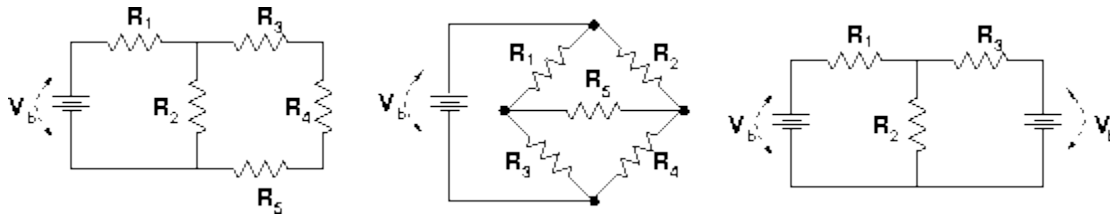# When to use Kirchhoff's laws

Here are three typical circuit diagrams that might need to be solved (e.g. given the resistances of all the resistors and the voltages of all the batteries, find all of the currents).

The figure on the left can be solved easily using the rules for adding resistances in parallel and series. Resistors R_3, R_4 and R_5 can be treated as if they were a single resistor of resistance R_{345}. This effective resistance can be added in parallel with R_2 to give another effective resistance R_{2345}. Finally, that effective resistance can be added in series with R_1 to calculate the net resistance $R = R_1 + R_{2345}$ seen by the battery. This value of R can be used to compute the current produced by the battery. The current from the battery all flows through R_1, so the voltage drop across R_1 can be computed using Ohm's law. Since the battery voltage is known, you can next compute the voltage drop across R_2. Now applying Ohm's law to R_2 tells you the current through it; etc. In this way you eventually figure out the currents and voltage drops everywhere in the circuit.

The middle and right-side figures cannot be solved by such a simple(?) strategy. Instead, you must write down Kirchhoff's laws and solve the equations.

For instance consider the right-hand figure. Give names to the unknown currents i_1, i_2 and i_3 through the 3 resistors (choosing the directions ad lib). These unknown currents can be found by solving 3 equations:
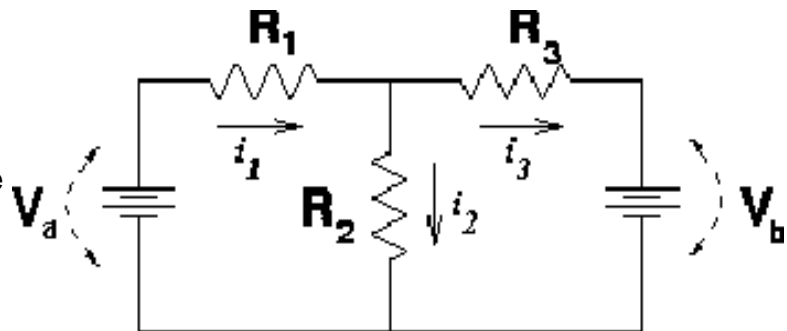
1. $i_1 = i_2 + i_3$
2. $V_b - i_1 R_1 - i_2 R_2 = 0$ 4.
3. $V_b + i_3 R_3 - i_2 R_2 = 0$

1. The first equation describes current conservation into the node.
2. The second equation expresses the requirement that voltage losses cancel voltage gains for the loop on the left.

3. The third equation expresses the same for the loop on the right. Note that if one makes a counter-clockwise loop, one goes against the current through R_3 and the sign of that term is therefore opposite the normal one.

You could also write an equation for a third loop that is defined by traveling around the outside of the circuit. That equation would be slightly more complicated because it would involve both batteries; but it is unnecessary since it would be merely a linear combination of Eq. 2 and Eq. 3 above.