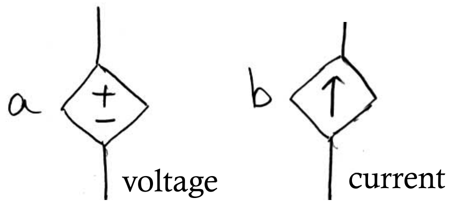
Variable Sources



a and *b* are variables in algebraic expressions.

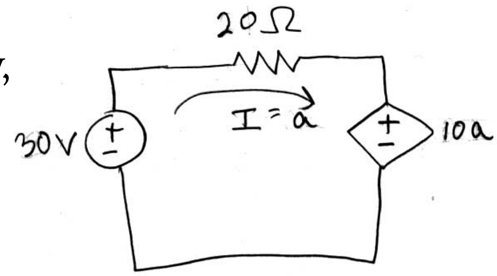
Example: By Ohm's law, voltage across resistor,

$V = IR = 20a$

By Kirchoff's voltage law,

$30 = 20a + 10a$

Therefore a = 1A



conversion of units implied

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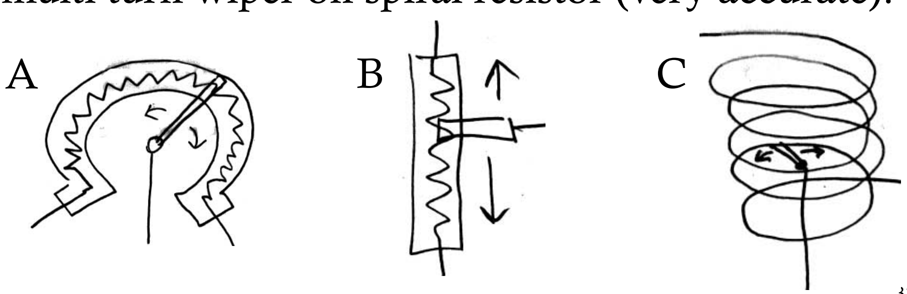
Potentiometer – "Pot"

Three-terminal device: fixed resistor with a movable wiper.

Physically: (A) single-turn wiper on a circular resistor, (B) linear wiper on straight resistor, (C) multi turn wiper on spiral resistor (very accurate).



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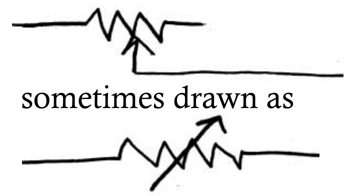
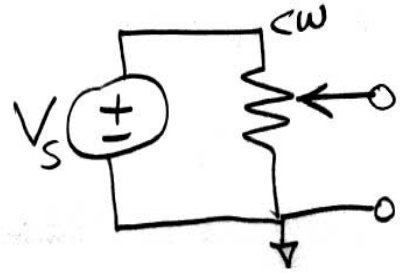
Potentiometer – "Pot"

- Ignore one lead and you have a simple two-lead variable resistor.



- Typical use: producing a variable fraction of voltage source V_S; pot provides both resistors of a voltage divider with output between 0 and V_S.

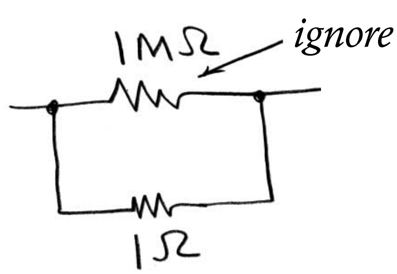
"cw" wiper at this end when turned clockwise



What to Ignore…

- Estimate the total resistance:

Resistors in *series*:
much smaller resistor is essentially a "short circuit" or piece of wire. ~1MΩ



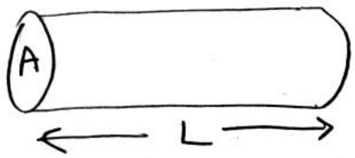
Resistors in *parallel*:
much larger resistor is essentially a "open circuit" or insulator. ~1 Ω

- Keep tolerance of resistors in mind (e.g. 5%).

Resistivity of materials

- A resistor consists of a material with a shape.

assume a cylinder
length L, area A



$$R = \rho \frac{L}{A}$$

- *Resistivity* ρ in ohm-meters

insulator (glass, quartz)	10^{16}-10^{10} ΩM
semi-conductor (silicon)	10^{3}-10^{-5} ΩM
conductors (metal)	10^{-6}-10^{-8} ΩM
superconductor	0 ΩM

- *Conductivity* $\sigma \equiv \frac{1}{\rho}$

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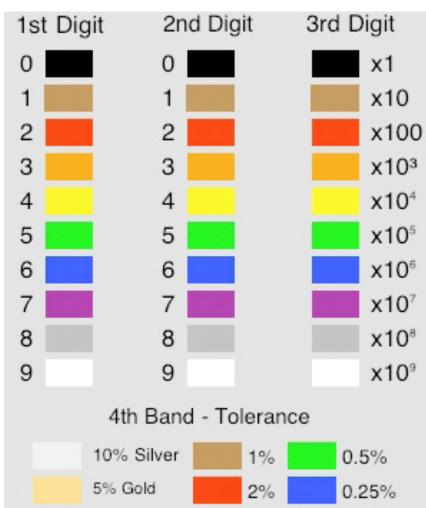
Resistor Color Code



Disk Capacitors Labeling

- 3 digits "ABC" = AB×10^{C} pF
  (AB plus C zeros)
- Examples
  - "682" = 6800 pF
  - "104" = 100,000 pF = 0.1μF

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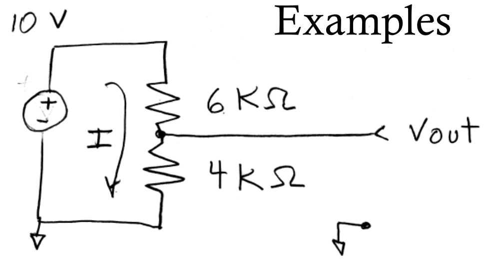
Examples



Voltage "Divider"

Same I through both resistors

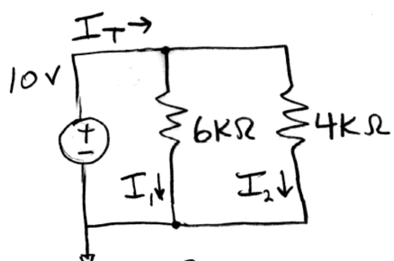
total resistance 10 KΩ

$$I = \frac{10\,V}{10K\,\Omega} = 1\,ma$$

$V_{out} = 1ma \cdot 4K\Omega = 4\,V$

leaves 6V across top resistor

Voltage across each resistor proportional to its resistance.



Parallel Resistors

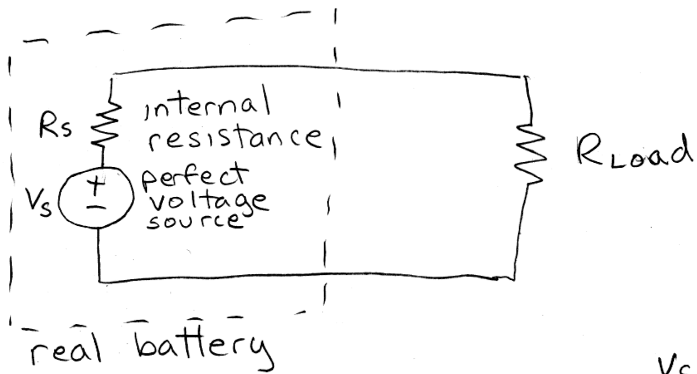
Same V across both resistors

$I_1 = 10V / 6K\Omega = 1.66\ ma$

$I_2 = 10V / 4K\Omega = 2.5\ ma$

$I_T = 4.16$

Real Voltage Source



limits maximum current to $\frac{V_S}{R_S}$
when load = 0Ω
car batteries have low internal resistance, can "source" 10's of "amps"
expected battery life rated in "ampere hours"
multiply by voltage to get total energy

Real Voltage Source

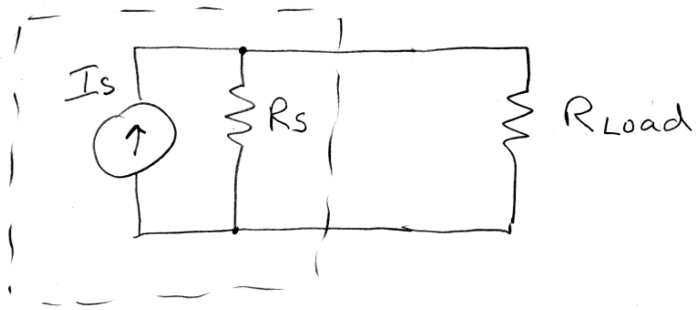
<u>Other</u> <u>examples</u> <u>of</u> <u>voltage</u> <u>sources</u>

electromagnetic generators
photo voltaic solar cells
fuel cells
friction ("static" electricity, lightening)
Nernst equation (ionic gradients)
others?
any case where $R_S << R_{Load}$

open faucet – nearly constant pressure

Real Current Source

Real current source



Limits maximum voltage to $I_S R_S$
when $R_{Load} = \infty \Omega$

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Real Current Source

Examples
Radio antenna
transistors
or any case where $R_S \gg R_{Load}$

dripping faucet – nearly constant flow

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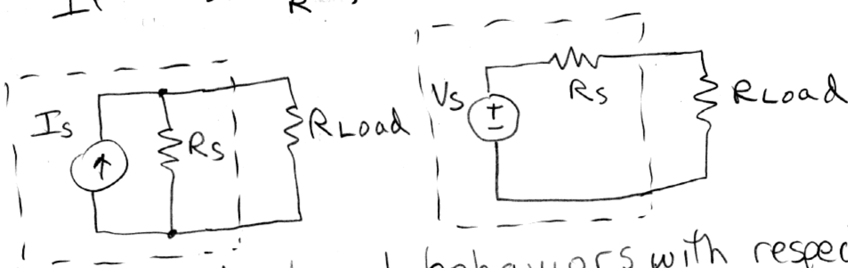
If $I_S = \frac{V_S}{R}$, then the two models



have identical behaviors with respect to R_{Load}:

	R_{Load}	I_{Load}	V_{Load}
"short circuit"	0 Ω	I_S	0 V
"open circuit"	∞ Ω	0 A	V_S

called *Thevenin* and *Norton* equivalents

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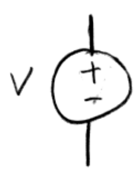
Thevenin Equivalent

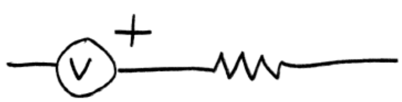
ANY NETWORK OF

 's,  I 's

and

 's

can be redrawn as



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Norton Equivalent

ANY NETWORK OF


's,

I's
and

V's

Can be rewritten as

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Superposition Theorem

<u>Superposition Theorem</u>: The current in a branch = sum of currents produced by each source with the other sources <u>set to ∅</u>

"set to ∅" means


→ short circuit $V=0$


→ open circuit $I=0$

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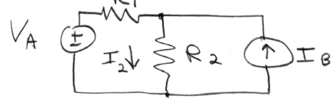
Superposition Theorem

Example (Scherz p75)

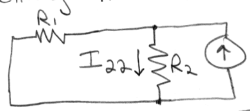


Break up $I_2 = I_{21} + I_{22}$

setting $I_B = 0$ (open circuit)

$I_{21} = \frac{V_A}{R_1 + R_2}$

Setting $V_A = 0$ (short circuit)



resistors in parallel have same voltage

$I_{22} R_2 = (I_B - I_{22}) R_1$ ← $(I_B - I_{22})$: current thru R_1

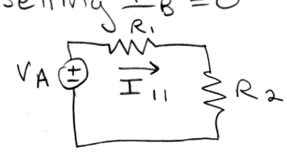
$I_{22} = \frac{I_B R_1}{R_1 + R_2}$ ← this known as the "current divider eq."

this is "–" in book wrong!!

$I_2 = I_{21} + I_{22} = \frac{V_A + I_B R_1}{R_1 + R_2}$

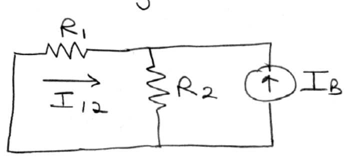
Continuing the example, solve for I_1 thru R_1

setting $I_B = 0$



$I_{11} = \frac{V_A}{R_1 + R_2}$

Setting $V_A = 0$



$-I_{12} R_1 = (I_B + I_{12}) R_2$ ← $(I_B + I_{12})$: current thru R_2

notice "–" because current is actually going the other way

$I_{12} = \frac{-I_B R_2}{R_1 + R_2}$

$I_1 = \frac{V_A - I_B R_2}{R_1 + R_2}$