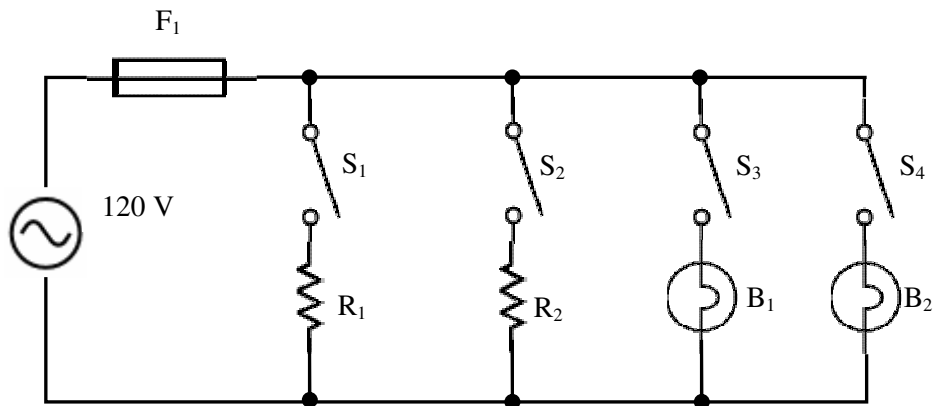


- 4) **Graded.** Draw a diagram of a parallel circuit that has an AC voltage supply, three bulbs, two switches (A and B), and a fuse. If both switches are open, no bulbs are lit. If switch A only is closed, then two bulbs are lit. If both switches are closed, then all three bulbs are lit. However, if both switches are closed, and the fuse burns out, one bulb will remain lit.

Use the following circuit diagram to answer questions 5) through 12)



- 5) Switches S_1 and S_2 are closed, and switches S_3 and S_4 are open. Resistor R_1 has a resistance of $10\ \Omega$, and resistor R_2 has a resistance of $15\ \Omega$. Bulb B_1 has a resistance of $240\ \Omega$, and bulb B_2 has a resistance of $100\ \Omega$. Fuse F_1 is rated at $15\ \text{A}$.
- What is the total current in the circuit?
 - What is the total resistance of the circuit?
 - Will Fuse F_1 burn out?
 - Will Fuse F_1 burn out if only switch S_1 is closed?

- 6) **Graded.** Switches S_1 , S_2 , and S_3 are closed, and switch S_4 is open. Resistor R_1 has a resistance of $20\ \Omega$; resistor R_2 has a resistance of $60\ \Omega$; bulb B_1 has a resistance of $100\ \Omega$; bulb B_2 has a resistance of $45\ \Omega$. Fuse F_1 is rated at $20\ \text{A}$.
- What is the total current in the circuit?
 - What is the total resistance of the circuit?
 - Will Fuse F_1 burn out?
- 7) **Graded.** Switches S_1 and S_3 are closed, and switches S_4 and S_2 are open. Resistor R_1 has a resistance of $22\ \Omega$; resistor R_2 has a resistance of $55\ \Omega$; bulb B_1 has a resistance of $120\ \Omega$; bulb B_2 has a resistance of $50\ \Omega$. Fuse F_1 is rated at $20\ \text{A}$.
- What is the total current in the circuit?
 - What is the total resistance of the circuit?
 - Will Fuse F_1 burn out?
- 8) **Graded.** Switches S_1 , S_2 , and S_4 are closed, and switch S_3 is open. Resistor R_1 has a resistance of $15\ \Omega$, resistor R_2 has a resistance of $45\ \Omega$, bulb B_1 has a resistance of $100\ \Omega$, and bulb B_2 has a resistance of $30\ \Omega$. Fuse F_1 is rated at $20\ \text{A}$.
- What is the total current in the circuit?
 - What is the total resistance of the circuit?
 - Will Fuse F_1 burn out?

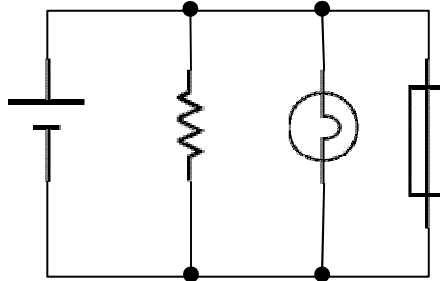
- 9) Resistor R_1 has a resistance of $20\ \Omega$; resistor R_2 has a resistance of $25\ \Omega$; bulb B_1 has a resistance of $40\ \Omega$; and bulb B_2 has a resistance of $75\ \Omega$. Fuse F_1 is rated at $15\ \text{A}$. You want to close as many switches as possible without burning out fuse F_1 . Which switches do you close? *(There may be multiple correct answers to this question.)*
- 10) **Graded.** Resistor R_1 has a resistance of $25\ \Omega$; resistor R_2 has a resistance of $30\ \Omega$; bulb B_1 has a resistance of $15\ \Omega$; and bulb B_2 has a resistance of $60\ \Omega$. Fuse F_1 is rated at $15\ \text{A}$. You want to close as many switches as possible without burning out fuse F_1 . Which switches do you close? *(There may be multiple correct answers to this question.)*
- 11) Resistor R_1 has a resistance of $30\ \Omega$; bulb B_1 has a resistance of $75\ \Omega$; and bulb B_2 has a resistance of $50\ \Omega$. Fuse F_1 is rated at $15\ \text{A}$. All four switches are closed. How much resistance must resistor R_2 have in order for the fuse not to burn out?
- 12) **Graded.** Resistor R_1 has a resistance of $60\ \Omega$; resistor R_2 has a resistance of $15\ \Omega$; bulb B_1 has a resistance of $100\ \Omega$. The fuse is rated at $15\ \text{A}$. How much resistance must bulb B_2 have in order for the fuse not to burn out?

Kenny is replacing some wiring in his house (parallel circuits). The wiring he is replacing is 12-gauge wiring (“gauge” is a rating system to tell how thick the wiring is: the smaller the number, the thicker the wire). However, he finds 22-gauge wire on sale for much less than the 12-gauge wiring. Use this information to answer questions 13) through 15).

- 13) **Graded.** Explain why it is risky for Kenny to use the thinner wiring to replace the thicker wiring.
- 14) **Graded.** Kenny can make reduce the risk by changing the fuse (or circuit breaker) for the circuit he is working on at the same time that he replaces the wiring. Will he want a fuse with a lower current rating or a higher one? Support your answer.
- 15) **Graded.** Before there were circuit breakers in houses, there were fuses. If a fuse burned out, some people would put a penny (big, fat piece of copper) into the fuse socket to replace the fuse. Why is this a bad idea?

Selected Answers

- 1) Draw a diagram of a parallel circuit that has three branches from a battery. On the first branch there is only a resistor. On the second branch, there is only a light bulb. On the third branch there is only a fuse.



- 5) Switches S_1 and S_2 are closed, and switches S_3 and S_4 are open. Resistor R_1 has a resistance of $10\ \Omega$, and resistor R_2 has a resistance of $15\ \Omega$. Bulb B_1 has a resistance of $240\ \Omega$, and bulb B_2 has a resistance of $100\ \Omega$. Fuse F_1 is rated at $15\ \text{A}$.

- a. What is the total current in the circuit?

Since S_3 and S_4 are open, there is no current going through those branches of the circuit. To find the total current, we need only to find the current going through the branches where S_1 and S_2 are located (where R_1 and R_2 are).

$$\text{The current through the } R_1 \text{ branch is } I_{R_1 \text{ branch}} = \frac{120\ \text{V}}{R_1 \text{ Resistance}} = \frac{120\ \text{V}}{10\ \Omega} = 12\ \text{A}.$$

$$\text{The current through the } R_2 \text{ branch is } I_{R_2 \text{ branch}} = \frac{120\ \text{V}}{R_2 \text{ resistance}} = \frac{120\ \text{V}}{15\ \Omega} = 8\ \text{A}.$$

Total current, according to Kirschhoff's current law is $I_{\text{total}} = I_{R_1 \text{ branch}} + I_{R_2 \text{ branch}}$

$$I_{\text{total}} = 12\ \text{A} + 8\ \text{A} = \mathbf{20\ \text{A}}$$

- b. What is the total resistance of the circuit?

Use Ohm's law here, but use the total current of the circuit to find the total resistance of the circuit.

$$R = \frac{V}{I} = \frac{120\ \text{V}}{20\ \text{A}} = \mathbf{6\ \Omega}$$

- c. Will Fuse F_1 burn out?

Yes, the fuse will burn out. The fuse is rated at $15\ \text{A}$, meaning that it can withstand up to $15\ \text{A}$ of current. More than $15\ \text{A}$ and it will burn out. Since the total current flowing through the fuse is $20\ \text{A}$, it will burn out.

- d. Will Fuse F_1 burn out if only switch S_1 is closed?

No, it will not. If only switch S_1 is closed, then the only closed branch will be the one with resistor R_2 on it. This branch has only $8\ \text{A}$ of current, and if that is the only branch closed, then $8\ \text{A}$ will also be the total current flowing through the circuit. The fuse will be able to handle the $8\ \text{A}$ of current.

- 9) Resistor R_1 has a resistance of $20\ \Omega$; resistor R_2 has a resistance of $25\ \Omega$; bulb B_1 has a resistance of $40\ \Omega$; and bulb B_2 has a resistance of $75\ \Omega$. Fuse F_1 is rated at $15\ \text{A}$. You want to close as many switches as possible without burning out fuse F_1 . Which switches do you close? (*There may be multiple correct answers to this question.*)

Because of where the fuse is located, the total current of the circuit will be the same as the amount of current flowing through the fuse. (It's a good idea if you make sure you understand why this statement is true for this circuit.)

So, all we have to do is to find the individual currents on each branch, and then find the combination of branches whose currents add up to values less than or equal to the capacity of the fuse.

For each branch, use Ohm's law to find the current on that branch:

$$I_{\text{branch}} = \frac{120\ \text{V}}{R_{\text{branch}}}$$

$$I_{R_1} = \frac{120\ \text{V}}{20\ \Omega} = 6\ \text{A}$$

$$I_{R_2} = \frac{120\ \text{V}}{25\ \Omega} = 4.8\ \text{A}$$

$$I_{B_1} = \frac{120\ \text{V}}{40\ \Omega} = 3\ \text{A}$$

$$I_{B_2} = \frac{120\ \text{V}}{75\ \Omega} = 1.6\ \text{A}$$

The sum of all four branches' currents is $6\ \text{A} + 4.8\ \text{A} + 3\ \text{A} + 1.6\ \text{A} = 15.4\ \text{A}$, which is greater than the fuse's rating. However, we can open ANY switch to reduce the total current below the fuse's limit.

So, we can close ANY three switches without burning the fuse.

- 11) Resistor R_1 has a resistance of $30\ \Omega$; bulb B_1 has a resistance of $75\ \Omega$; and bulb B_2 has a resistance of $50\ \Omega$. Fuse F_1 is rated at $15\ \text{A}$. All four switches are closed. How much resistance must resistor R_2 have in order for the fuse not to burn out?

First, find the current on the branches for which we can calculate it:

$$I_{R_1} = \frac{120\ \text{V}}{30\ \Omega} = 4\ \text{A}$$

$$I_{B_1} = \frac{120\ \text{V}}{(75\ \Omega)} = 1.6\ \text{A}$$

$$I_{B_2} = \frac{120\ \text{V}}{50\ \Omega} = 2.4\ \text{A}$$

Without the current flowing through R_2 , we have $4\ \text{A} + 1.6\ \text{A} + 2.4\ \text{A} = 8\ \text{A}$.

The total current that the fuse can handle is $15\ \text{A}$. So, $15\ \text{A} - 8\ \text{A} = 7\ \text{A}$ is the remaining current that the fuse can handle, and the maximum current that may flow through the R_2 branch of the circuit.

$$I_{R_2} = 7\ \text{A}$$

$$V_{R_2} = 120\ \text{V}$$

$$R_{R_2} = \frac{V_{R_2}}{I_{R_2}} = \frac{120\ \text{V}}{7\ \text{A}} = 17.14\ \Omega$$

So, the resistance of resistor R_2 must be $17.14\ \Omega$ or greater. (If the resistance is greater, then the current must be smaller.)