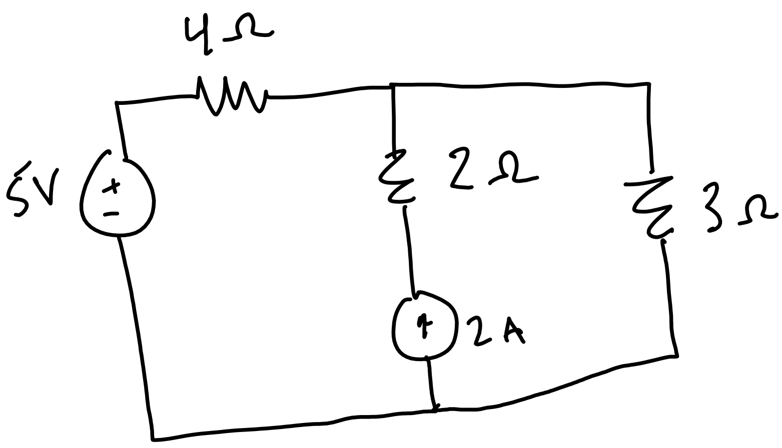
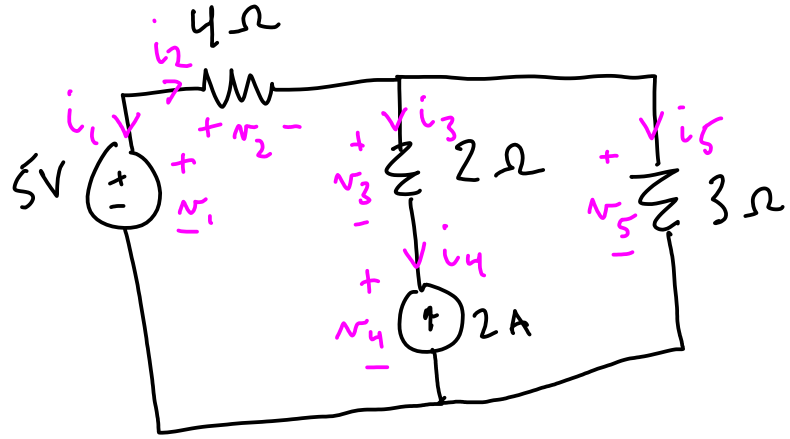
"Brute-force" method

goal: solve for all branch voltages and currents



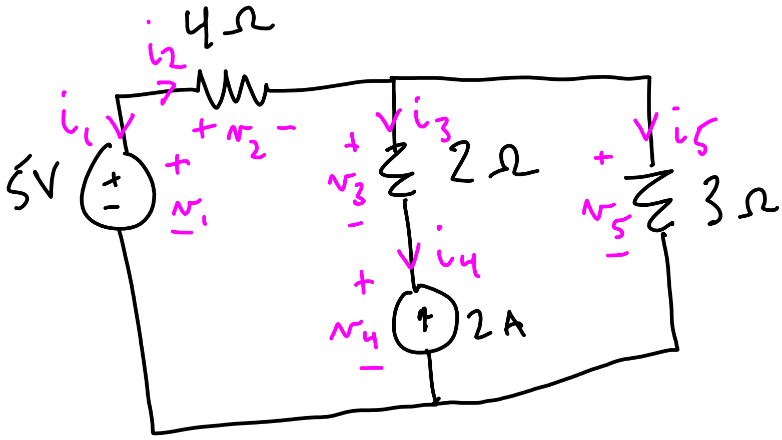
1) label each branch variable with a name and direction (arbitrary but consistent with our convention that the current variable is defined to be flowing into the "+" side of the voltage variable



in a circuit with B branches and N nodes, we'll have:

- B constitutive (component) equations
- N−1 linearly-independent KCL equations
- B−N+1 linearly-independent KVL equations

2B total equations for our 2B unknowns



Constitutive equations:

$v_1 = 5\,V$

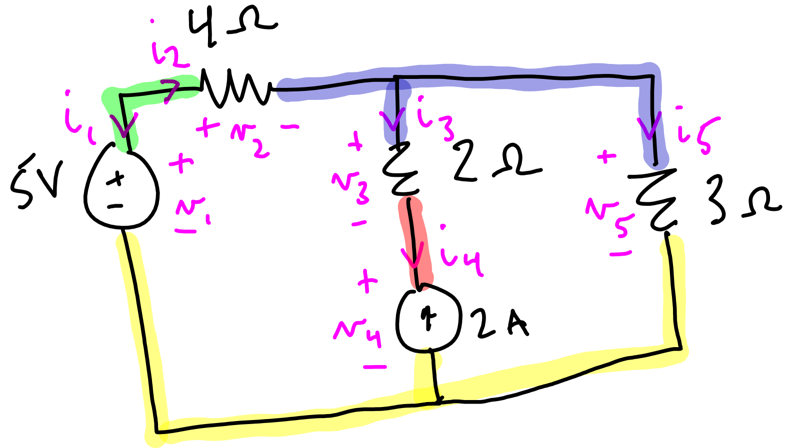
$v_2 = i_2 \cdot 4\,\Omega$

$v_3 = i_3 \cdot 2\,\Omega$

$i_4 = -2\,A$

it might be tempting to try to say something about v_4 here, but we can't (yet) because the current source doesn't constrain v_4 at all

$v_5 = i_5 \cdot 3\,\Omega$

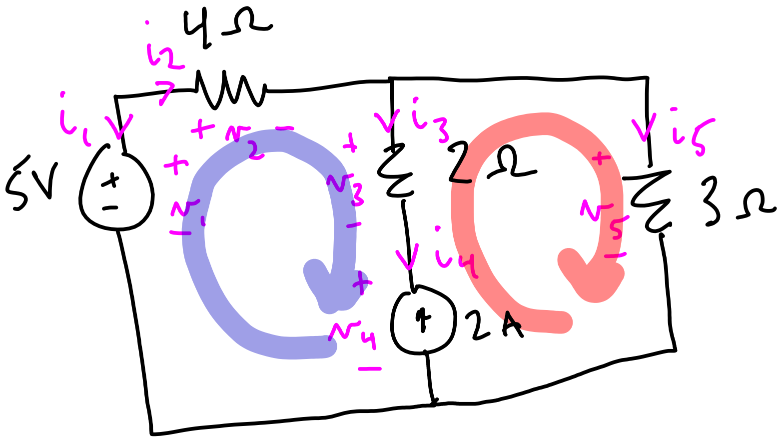


we have 4 nodes, so we'll have 3 (N-1) linearly-independent KCL equations. pick any 3 nodes.

green node (top-left): $i_1 + i_2 = 0$

blue node (top-right): $i_2 = i_3 + i_5$

red node (middle): $i_3 = i_4$



need 2 linearly-independent KVL equations.

one general method: pick the smallest enclosed regions that span the whole circuit

this works if the circuit is planar (2-D with no wires jumping over each other)

blue loop (left): $v_1 = v_2 + v_3 + v_4$

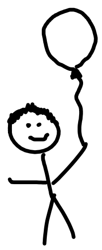
red loop (right): $v_4 + v_3 = v_5$

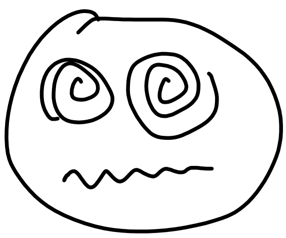
now we have 10 equations in 10 unknowns, so we can solve:

```
import sympy

syms = sympy.symbols('v1,v2,v3,v4,v5,i1,i2,i3,i4,i5')
v1, v2, v3, v4, v5, i1, i2, i3, i4, i5 = syms

constitutive = [
    v1 - 5,
    v2 - i2 * 4,
    v3 - i3 * 2,
    i4 + 2,
    v5 - i5 * 3
]

kcl = [
    i1 + i2,
    i2 - i3 - i5,
    i3 - i4,
]

kvl = [
    v1 - v2 - v3 - v4,
    v4 + v3 - v5
]

result = sympy.solve([*constitutive, *kvl, *kcl], syms)

units = {'v': 'V', 'i': 'A'}

for var in syms:
    print (f"{var} = {result[var]}{units[var.name[0]]}")
```

```
v1 = 5V
v2 = -4/7V
v3 = -4V
v4 = 67/7V
v5 = 39/7V
i1 = 1/7A
i2 = -1/7A
i3 = -2A
i4 = -2A
i5 = 13/7A
```

yay!





if this approach feels algebraically painful, fear not! we'll find simpler ways to solve circuits over the coming weeks!