**Making Circuits of Boolean Algebra Properties**

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***Objective***

*Develop an intuitive sense of the Boolean algebra properties. Further familiarize yourself with Logisim. Get extra practice using logic gates. Have an early introduction to constants.*

***Instructions***

*Create a physical representation of each Boolean algebra property using Logisim with the following wiring components and logic gates.*

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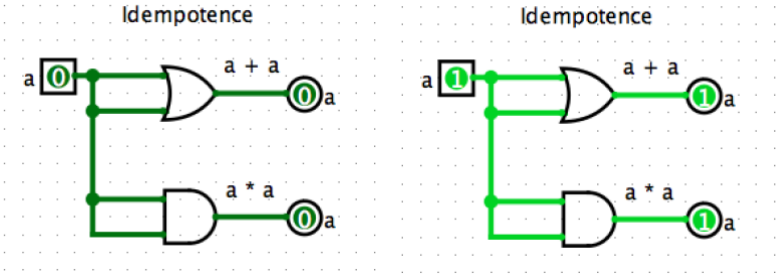
1. **Idempotence**

$$a + a = a$$
$$a * a = a$$

Use one input pin, two output pins, one OR gate, and one AND gate. *(Hint: The input will connect both equations.)*

The solution for this circuit is provided below as an example:




*Note:*
*Notice how toggling input 'a' sends a current through the logic gates.*
*The upper output 'a' and lower output 'a' are both equal to whatever value input 'a' has.*

2. **Complementation**

$$a + a' = 1$$
$$a * a' = 0$$

Use one input pin, two output pins, two NOT gates, one OR gate, and one AND gate.

3. **Identity**

$$a + 0 = a$$
$$a * 1 = a$$

Use one input pin, one 0 constant, one 1 constant, two output pins, one OR gate, and one AND gate. *(Hint: Constants are found in the wiring folder.)*

4. **Annihilator**

$$a + 1 = 1$$
$$a * 0 = 0$$

Use one input pin, one 0 constant, one 1 constant, two output pins, one OR gate, and one AND gate.

5. **Double Negation**

$$(a')' = a$$

Use one input pin, two NOT gates, and one output pin.

6. **Associativity**

$$a + (b + c) = (a + b) + c$$
$$a * (b * c) = (a * b) * c$$

Use three input pins, four output pins, four OR gates, and four AND gates. *(Hint: Both sides of the equations are an output.)*

7. **Distributivity**

$$a * (b + c) = (a * b) + (a * c)$$
$$a + (b * c) = (a + b) * (a + c)$$

Use three input pins, four output pins, five OR gates, five AND gates. *(Hint: Both sides of the equations are an output.)*

8. **Commutativity**

$$a + b = b + a$$
$$a * b = b * a$$

Use two input pins, four output pins, two OR gates, and two AND gates. *(Hint: Both sides of the equations are an output.)*

9. **Absorption**

$$a * (a + b) = a$$
$$a + (a * b) = a$$

Use two input pins, two output pins, two OR gates, and two AND gates.

10. **De Morgan**

$$a' * b' = (a + b)'$$
$$a' + b' = (a * b)'$$

Use two input pins, four output pins, six NOT gates, two OR gates, and two AND gates. *(Hint: Both sides of the equations are an output.)*