Shocking Joe

1. Draw a circuit diagram to model this situation. Make sure to include the resistance of Joe, the resistance of the saw motor (between hot and neutral), the damage resistance between the hot line and the saw case, and the resistances of the three wires in the power cord connecting the saw to the electrical receptacle.

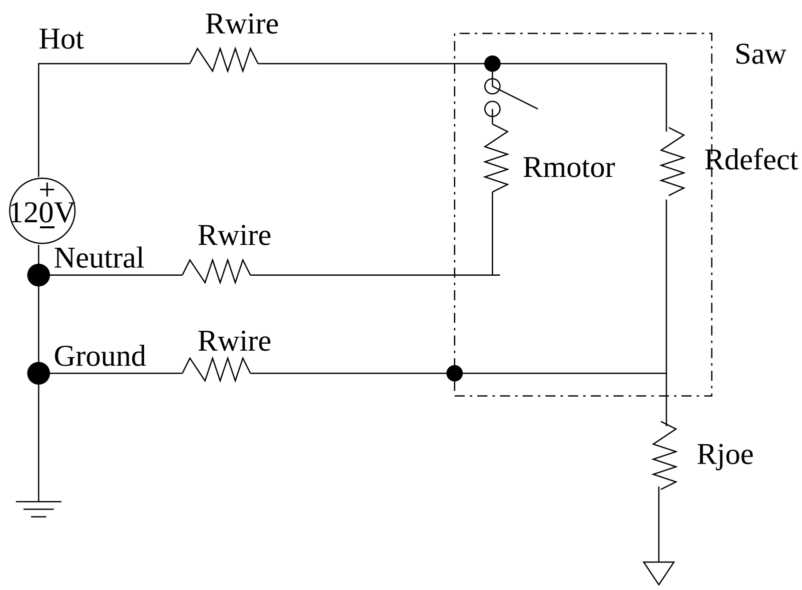

Figure 1: Circuit Diagram of the Situation

2. Suppose first for simplicity that the power cord from the saw to the receptacle has zero resistance. Argue that Joe is safe—no current flows through him.

   The case Joe is holding is connected to ground through the ground wire, which is assumed to have zero ohms. Thus the voltage of the case to ground is zero and no current flows through Joe.

3. Now make the more realistic assumption that the power cord has a resistance of about 2.7 Ohms per 1000 feet (i.e., each of the three wires in the power cord has about 2.7 Ohms per 1000 feet). Starting with your circuit model from part 1, draw the Thévenin equivalent system as seen by Joe. (Assume that the saw is turned off when Joe plugs it in, so that no current passes through the motor.) Show your work.

   Since the saw is turned off, $R_{motor} = \infty$. The circuit diagram is reduced to Figure 2. To get the Thévenin's resistance, we short the voltage source and get $R_{th} = .27 \parallel 100.27 \approx 0.27\Omega$. V_{th} can be found using the voltage divider rule to be $\frac{.27*120}{100.27+.27}V \approx .322V$. Figure 3 shows Thévenin equivalent system as seen by Joe.

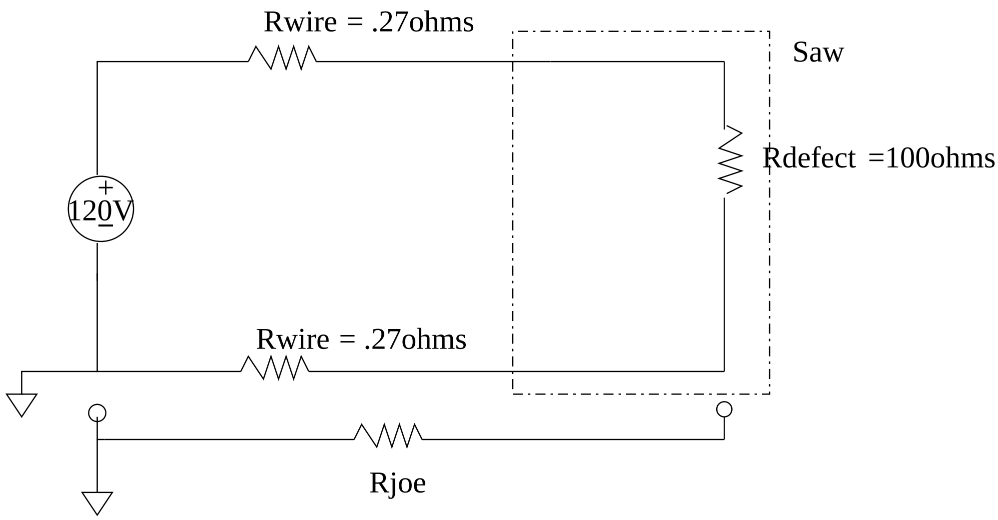

Figure 2: Reduced circuit diagram of the situation

If the saw is turned on,

$$R_{th} = R_{wire} \parallel (R_{defect} + R_{wire} \parallel (R_{motor} + R_{wire}))$$

$$V_{th} = \frac{R_{wire} Vs}{R_{wire} + R_{defect} + R_{wire} \parallel (R_{motor} + R_{wire})}$$

4. Assume that Joe, as a conductor of electricity, has a resistance of about 10^4 Ohms to ground. Using your Thévenin model from part 3, about how much current will flow through Joe when he plugs in the saw? Is he safe?

   Yes, Joe is safe because only about .032mA is flowing through him.

   $$i_{joe} = \frac{.322}{10^4} = .032mA$$

5. Suppose instead that Joe has been working hard and is all sweaty, so that his resistance as a conductor of electricity drops to 100 Ohms. About how much current will flow through him now? Is this safe?

   Joe will jump since $i_{joe} = \frac{.322}{100.27} = 3.2mA$

6. Suppose that the receptacle is not correctly grounded, leaving the power cord's ground wire as an open circuit. How does that change your answer to parts 4 and 5?

   For 4, $i_{joe} = \frac{120}{10^4} = 12mA$. *Joe will be hurt.*
   For 5, $i_{joe} = \frac{120}{200.27} = 600mA$. *Joe will be fried.*

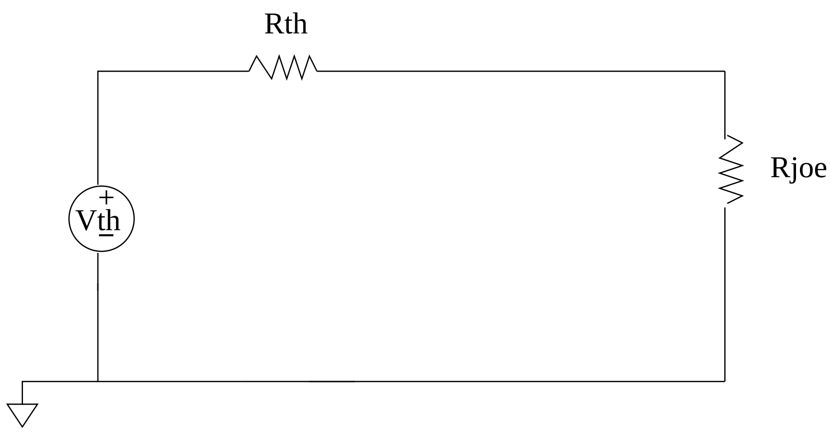

Figure 3: Thévenin equivalent system