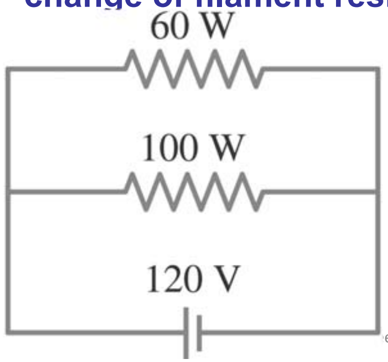
1) <u>increases</u>
2) remains the same
3) decreases
4) drops to zero

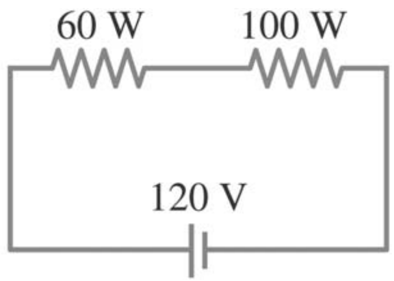
As we add parallel resistors, the overall resistance of the circuit drops. Since *V* = *IR*, and *V* is held constant by the battery, when resistance decreases, the current must increase.



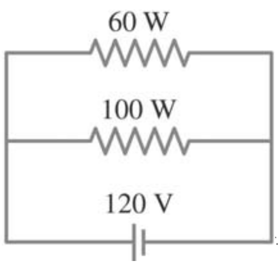
Example

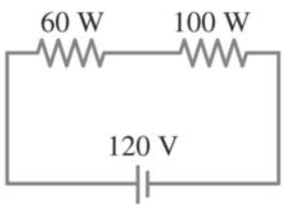
- **An illuminating surprise.**
- **A 100-W, 120-V lightbulb and a 60-W, 120-V lightbulb are connected in two different ways as shown. In each case, which bulb glows more brightly? Ignore change of filament resistance with current (and**



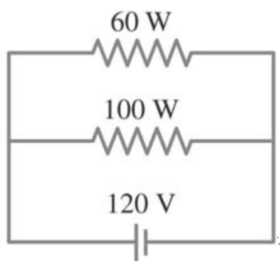


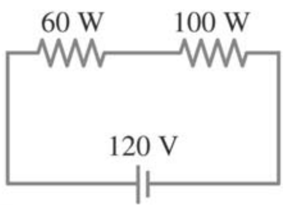
- <u>In parallel</u> :
  - P = V^2/R, so at constant voltage the bulb dissipating more power will have lower resistance.
  - Each bulb sees the full 120V drop, as they are designed to do, so the 100-W bulb is brighter.





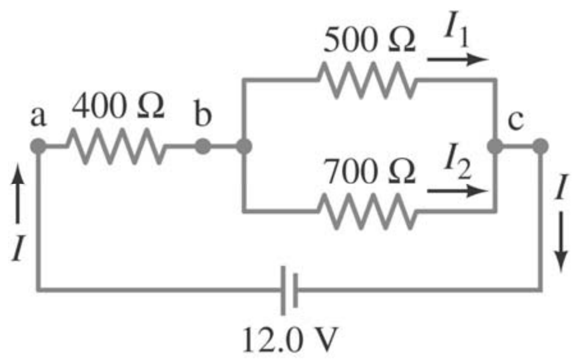
- <u>in series</u> :
  - the 60-W bulb – whose resistance is higher – will be brighter.
  - (More of the voltage will drop across it than across the 100-W bulb).





Example

- **What is the current through each resistor shown?**

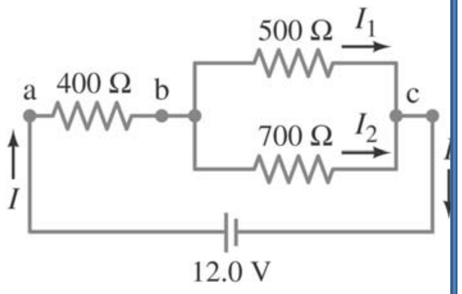


- $R_{1,2} = \frac{500 \times 700}{(500+700)} = 291.67\ Ohm$

- $R_{1,2\ ab} = 291.67 + 400 = 691.67\ ohm$

- $I_{ab} = \frac{12}{691.67} = 0.017\ Amp$

- $V_{1,2} = 0.017 \times 291.67$



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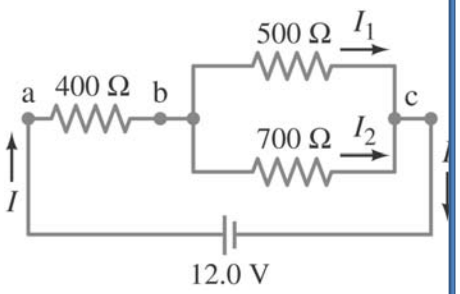
- $R_{1,2\ ab} = 291.67 + 400 = 691.67\ ohm$

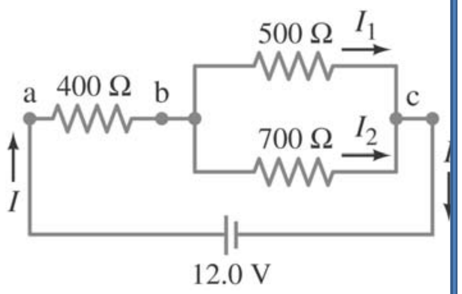
- $I_{ab} = \frac{12}{691.67} = 0.017\ Amp$

- $V_{1,2} = 0.017 \times 291.67 = 4.96\ Volt$



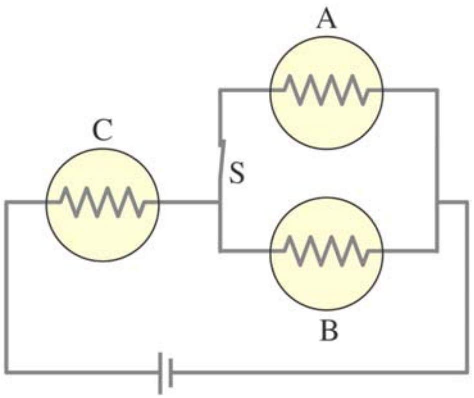
- $I_1 = \frac{4.96}{500} = 0.01$ Amp

- $I_2 = \frac{4.96}{700} = 0.0071\ Amp$



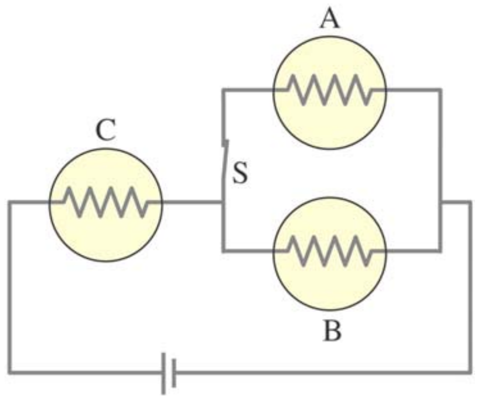
Example

- **The circuit shown has three identical lightbulbs, each of resistance R.**
- **(a) When switch S is closed, how will the brightness of bulbs A and B compare with that of bulb C?**
- **(b) What happens when switch S is opened? Use a minimum of mathematics in your answers.**



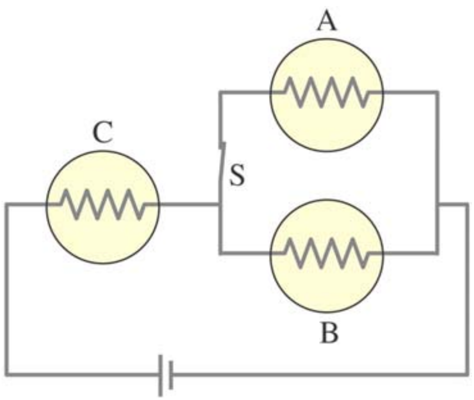
- switch closed: $R_{ab1} < R_{c1}$
- $P = I^2 R$
- $P_{C1} > P_{ab1}$
- C is brighter than A, and B

- switch is open : $R_{C2} = R_{B2}$
- $P = I^2 R$
- $P_{C2} = P_{B2}$
- C & B bright equally



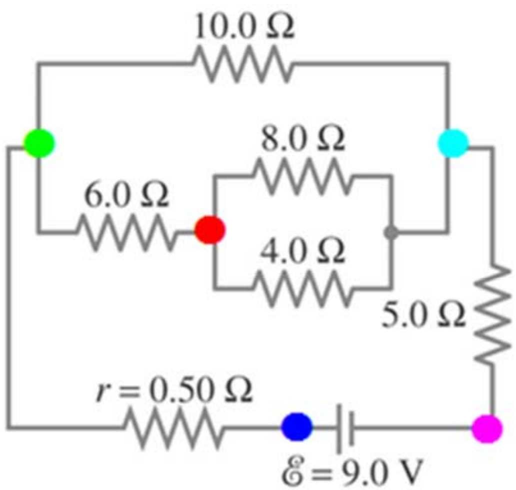
- $R_{abc1} < R_{abc2}$
- $I_{abc1} > I_{abc2}$
- C_1 is brighter than C_2

- $V_{b2} > V_{b1}$
- B_2 is brighter than B_1



example

- **A 9.0-V battery whose internal resistance r is 0.50 Ω is connected in the circuit shown.**
- **(a) How much current is drawn from the battery?**
- **(b) What is the terminal voltage of the battery?**
- **(c) What is the current in the 6.0-Ω resistor?**



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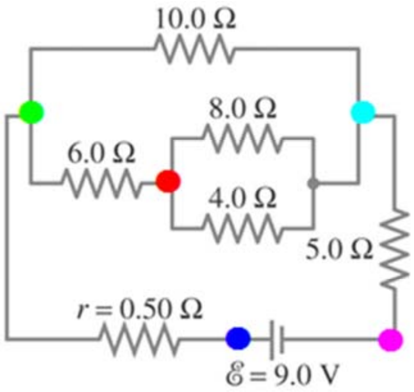

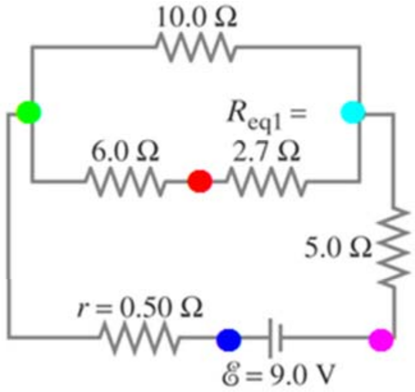

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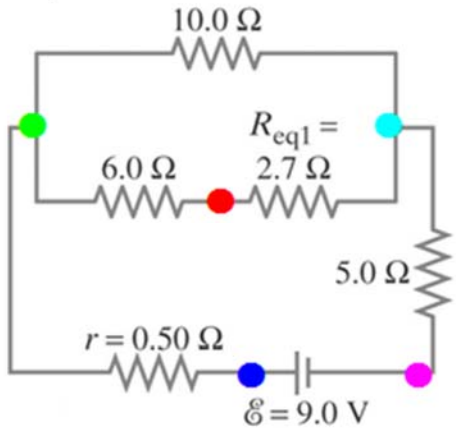
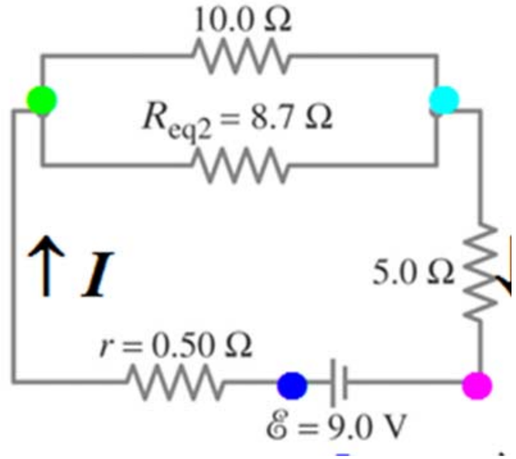
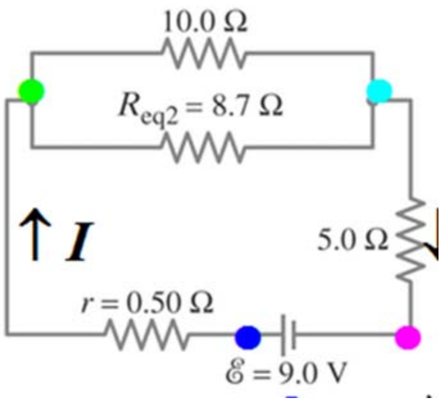
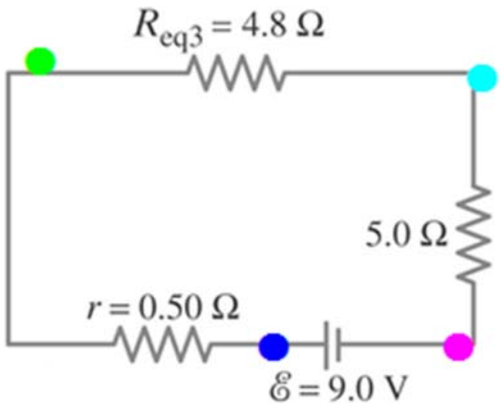
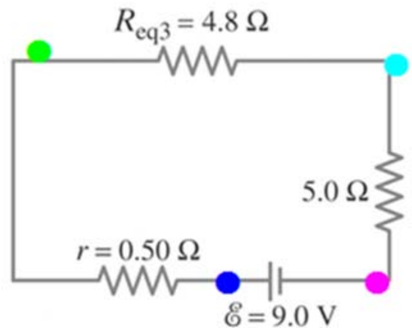




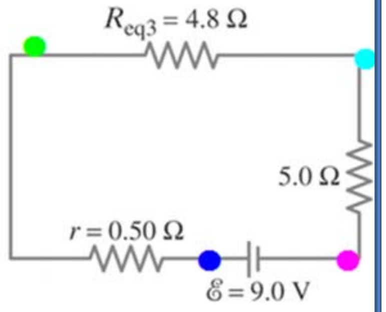


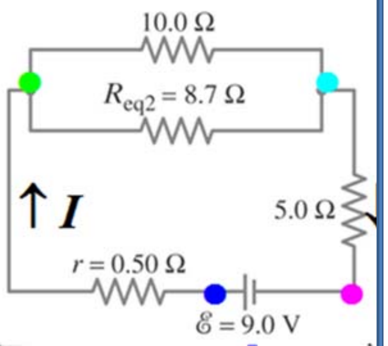


- $Req = 0.5 + 4.8 + 5$
  $= 10.3\ ohm$
- $I = \frac{9}{10.3} = 0.87\ Amp$
- $V_{batTerm} = 9\ - 0.5\ \times 0.87$
  $= 8.565$ Volt

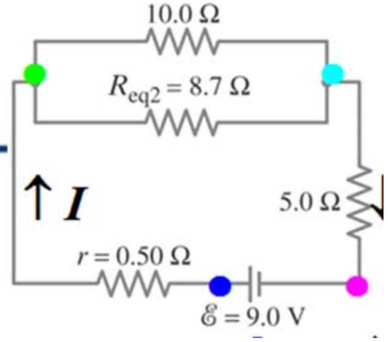


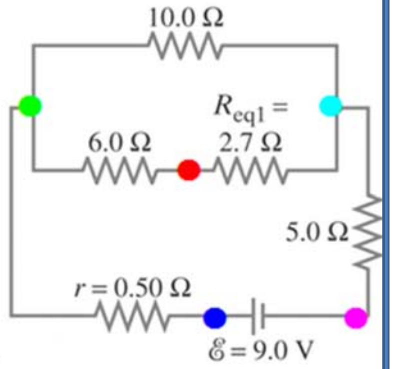
- $Veq3 = Veq2 = V_{10ohm} = 0.87 \times 4.8 = 4.176\ volt$





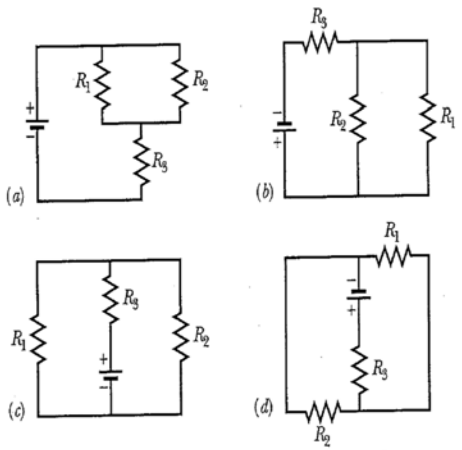
- $I_{6ohm} = \frac{4.176}{8.7} = 0.48$ Amp



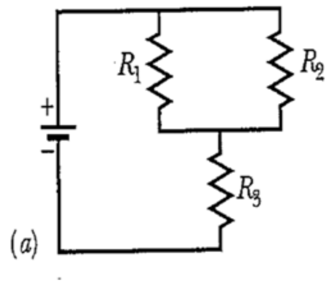


MCQ

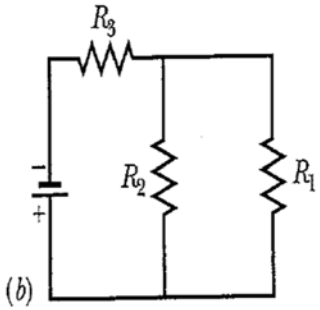
- **Assume that in each circuit the battery gives 12 V and each resistor has a resistance of 4 ohms. In which circuit does the largest current flow through the battery? What is that current?**



- R1,2 = 4/2 = 2 ohm
- R 1,2,3 = 6 ohm
- I = 12/6 = 2 Amp



- R1,2 = 4/2 = 2 Ohm
- R1,2,3 = 2 + 4 = 6 Ohm
- I = 12/6 = 2 Ohm



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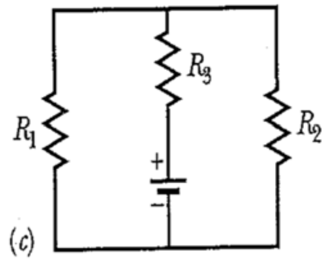

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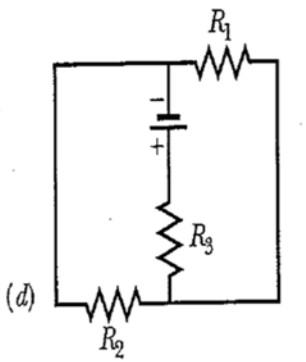
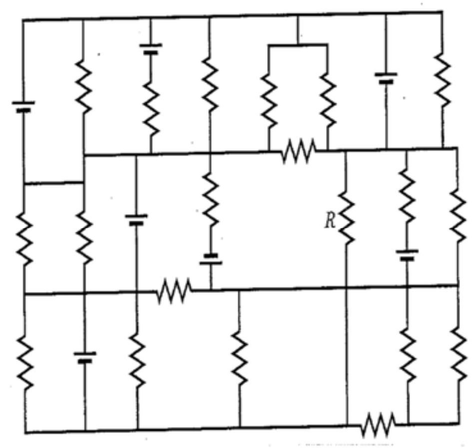


MCQ

- If each resistor has a resistance of 4 Ω and each battery is a 4 V battery, what is the current flowing through the resistor labelled “R”?
- (a) 0 A
- (b) 2 A
- (c) 4 A
- (d) 8 A
- (e) 16 A



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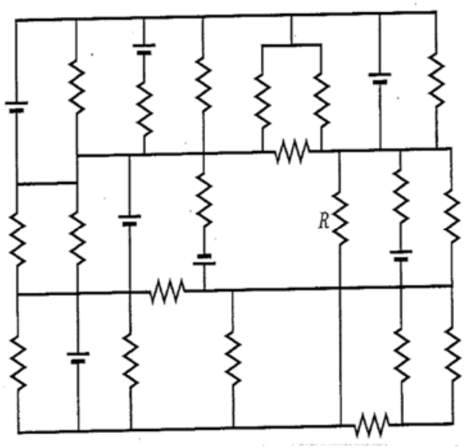

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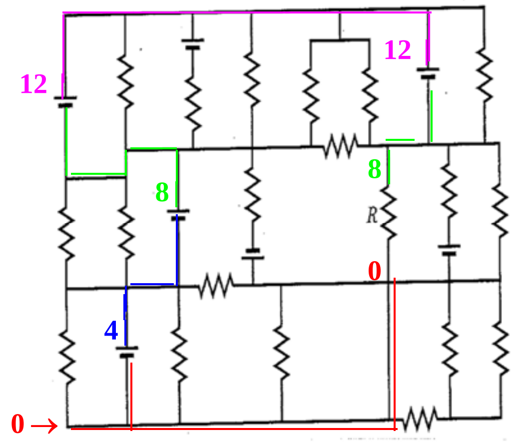
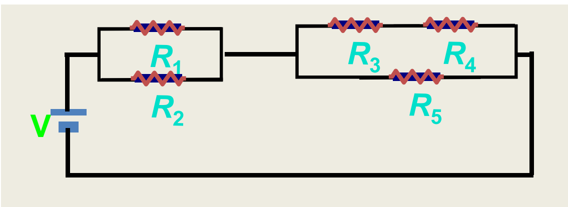
$$I = \frac{V}{R} = \frac{8}{4} = 2\ A$$



MCQ

- Which resistor has the greatest current going through it? Assume that all the resistors are equal.

1) R_1
2) both R_1 and R_2 equally
3) R_3 and R_4
4) R_5
5) all the same



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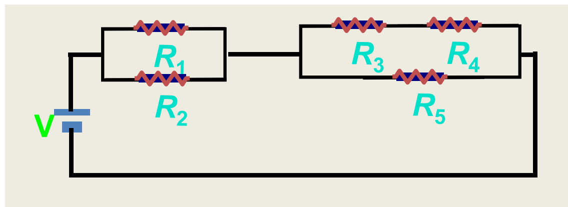
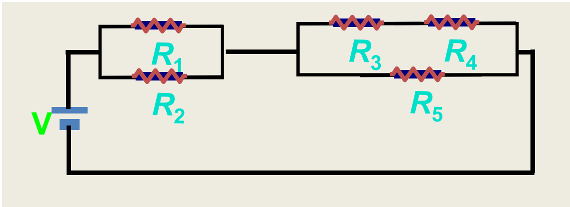


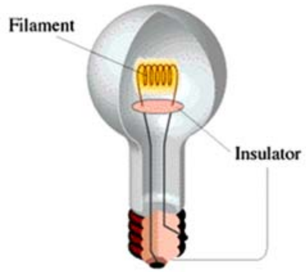
- The same current must flow through the left and right combinations of resistors. On the LEFT, the current splits equally, so $I_1 = I_2$. On the RIGHT, more current will go through R_5 than $R_3 + R_4$, since the branch containing R_5 has less resistance.



MCQ

- Two lightbulbs operate at 120 V, but one has a power rating of 25 W while the other has a power rating of 100 W. Which one has the greater resistance?

1) the 25 W bulb
2) the 100 W bulb
3) both have the same
4) this has nothing to do with resistance



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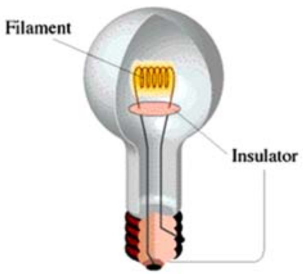

Since $P = V^2 / R$, the bulb with the lower power rating has to have the higher resistance.