Chapter 2 — Circuit Elements.

For now --
- Voltage sources
- Current sources
- Resistance
- Controlled sources

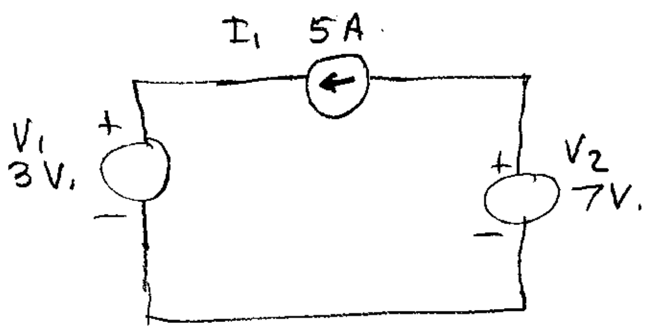
Also — Conventions:
Direction of current flow.

CH 2.
Problems:
1–16
21, 23

Terms: Nodes, Loops
"Connection is valid"

"Validity" of a circuit ...
Voltage & current sources —

Some just don't work

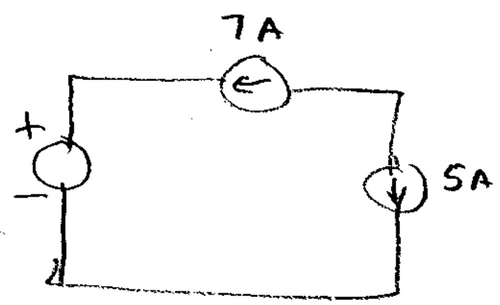


This one is Valid ..

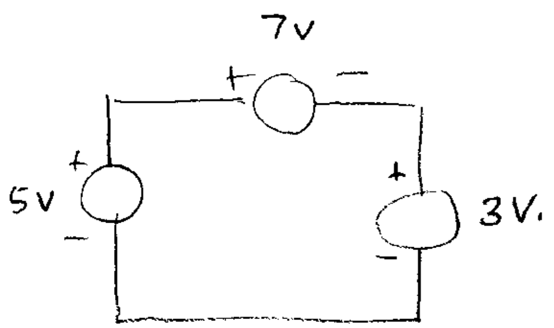
$I(V_1) =$

$I(V_2) =$

$V(I_1) =$

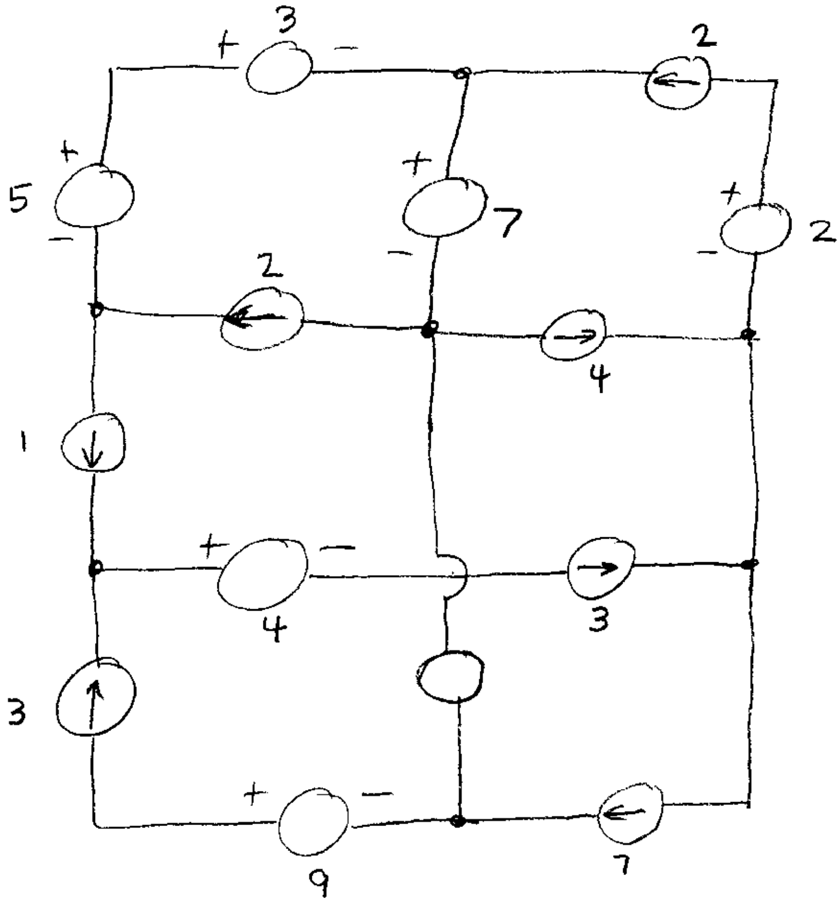


This one is not valid
$I = ?$
"Cut set" of current sources.



Not valid
$V = ?$
Loop of voltage sources

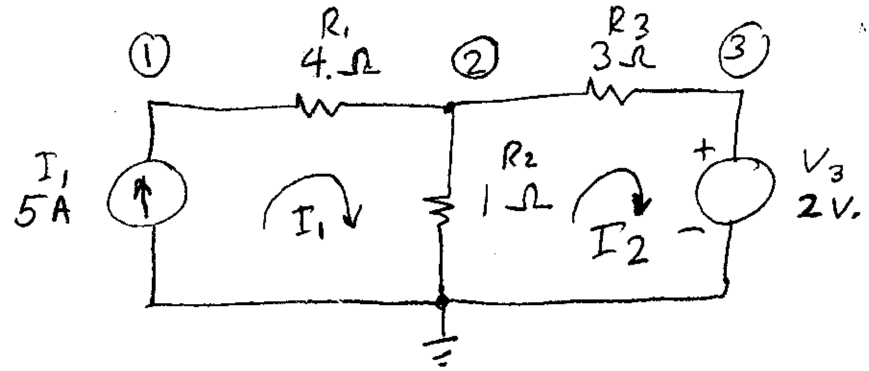
Is this circuit valid?



Kirchoff's laws ....

"sum of currents into (out of) a node = 0."

"Sum of voltages around a loop = 0".



Node eq.: (out-of)

$$-I_1 + \frac{V_1 - V_2}{R_1} = 0 \quad \text{Node ①}$$

$$\frac{V_2 - V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_2 - V_3}{R_3} = 0 \quad \text{Node ②}$$

~~$V_3 = 2$~~ Node ③

← current in voltage source is arbitrary, so don't write a node equation for this node.

Loopeq:

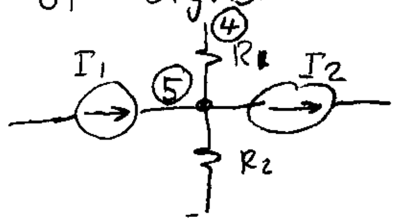
~~$I_1 = 5$~~ ← voltage across current source is arbitrary, so don't write loop equation for this loop.

$$R_2(I_2 - I_1) + R_3 I_2 + V_3 = 0$$

Node eq. guides...

- → Call one node ground, node 0, it's voltage is 0.
- → First, write it in symbolic form.
- → Be careful of signs.

Into:



$$I_1 - I_2 + \frac{V_4 - V_5}{R_1} + \frac{-V_5}{R_2} = 0$$

Out-of

$$-I_1 + I_2 + \frac{V_5 - V_4}{R_1} + \frac{V_5}{R_2} = 0$$

- → Then simplify
- → Then substitute values.

Write a node equation for every node,
But not for nodes with grounded voltage source
and not for both ends of a floating voltage source

<u>Write everything</u>

Don't skip steps.

Finish solving the example --- (node equations).

Group V terms; put terms not having a V on the right --

(1) $$V_1\left(\frac{1}{R_1}\right) + V_2\left(-\frac{1}{R_1}\right) = I_1$$

(2) $$V_1\left(-\frac{1}{R_1}\right) + V_2\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right) + V_3\left(-\frac{1}{R_3}\right) = 0$$

Solve by substitution:

(1) $$V_1\left(\frac{1}{R_1}\right) = I_1 - V_2\left(-\frac{1}{R_1}\right)$$

$$V_1 = R_1 I_1 - V_2\left(-\frac{R_1}{R_1}\right)$$

$$V_1 = R_1 I_1 + V_2$$

(2) substitute V_1

$$(R_1 I + V_2)\left(-\frac{1}{R_1}\right) + V_2\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right) + V_3\left(-\frac{1}{R_3}\right) = 0$$

Simplify

$$-\frac{R_1 I}{R_1} + V_2\left(-\frac{1}{R_1}\right) + V_2\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right) + V_3\left(-\frac{1}{R_3}\right) = 0$$

$$-I_1 + V_2\left(\frac{1}{R_2}+\frac{1}{R_3}\right) + V_3\left(-\frac{1}{R_3}\right) = 0$$

Substitute values

$$-5 + V_2\left(\frac{1}{1} + \frac{1}{3}\right) + 2\left(-\frac{1}{3}\right) = 0$$

$$-15 + V_2(3+1) - 2 = 0$$

$$-17 + V_2(4) = 0$$

$$V_2(4) = 17$$

$$V_2 = \frac{17}{4} = 4,25$$

$$V_1 = R_1 I_1 + V_2$$

$$= (4)(5) + 4,25$$

$$= 20 + 4,25$$

$$= 24,25$$

→ I didn't apply any cleverness here ..

Just follow the rules!

Find currents by Ohms Law.

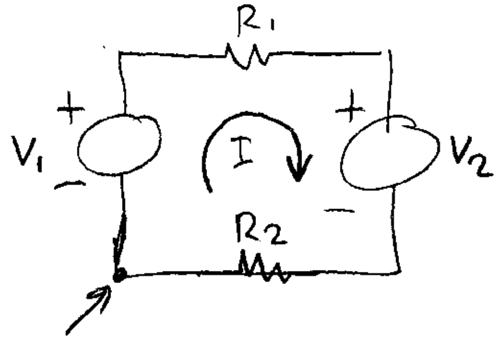
$$I_2 = \frac{V_{R3}}{R_3} = \frac{V_2 - V_3}{R_3} = \frac{4,25 - 2}{3} = \frac{2,25}{3} = .75\ A$$

Then check ① Makes sense?

② by simulation

Loop equations

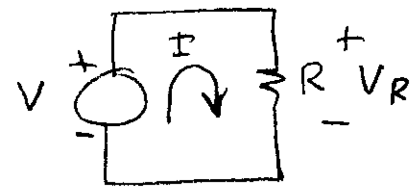
- Choose loops carefully –
  - Need to include all branches
  - It can be tricky to pick the loops
- Be careful of signs ..



pick a starting point

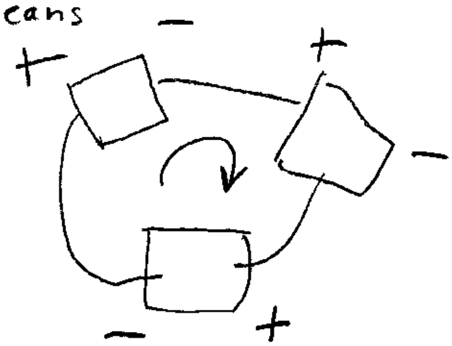
If I is positive,
Voltage across R is positive.

So ...



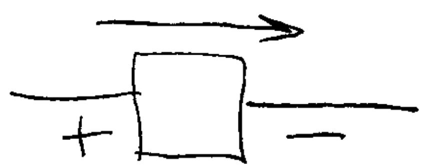
$$-V_1 + IR_1 + V_2 + IR_2 = 0$$

That means



assumed voltage direction.

When current goes through an element



The "from" end has + voltage
the "to" end has – voltage

So a resistor has the same sign for voltage + current.

Finish solving the example (p. 3)

$$R_2(I_2 - I_1) + R_3(I_2) + V_3 = 0$$

Group I terms, put terms not having I on the right ..

$$I_1(-R_2) + I_2(R_2 + R_3) = -V_3$$

Substitute:

$$5(-1) + I_2(1+3) = -2$$

$$-5 + I_2(4) = -2$$

$$I_2(4) = 3$$

$$I_2 = \frac{3}{4} = .75$$

Find voltages by Ohm's Law

$$V_{R3} = I_{R3} R_3 = \left(\frac{3}{4}\right)(3) = \frac{9}{4} = 2.25$$

$$V_{R1} = I_{R1} R_1 = (5)(4) = 20$$

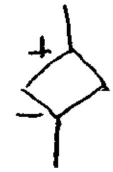
$$V_{R2} = I_{R2} R_2 = (I_1 - I_2) R_2 = (5 - .75)(1)$$

$$= 4.25$$

Controlled sources

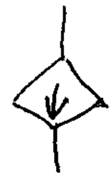
(This is how we make amplifiers)

E = VCVS = Voltage controlled voltage source



H = CCVS = Current controlled voltage source ("trans resistance")

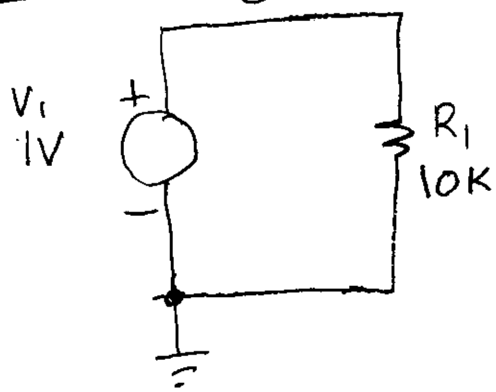
G = VCCS = Voltage controlled current source ("trans conductance")

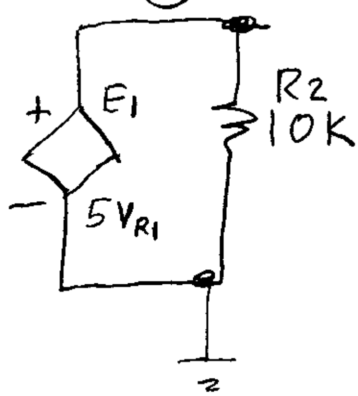


F = CCCS = Current controlled current source

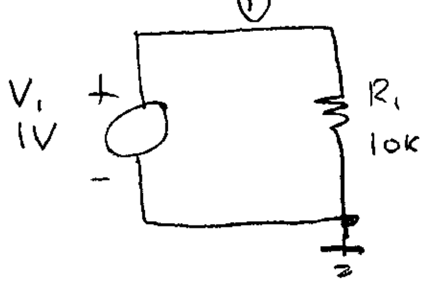
Example:

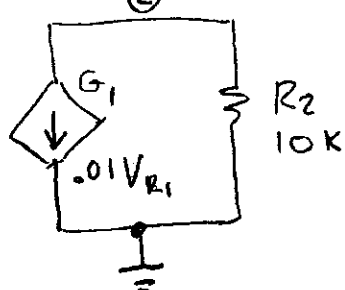
VCVS



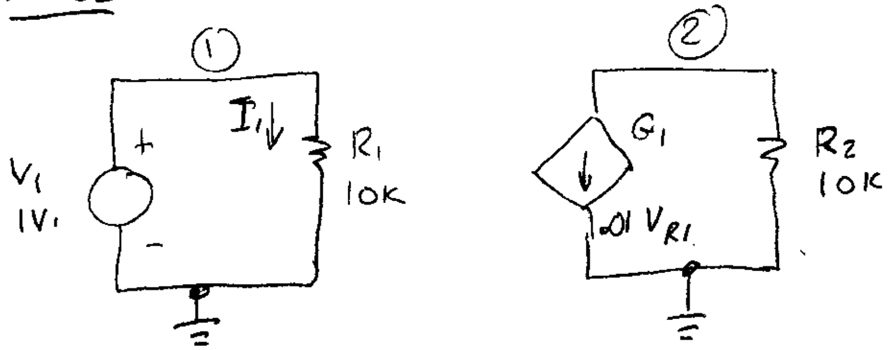


$$V_2 = 5\,V_{R1} = \boxed{5}$$





VCCS



← FET or tube amplifier

Node ② :

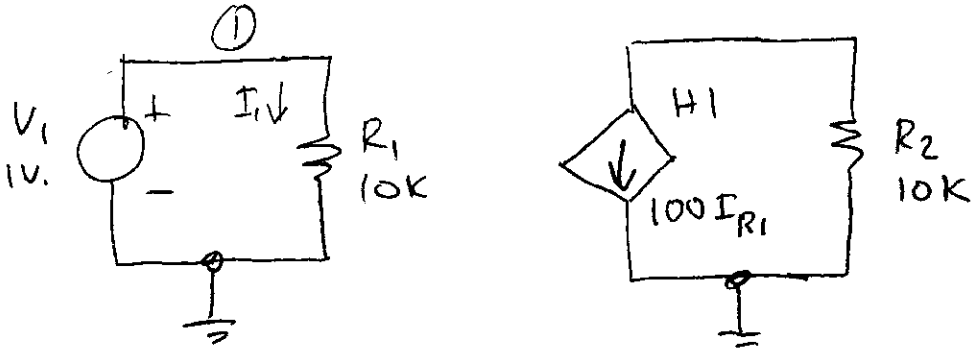
$$G_1 V_1 + \frac{V_2}{R_2} = 0$$

$$(.01)(1) + \frac{V_2}{10K} = 0$$

$$\frac{V_2}{10K} = -.01$$

$$V_2 = (-.01)(10K) = \boxed{-100}$$

CCCS



← BJT amplifier.

$$I_{R1} = \frac{V_1}{R_1}$$

$$H_1 I_{R1} + \frac{V_2}{R_2} = 0$$

$$H_1\left(\frac{V_1}{R_1}\right) + \frac{V_2}{R_2} = 0$$

$$100\left(\frac{1}{10K}\right) + \frac{V_2}{10K} = 0$$

$$100 + V_2 = 0$$

$$V_2 = -100$$