# Physics 364 / 564

**Reminder**:

Lecture: Mondays only, 2-3:30

Labs: Mondays & Thursdays, 5-9pm

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$$\vec{J} = \sigma \vec{E}$$

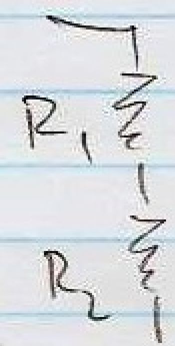
Ohm's Law: $V = IR$ (physics: acceleration between scatters)

Kirchoff: KCL $\equiv$ $\sum I = 0$ into one node
(conservation of charge)

KVL $\equiv$ $\sum_{loop} \Delta V = 0$ (conservation of energy)

$$\left( \oint \vec{E} \cdot d\vec{l} = - \frac{d}{dt} \Phi_B \right)$$

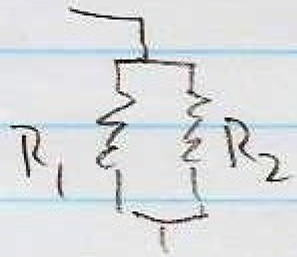
Series




$$\Delta V = IR_1 + IR_2 = I(R_1 + R_2)$$

$$R_{series} = R_1 + R_2$$

parallel




$$I = \frac{\Delta V}{R_1} + \frac{\Delta V}{R_2} = \Delta V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$1/R_{\parallel} = 1/R_1 + 1/R_2$$

$$\Rightarrow R_1 /\!/ R_2 = \frac{R_1 R_2}{R_1 + R_2}$$

shortcuts: $R + r \simeq R$

$(R \gg r)$ $R /\!/ r \simeq r$

$$R /\!/ R = \tfrac{1}{2} R$$

$$R /\!/ 2R = (2R /\!/ 2R) /\!/ 2R = \tfrac{2}{3} R$$

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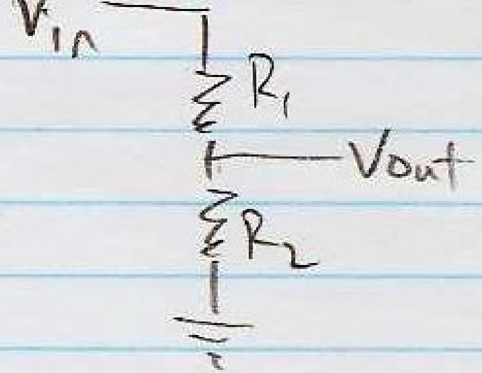
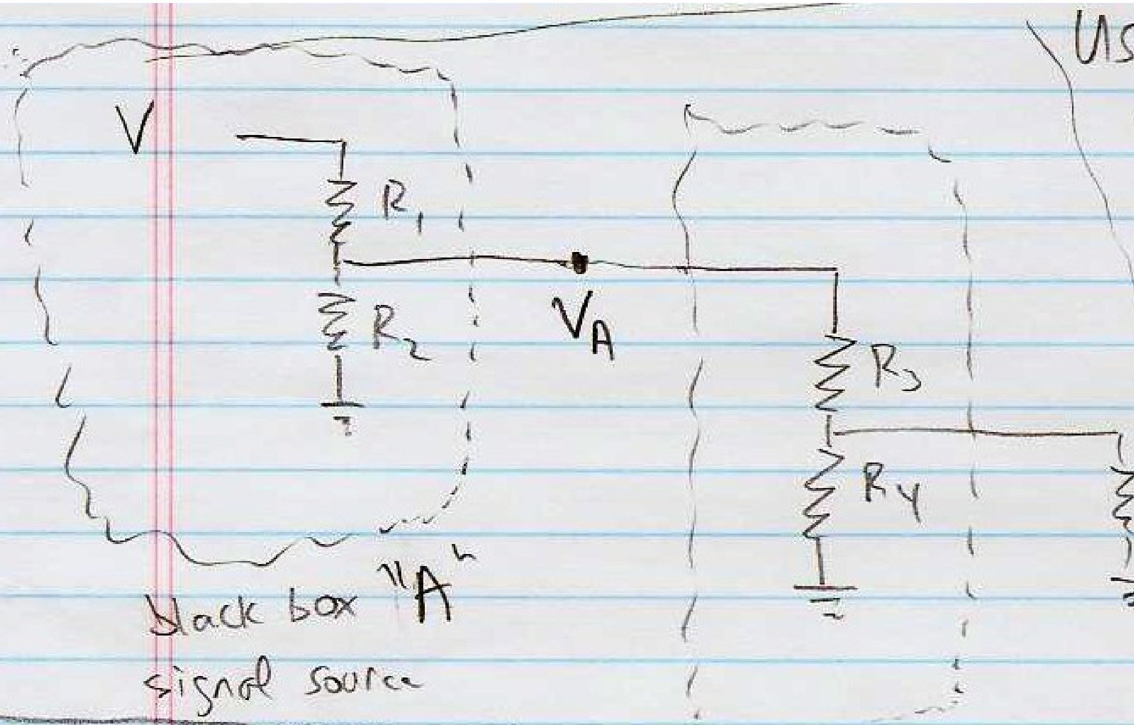
voltage divider: see again and again, in various forms




$$\frac{V_{out}}{V_{in}} = \frac{R_2}{R_1+R_2}$$




Use voltage dividers b/c they are what you know so far. More complicated boxes later.

Some assumption about $R_5$ needed to evaluate $R_{in}$

Some assumption about V (ideal?) needed to evaluate $V_{out}$

black box load "B"

To A, B looks just like $R_3 + (R_4 // R_5)$ to ground

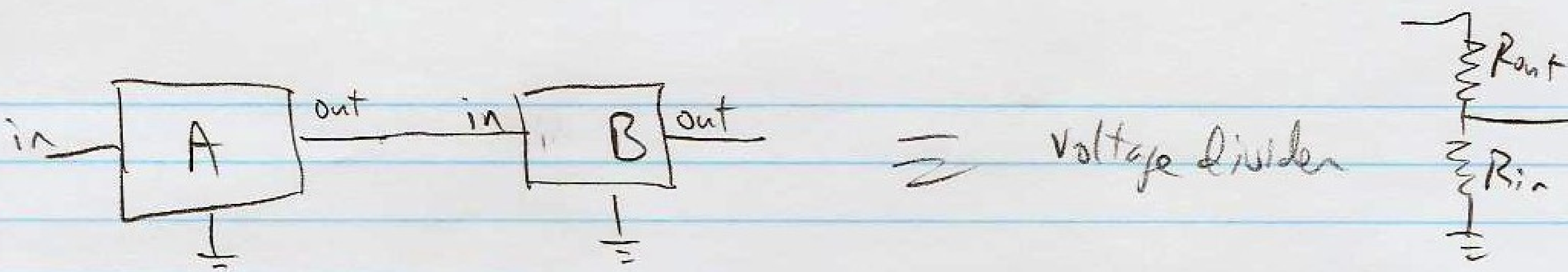
We say "input impedance" of B is $R_3 + (R_4 // R_5)$

To B, A looks like $R_{th} = R_1 // R_2$ to $V_{th} = \frac{V R_2}{R_1 + R_2}$

If $R_{in}(B) \gg R_{out}(A)$ then "loading" A with B does not cause A to "droop"/"sag".

(Analogous (opposite) rule for current sources.)

→ e.g. you build amplifier to boost a voltage, don't want to lose your voltage gain b/c can't drive load.




When circuit fragment A drives circuit fragment B, rule of thumb: $R_{out}(A) \ll R_{in}(B)$

e.g. $R_{in}(B) \gtrsim 10 \times R_{out}(A)$

I use $\times 100$ in HW problems for emphasis, but that is often excessive. Depends on acceptable droop.

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Can design circuit fragments independently if follow rule of thumb.

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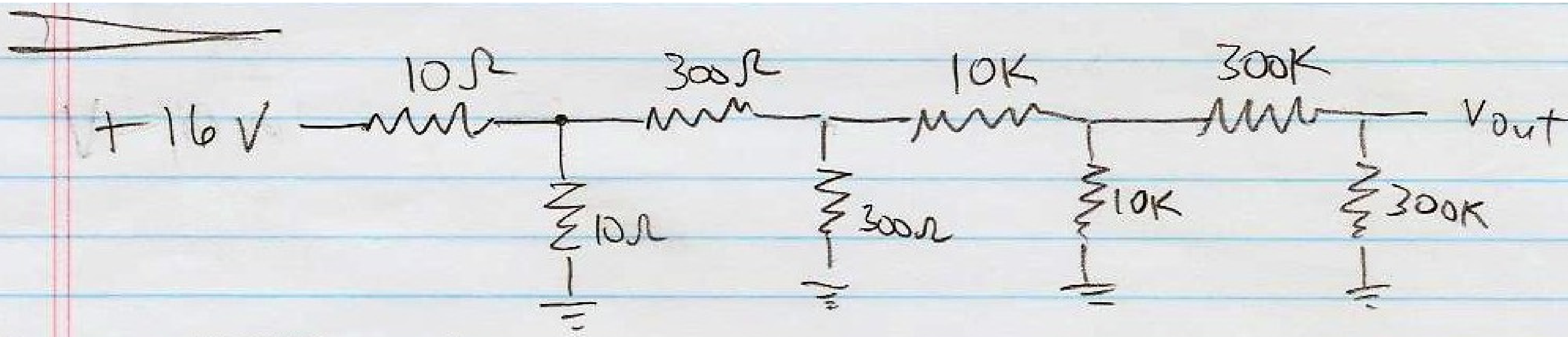
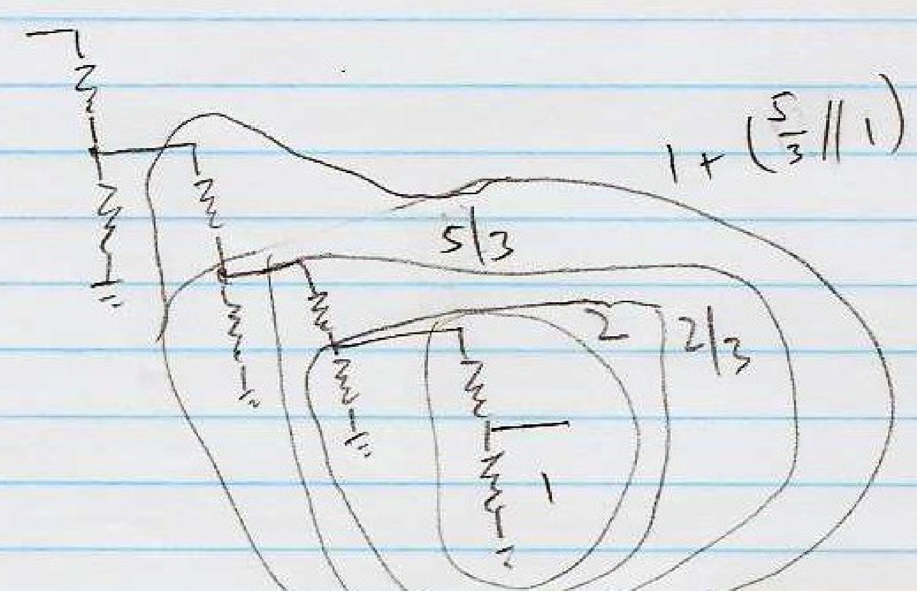



.98 volt

What is Vout? (Discuss with neighbor!)

Now what if every resistor is 1K?




≃ 0.47V

To determine impedance: change V, measure $\frac{\Delta V}{\Delta I} \equiv R$

extreme case: $\frac{V_{th}}{I_{sc}}$ compares open circuit w/ short circuit

we forced $V_{out}$ to be 0 volts, then measured $\Delta I$.

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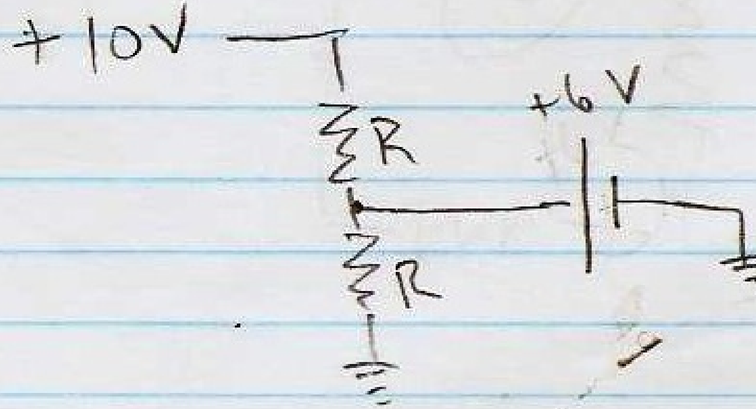
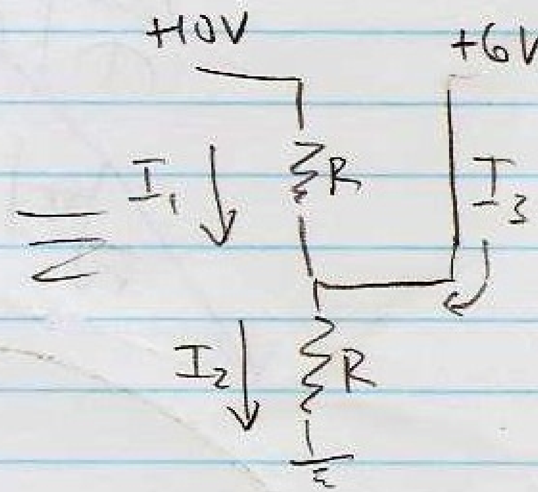



(many ways to draw)

$$I_1 = \frac{10V - 6V}{R} = \frac{4V}{R}$$

$$I_2 = 6V/R$$

$$I_3 = I_2 - I_1 = \frac{2V}{R}$$

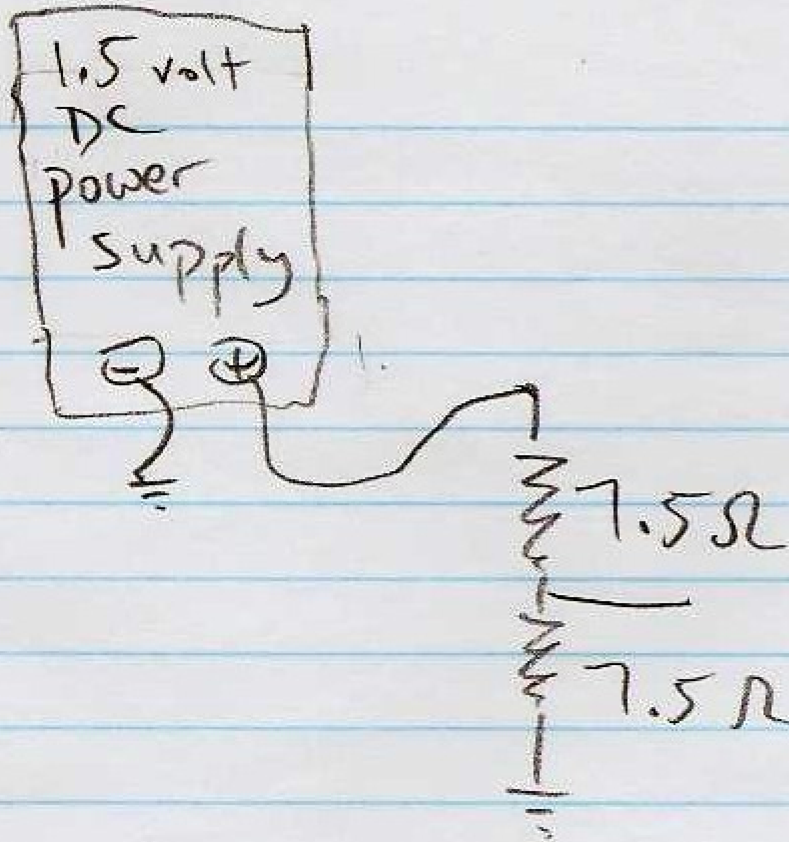
after forcing divider output to +6V,

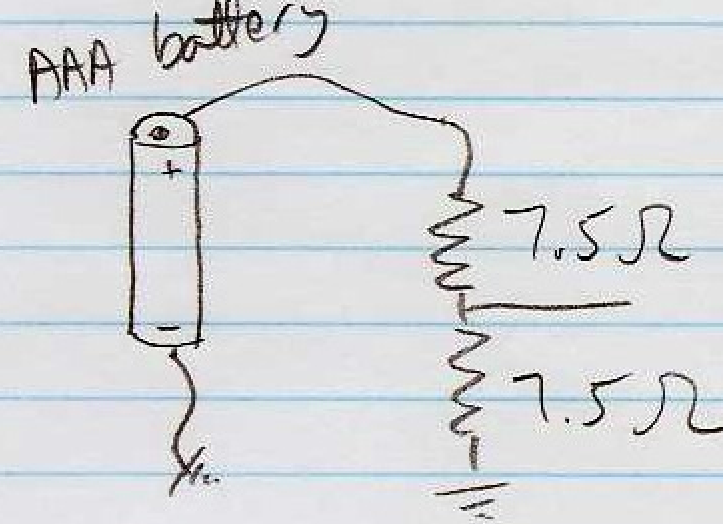
$$\Delta V = 6V - V_{th} = 6V - 5V = 1V$$

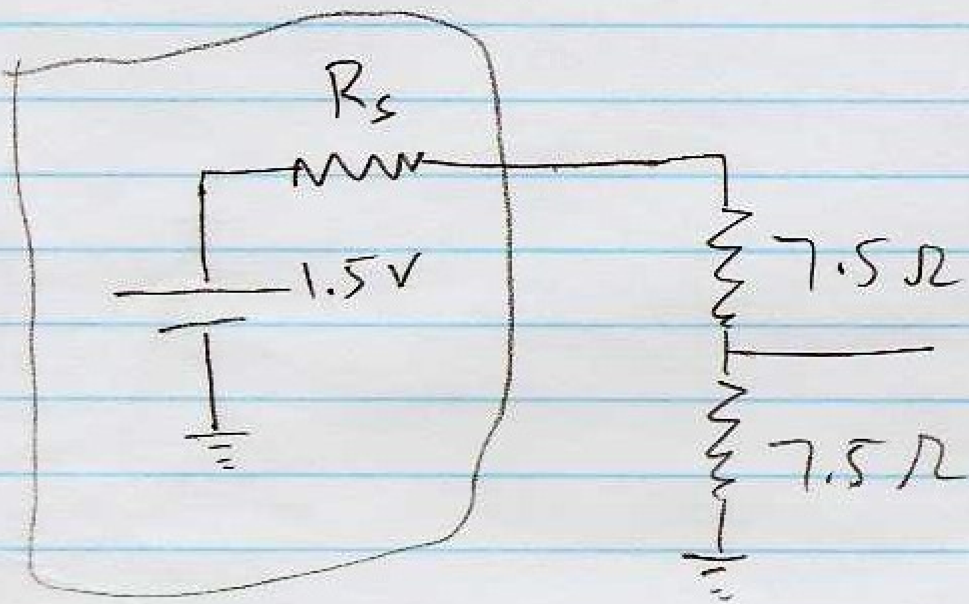
$$\Delta I = I_3 - 0 = \frac{2V}{R}$$

$$\Delta V / \Delta I = R/2$$

Same as $R_{th}$ !



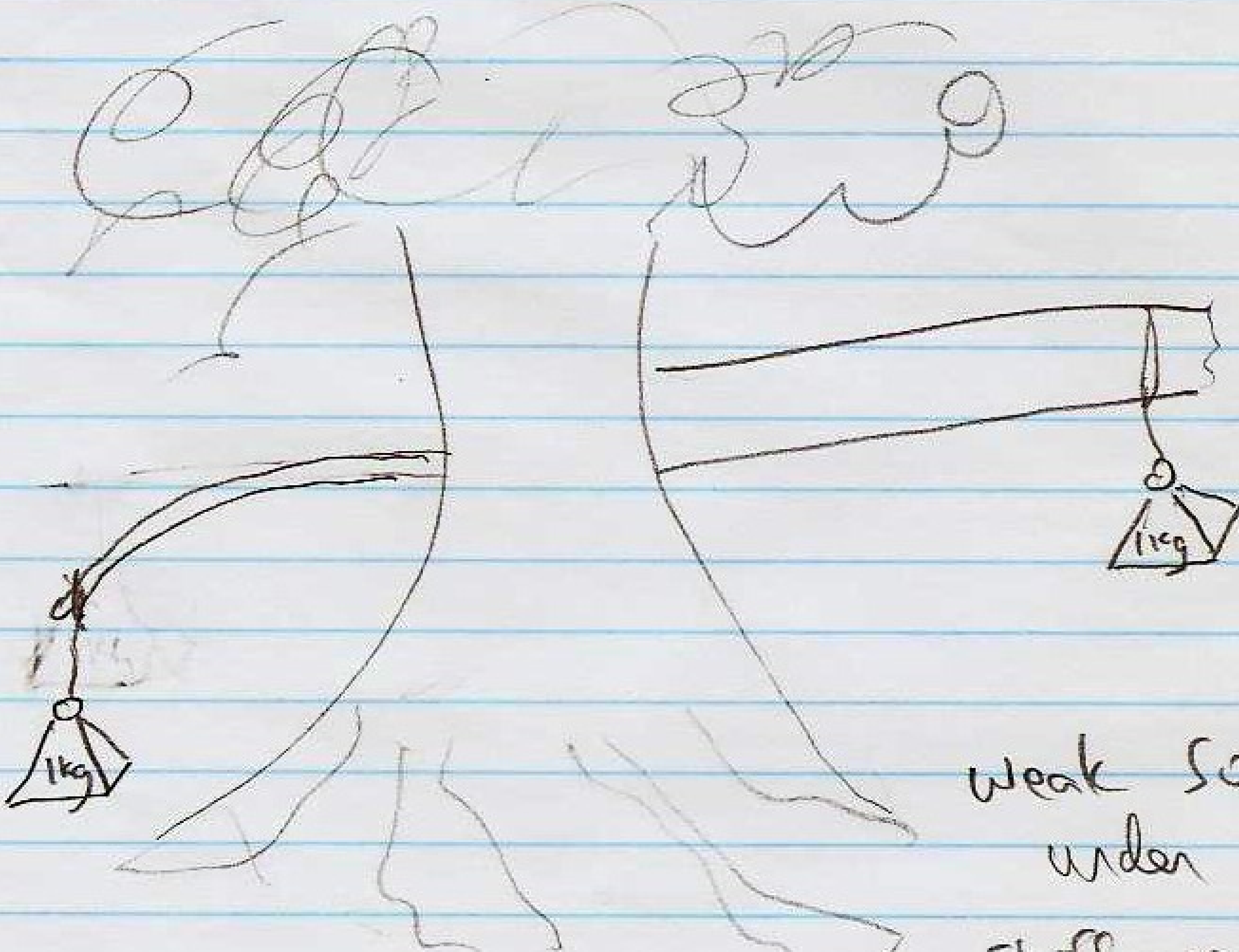




**Note**:
AAA battery is a bit less weak than I thought. Its internal resistance is about 0.2 – 0.3 ohms, according to a vendor data sheet. So 1.5 ohm would have been a better choice here than 7.5 ohm.

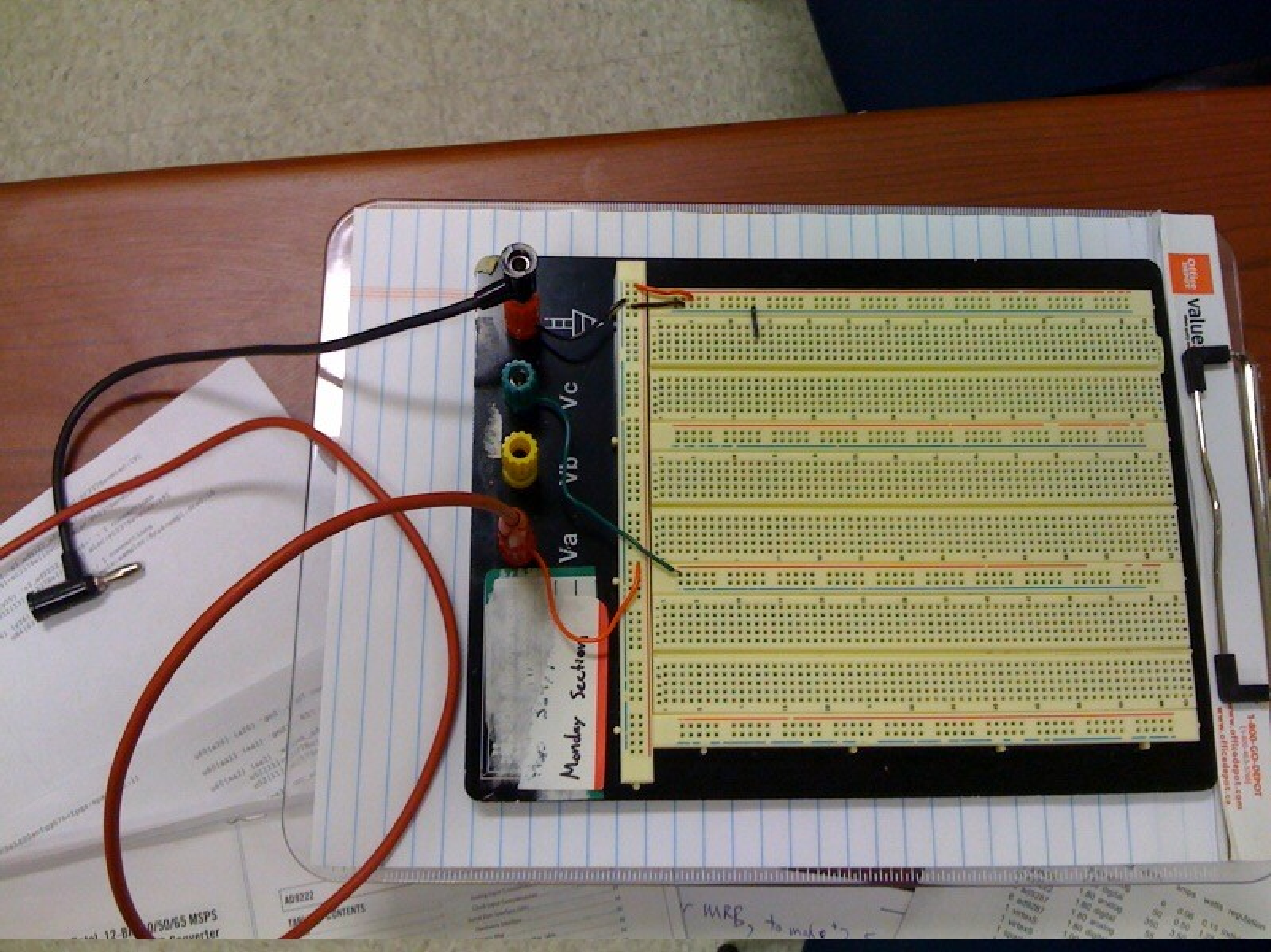
"stiff" voltage source $\equiv R_s \ll R_{in}$

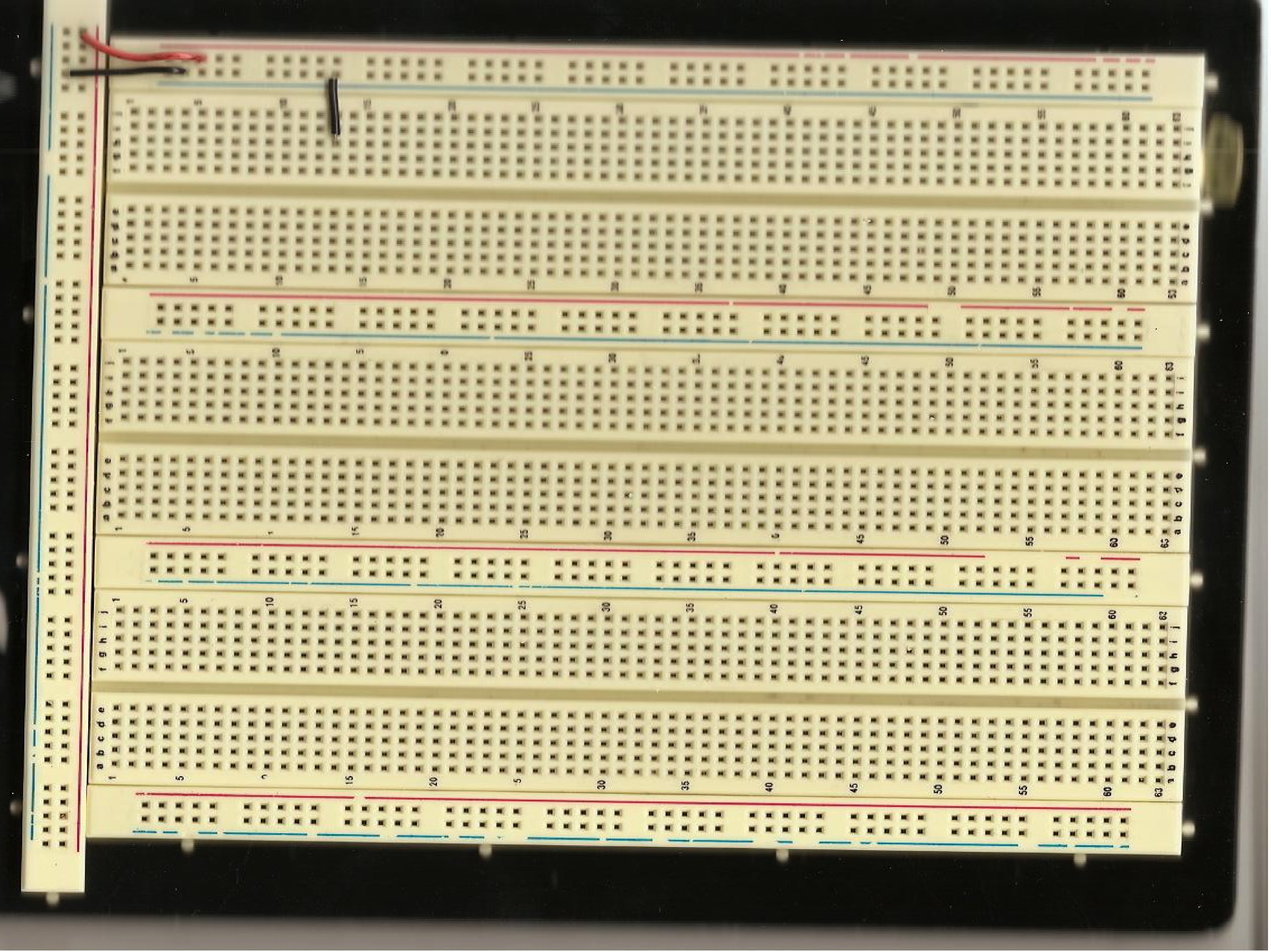
"weak" voltage source $\equiv R_s \sim R_{in}$




weak source droops/sags under load.

stiff source unchanged


Vc
Vb
Va
Monday Section



# Sample Lab Reports

- I did 2/5 of Lab 1; Jose did 4/5.
  - I would have given my own report (if 5/5 done) an A-
  - Jose would have given his own report (if 5/5 done) an A-

- http://positron.hep.upenn.edu/pet/wiki/index.php/Us
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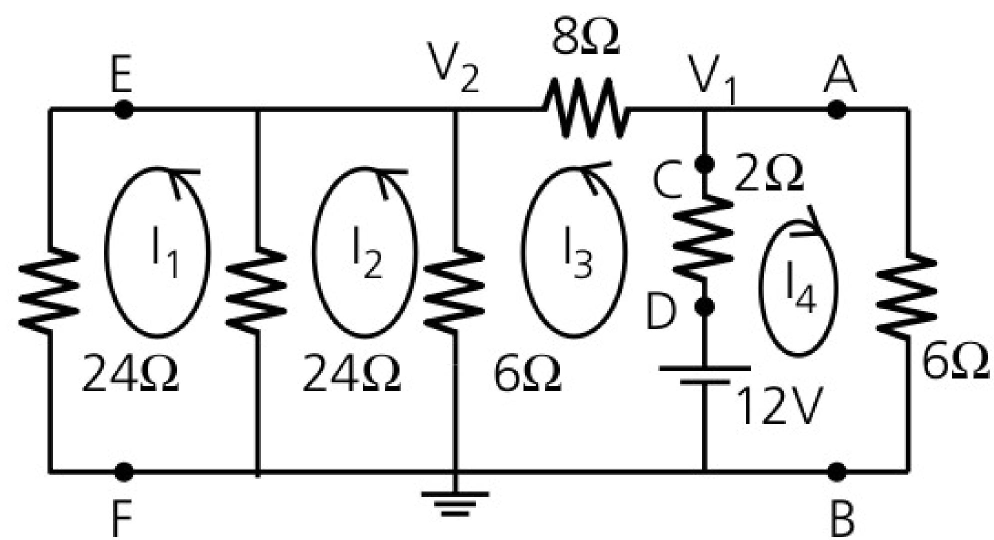
- Note that Jose will be grading the reports ....

*Series and parallel resistors, mesh currents, node voltages, Thevenin and Norton.* (a) Write down the equations for the mesh currents $I_{1-4}$ in figure 2.25, but do not solve them. (b) Find the current $I_3 + I_4$ supplied by the battery by simplifying series and parallel combinations of resistors. (c) Find $V_1$ and $V_2$. (d) Hence find $I_{1-4}$ and check them against (a). (e) Find the Thevenin equivalent of the circuit to the left of $AB$; use this to check $I_4$. (f) Find the Norton equivalent of the circuit across the terminals $CD$. Use this to check $I_3 + I_4$. (g) Find the Norton equivalent of the circuit to the right of $EF$; use it to check $I_1$. (Ans: (a) $I_3 + I_4 = 2$ A; (c) $V_1 = 8$ V; $V_2 = 8/3$ V; (d) $I_1 = 1/9$ A; $I_2 = 2/9$ A; $I_3 = 2/3$ A; $I_4 = 4/3$ A; (e) $V_{EQ} = 144/14$ V, $R_{EQ} = 24/14\ \Omega$; (f) $I_{EQ} = 3$ A, $R_{EQ} = 4\ \Omega$; (g) $I_{EQ} = 18/19$ A, $R_{EQ} = 24 \times 19/143\ \Omega$.)



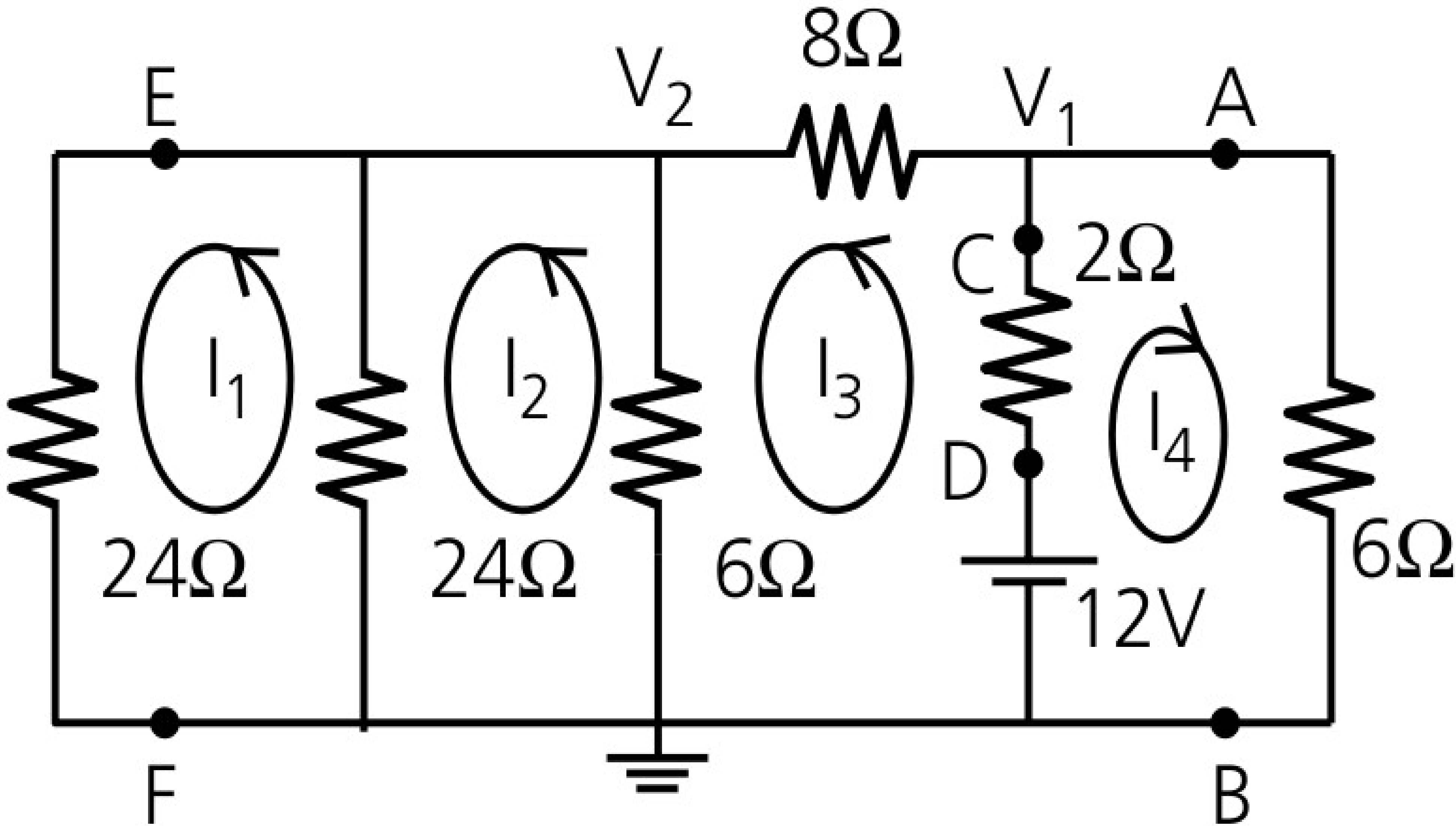



Fig. 2.25.

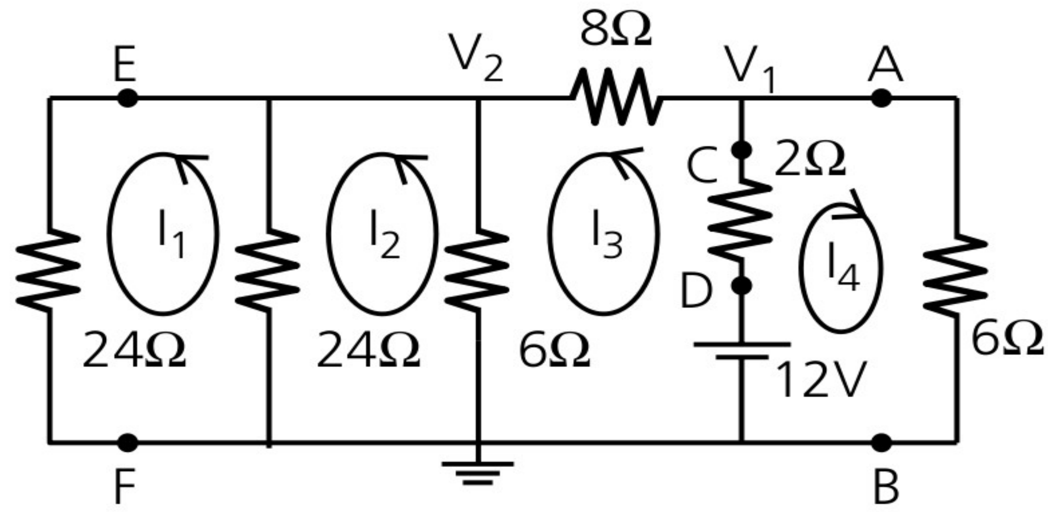



Fig. 2.25.

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