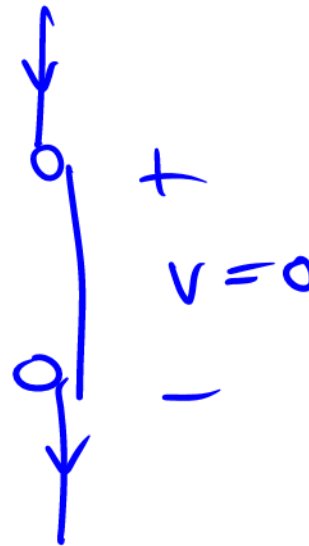
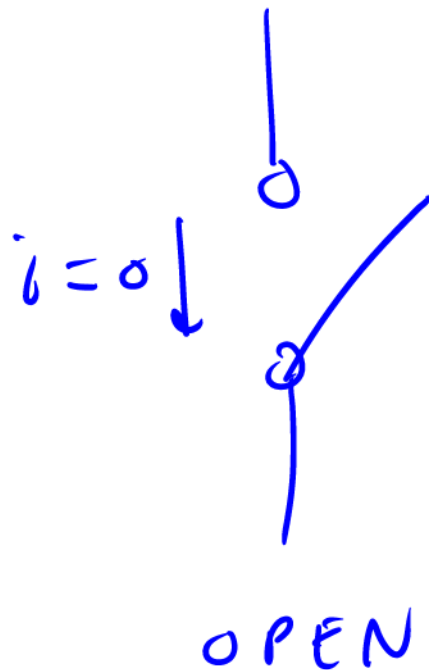


TRANSIENT
CURRENT WOULD
EQUALIZE THE
POTENTIALS

0V

Example 4: An Ideal Switch / A Short Circuit

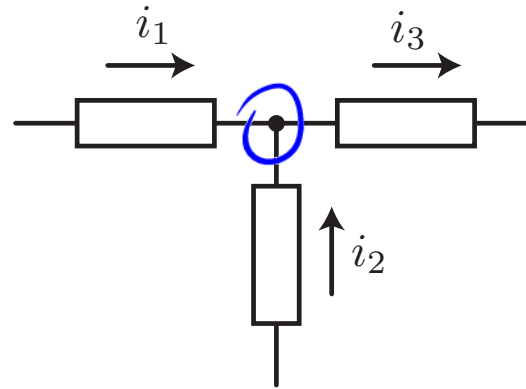
- An ideal switch cannot absorb power because in either state, the voltage or current is zero so $p(t) \equiv 0$.
- An ideal wire is an equipotential surface, and so it cannot support a voltage from one end to the other. The power dissipated by an ideal wire is also zero.
- An ideal wire is also called a "short circuit", especially when placed from one point to the other, we say the nodes are "shorted".



KCL: Kirchoff's Current Law

$$\sum_K i_{in,k} = 0$$

$$\sum_{\text{NODE } K} i_{out,k} = 0$$



$$i_1 + i_2 = i_3$$

IN FLOW = OUT FLOW

- KCL states that the net charge flowing into any node of a circuit is identically zero. In the example shown

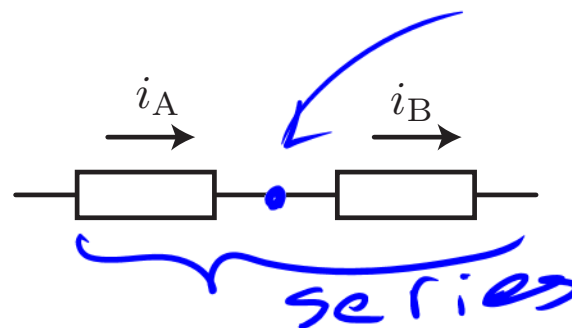
$$i_1 + i_2 - i_3 = 0$$

- The reason for this is clear from the flow nature of current. Some of the currents flow in, some flow out, but in the net all must balance out.
- A direct implication of KCL is that series elements have equal currents, $i_A = i_B$.

OUT

$$-i_A + i_B = 0$$

$$\Rightarrow i_A = i_B$$

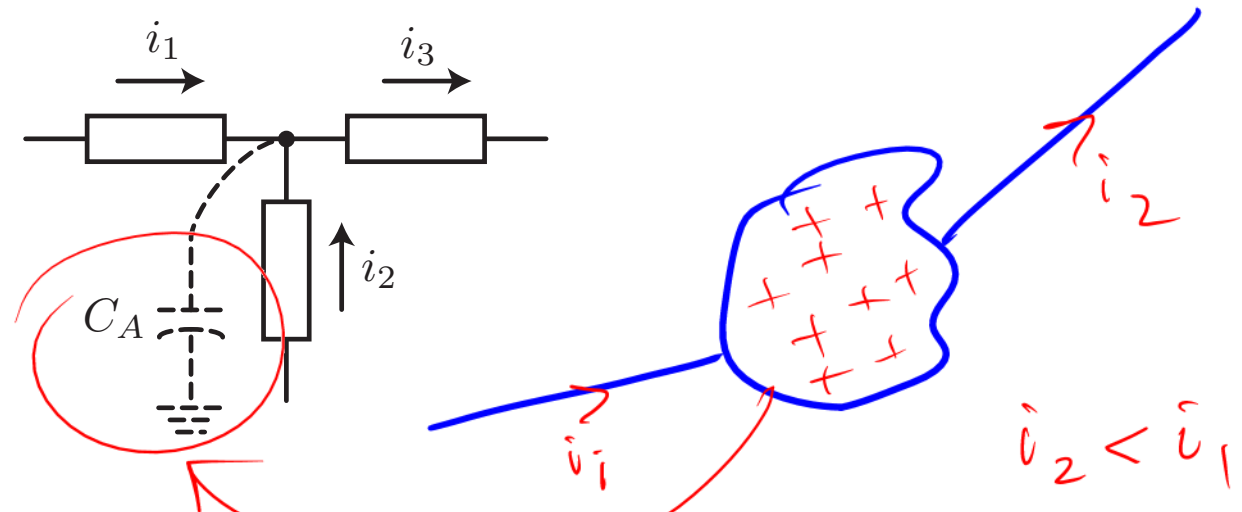


$$i_A + (-i_B) = 0$$

$$i_A = i_B$$

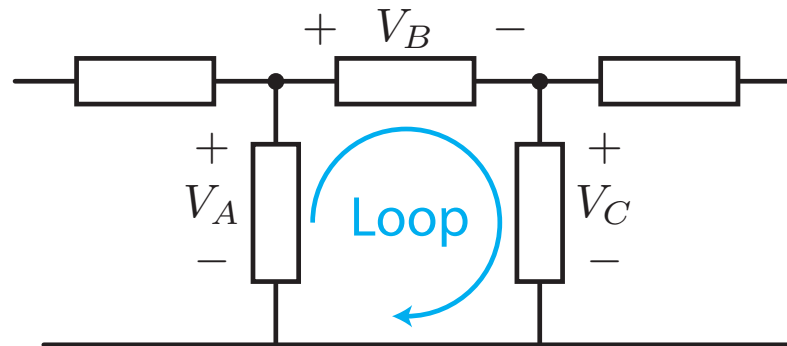
series connection

Aside: Origin of KCL



- KCL is related to charge conservation. Note that this is just a re-statement of current continuity $\nabla \cdot \mathbf{J} = -\frac{\partial \rho}{\partial t}$.
- If the net current is not zero, then somehow charge must be accumulating at a node. This can only happen if the node in question has some capacitance (say to ground). But such a capacitance can always be included as a separate component (come back and re-read this after we define capacitance!). So if we say that the node has zero capacitance, or $C_A \equiv 0$, then KCL makes sense.

KVL: Kirchoff's Voltage Law



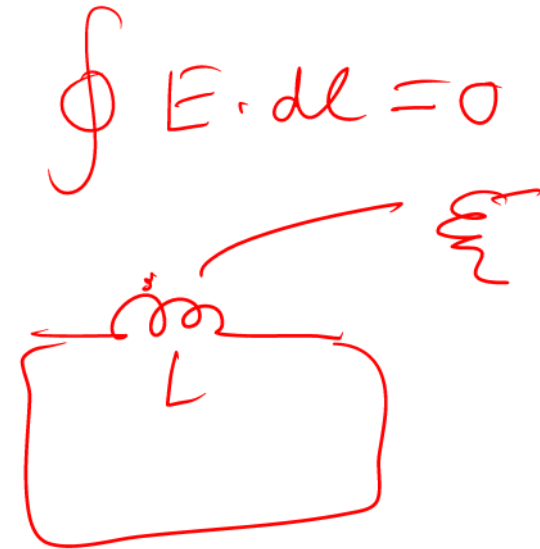
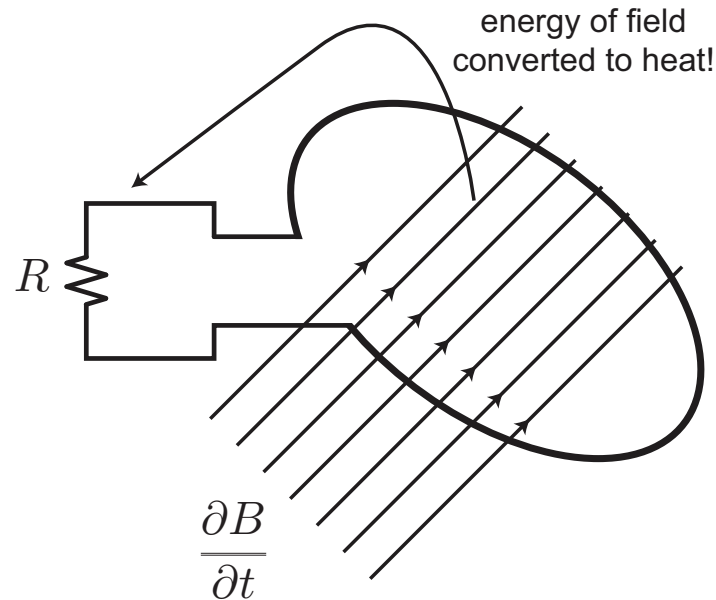
- KVL states that the net potential around any loop in a circuit is zero

$$\sum_{Loop} V_k = 0$$

- Or more explicitly, for the example shown, $-V_A + V_B + V_C = 0$. In other words, the net energy in going around a loop is zero.
- Notice that if we had defined the loop in the opposite direction, then we have: $V_A - V_C - V_B = 0$, or by multiplying the equation by -1 , the same relation.

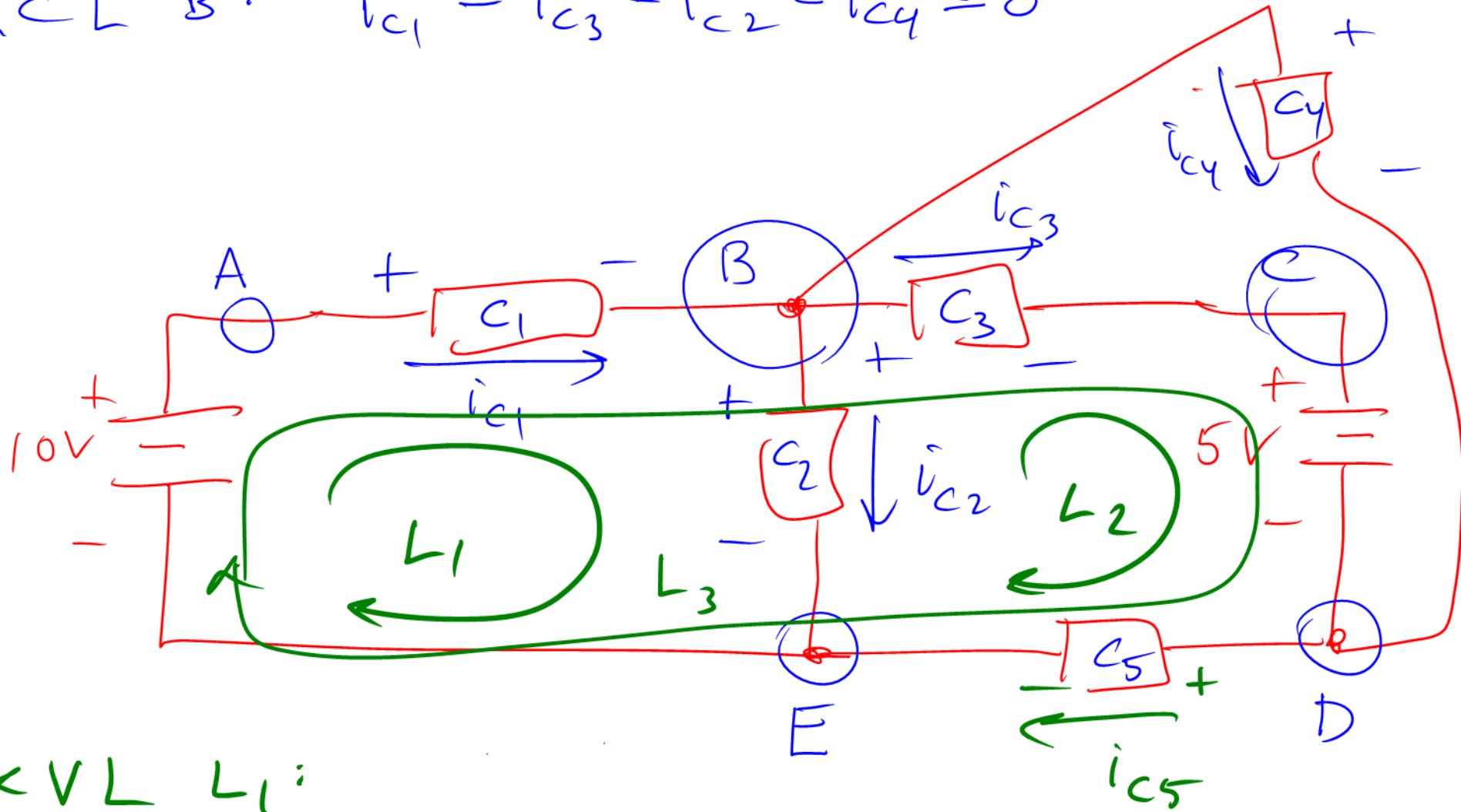
$$-V_C - V_B + V_A = 0$$

Aside: E&M Connection



- This makes sense if the voltage arises from electrostatic sources, which leads to a conservative field. Then if we calculate the net energy in traversing any closed path, including any loop in a circuit, it must be zero since we return to the same point.
- You may be wondering about a non-electrostatic situation in which the field is not conservative. In this situation, if there is a changing magnetic field crossing the loop (such as in a motor), then energy can be transferred into or out of the circuit. This can be represented as coupled inductors linking the loop to other circuitry, a detail which we will ignore in this class.

KCL B: $i_{c1} - i_{c3} - i_{c2} - i_{c4} = 0$



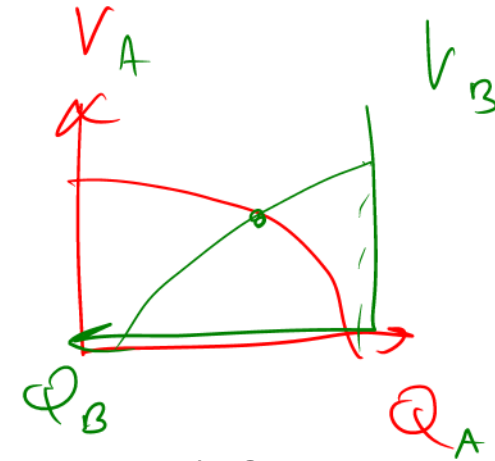
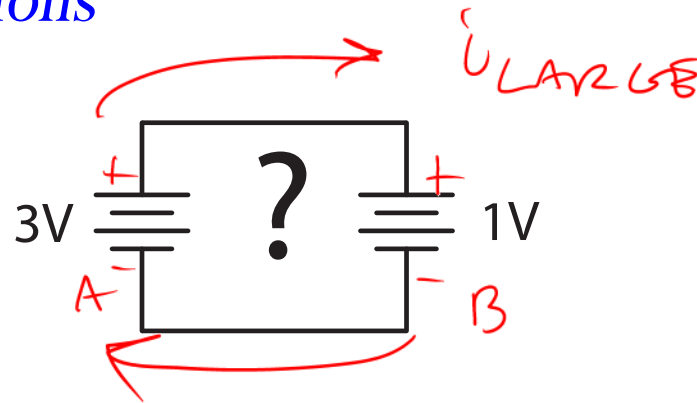
KVL L_1 :

$$-10V + V_{c1} + V_{c2} = 0$$

KVL L_3 :

$$-10V + V_{c1} + V_{c3} + 5V + V_{c5} = 0$$

KVL Implications



- All shunt (or parallel) components have the same voltage.
- This is why you should *never* connect batteries in parallel (It violates KVL). Since each one has a fixed potential across its terminals, it is simply not possible to do this. In practice, a large current would flow from the higher voltage battery to the lower one, possibly burning the wires connecting them. The magnitude of the current is limited by the internal resistances of the batteries (come back and re-read this after we talk about resistance).

KVL

$$-V_A + V_B = 0$$

$$-3V + 1V \neq 0 \quad ?$$

