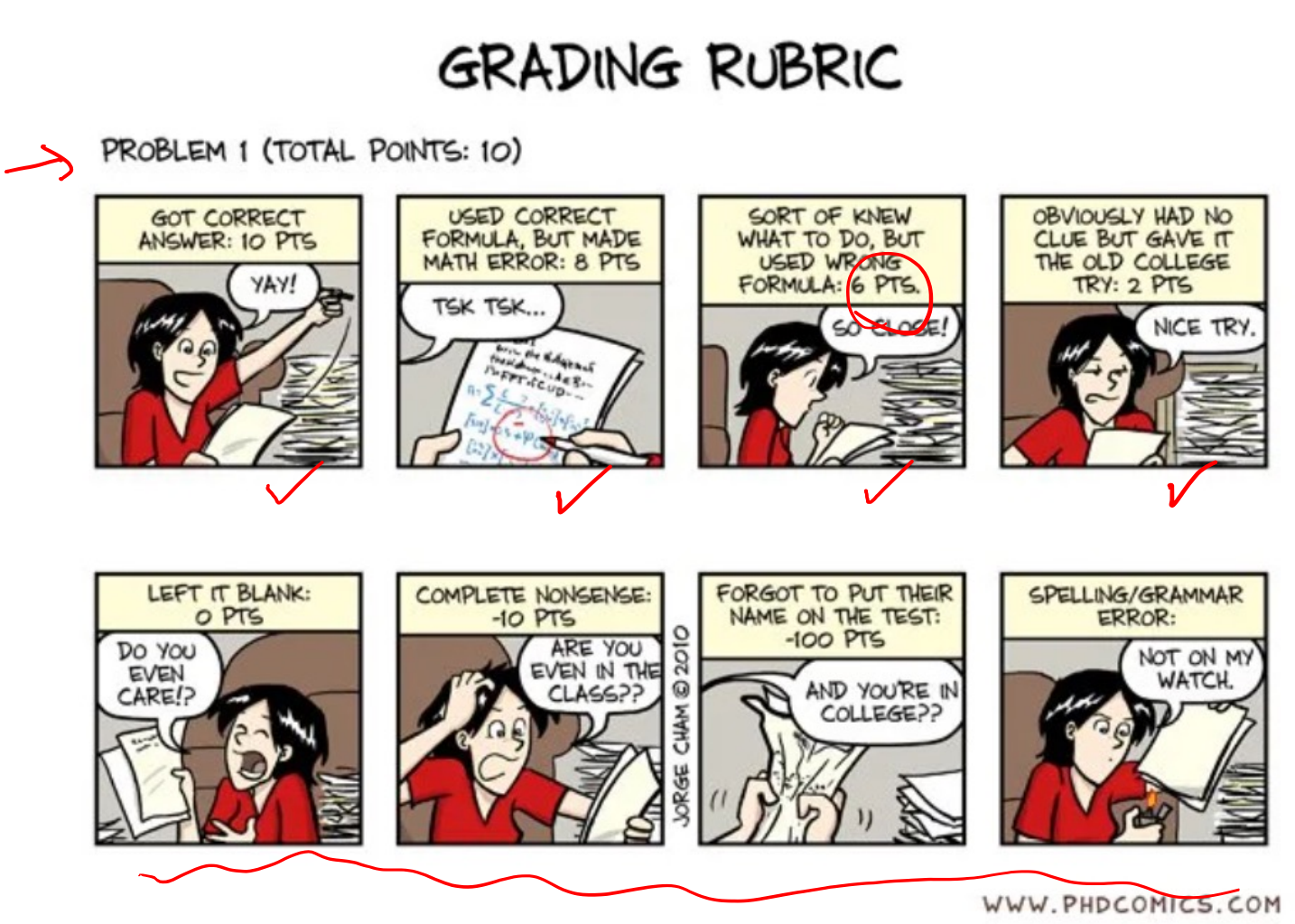
EECS 16A

Spring 2023 - Profs. Muller & Waller

Power and I/V Measurement



Midterm is Tomorrow! 7-9pm

PRINT your student ID: _____

PRINT AND SIGN your name: _____, _____ _____
(last name) (first name) (signature)

PRINT the time of your discussion section and your GSI(s) name: _____

PRINT the student IDs of the person sitting on your right: _____ and left: _____

General Notes

- This exam has a combination of multiple choice, fill-in-the-blank, and free-response questions.
- **You must adhere to the following format to receive full credit:**
  - For fill in the blank questions, **legibly write your final answer entirely in the provided boxes**.
  - For questions with **circular bubbles**, select exactly *one* choice, by filling the bubble ●.
    ● You must choose either this option. ○ Or this one, but not both!
  - For questions with **square boxes**, you may select *multiple* choices, by filling the squares ■.
    ■ You could select this choice. ■ You could select this one too!
  - For free-response questions please show your work in the provided empty boxes. Doing so enables us to reward you partial credit where applicable.

Midterm is Tomorrow! 7-9pm

1. HONOR CODE

Please read the following statements of the honor code, and sign your name (you don't need to copy it).

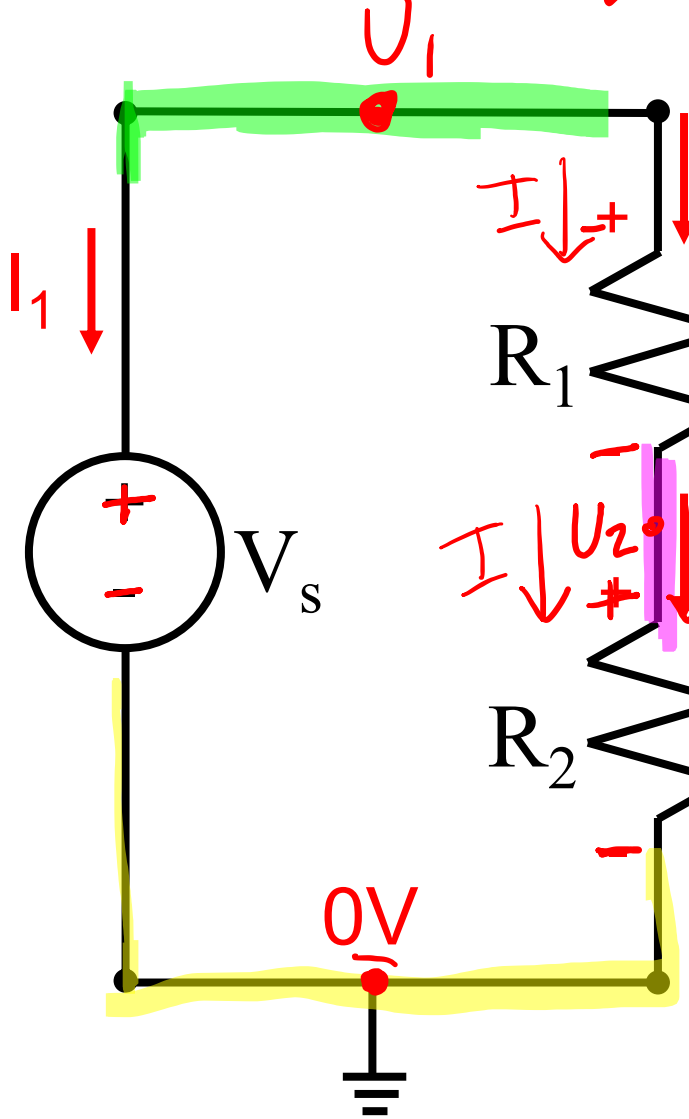
I will respect my classmates and the integrity of this exam by following this honor code. I affirm:

- *I have read the instructions for this exam. I understand them and will follow them.*
- *All of the work submitted here is my original work.*
- *I did not reference any sources other than my unlimited printed resources.*
- *I did not collaborate with any other human being on this exam.*

Other admin:

- I will take over office hours Wednesday 11am– 12pm in my office 564 Cory Hall

Last Lecture: Kirchoff's Current Law (KCL)



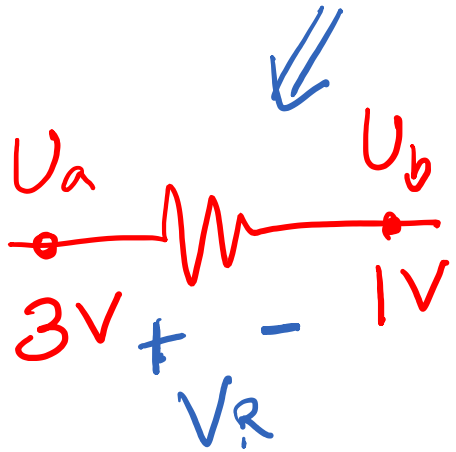
Voltage divider

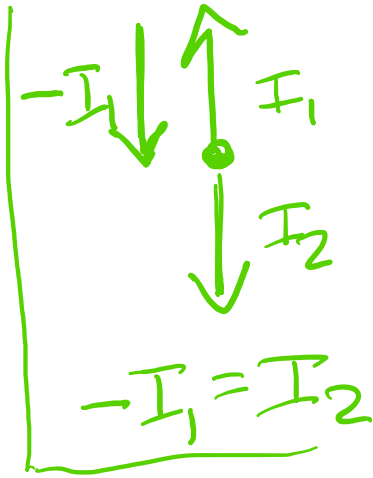
KCL

$\Rightarrow I_1 + I_2 = 0$

$I_2 = -I_1 = I$

$I_2 = I_3 = I$



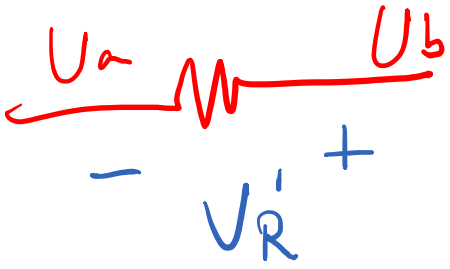


$V_R = U_a - U_b$

$= 3V - 1V$

$= 2V$

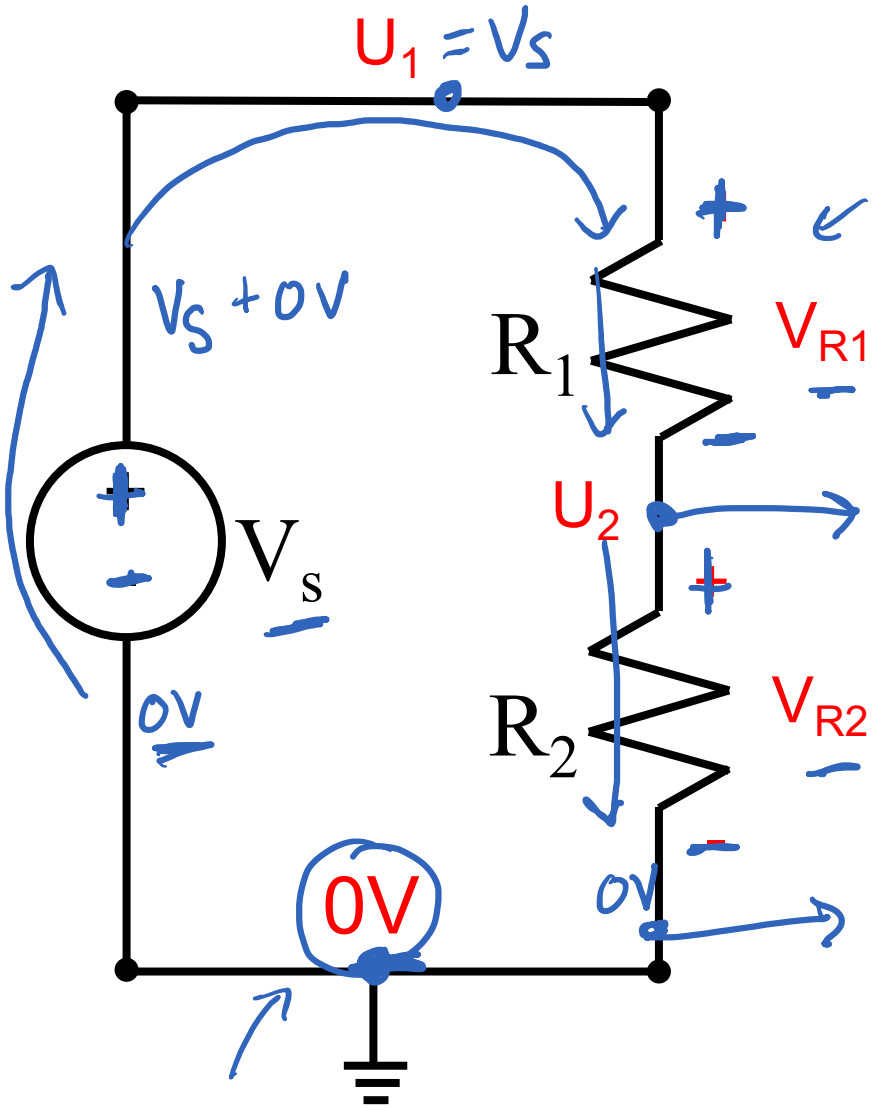
$\Rightarrow$



$V_R' = U_b - U_a$

$1V - 3V = -2V$

Last Lecture: Kirchoff's Voltage Law (KVL)



$\sum V_{elem} = 0$ ← in the loop

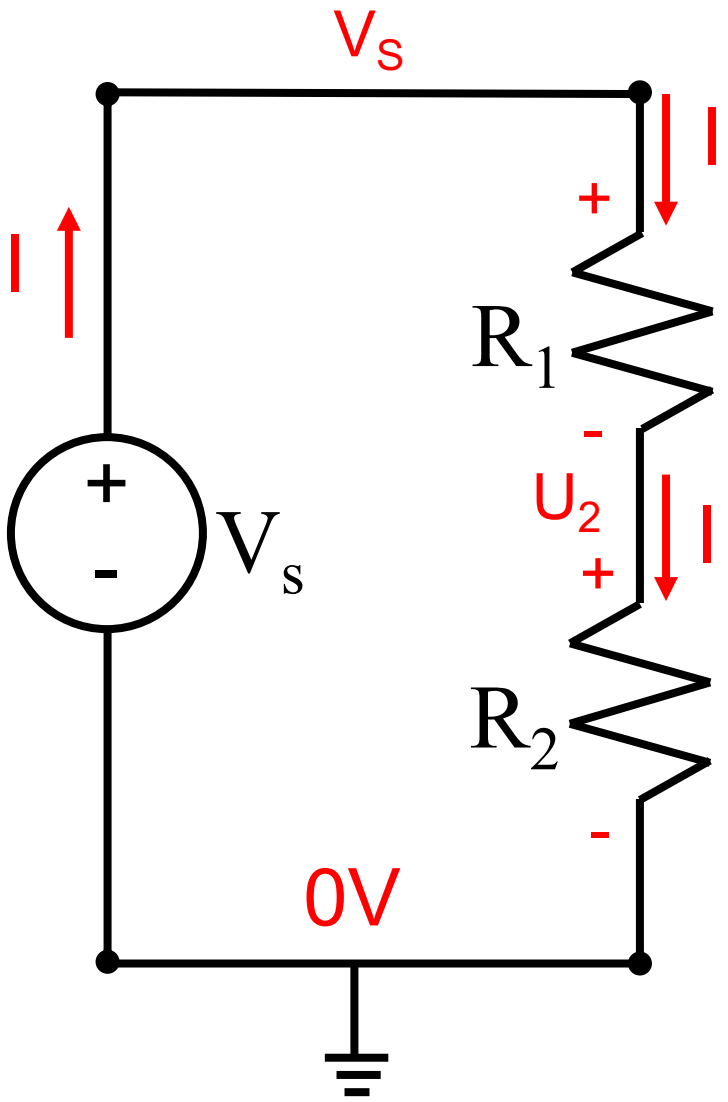
+ ← subtracting V_{R1}

$V_S - V_{R1}$

+ ← subtract

$V_S - V_{R1} - V_{R2} = 0$ ← KVL

Last Lecture: Ohm's Law



Is the system of equations complicated? Linear Algebra can help! $A\vec{x} = \vec{b}$

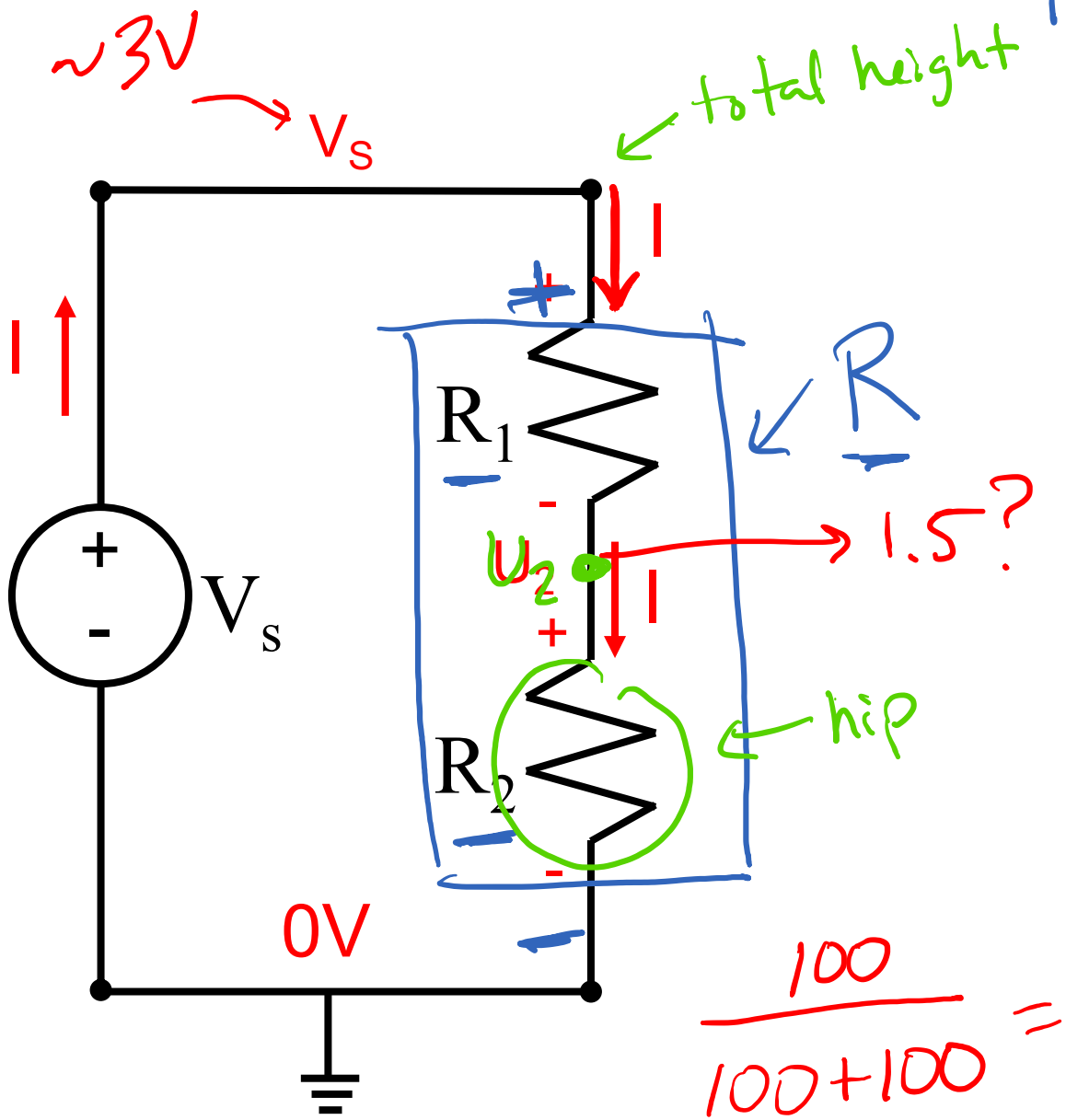
$IR_1 + U_2 = V_S$

$IR_2 - U_2 = 0$

$$\begin{bmatrix} R_1 & 1 \\ R_2 & -1 \end{bmatrix} \begin{bmatrix} I \\ U_2 \end{bmatrix} = \begin{bmatrix} V_S \\ 0 \end{bmatrix}$$

$\vec{x}$

Voltage Divider Observations



$RI = V$

$I = (V_S - 0)/R$

$I = \frac{V_S}{R}$

$$I = \frac{V_S}{(R_1 + R_2)}$$

resistance add in series

$$U_2 = \frac{V_S R_2}{R_1 + R_2} = V_S\left(\frac{R_2}{R_1 + R_2}\right)$$

ratio $= \frac{1}{2}$

divides the voltage

$\frac{100}{100+100} = \frac{1}{2}$

Power and Energy in Circuits

Current: flow of charges (electrons moving from point A→B inside a material)

$$I = \frac{dQ}{dt}$$

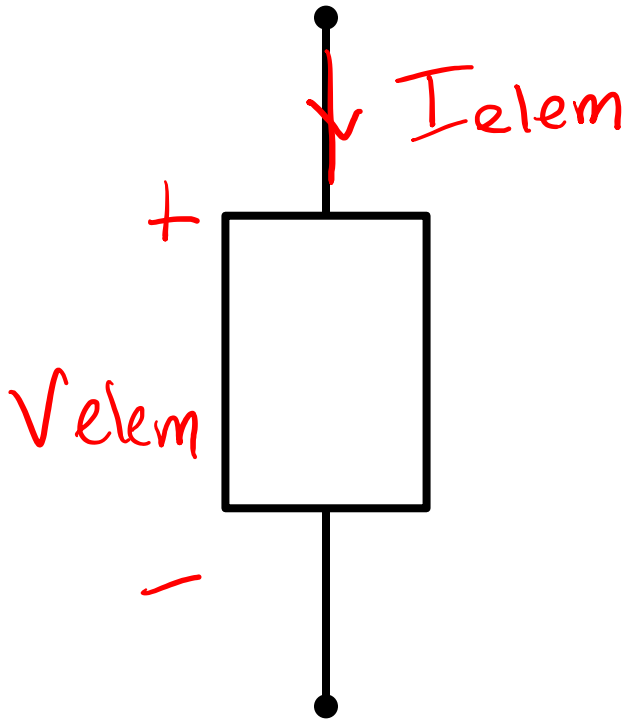
Voltage: provides the **energy** [Joules] to move charge from A→B. 1 Volt provides 1 Joule of energy to 1 Coulomb of charge.

$$V_{AB} = \frac{dE}{dQ}$$

Power [Watts]: the rate at which **energy** is transferred

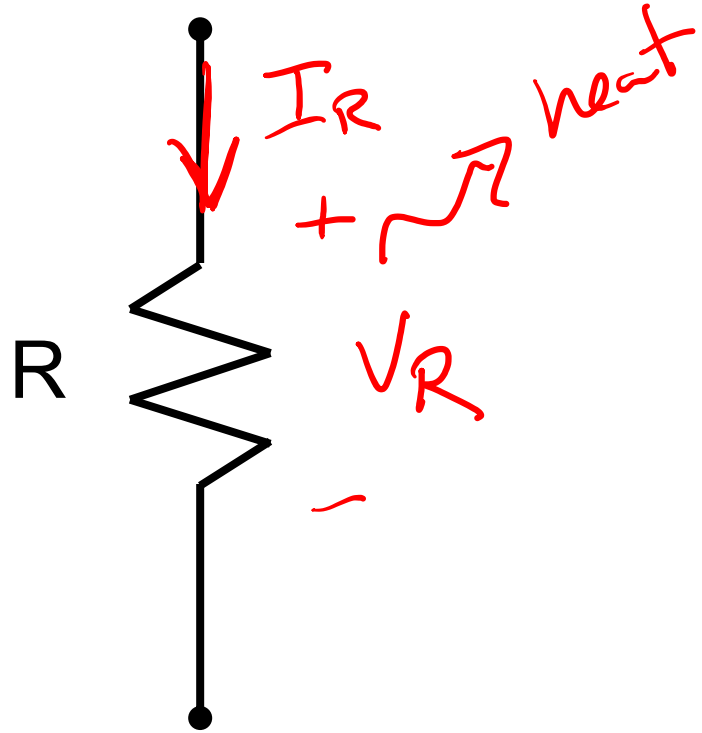
$$P = \frac{dE}{dQ}\,\frac{dQ}{dt} = \frac{dE}{dt} = V_{AB} \cdot I$$

Power in an Element



$$P_{elem} = V_{elem} \cdot I_{elem}$$

Power in a Resistor



"dissipate" power

$$\text{Power [Watts]} = V_R \cdot I_R$$

$$I_R = \frac{V_R}{R}$$

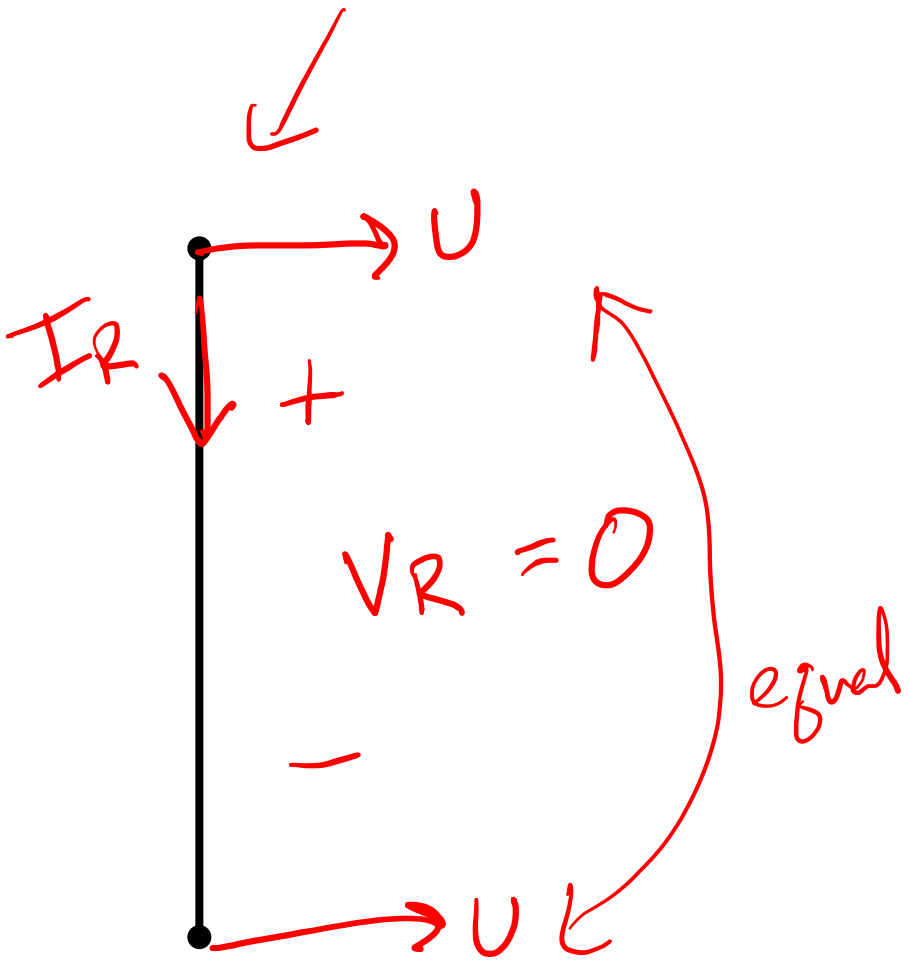
$$\text{Power} = V_R \cdot \frac{V_R}{R} = \frac{V_R^2}{R}$$

$$V_R = I_R R$$

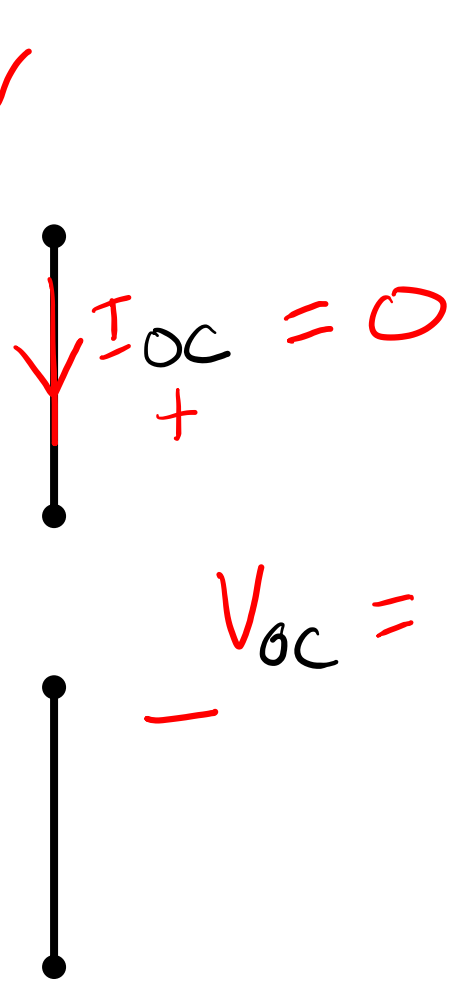
$$\text{Power} = I_R \cdot R \cdot I_R = I_R^2 \cdot R$$

always +

Power in Wires and Open Circuits

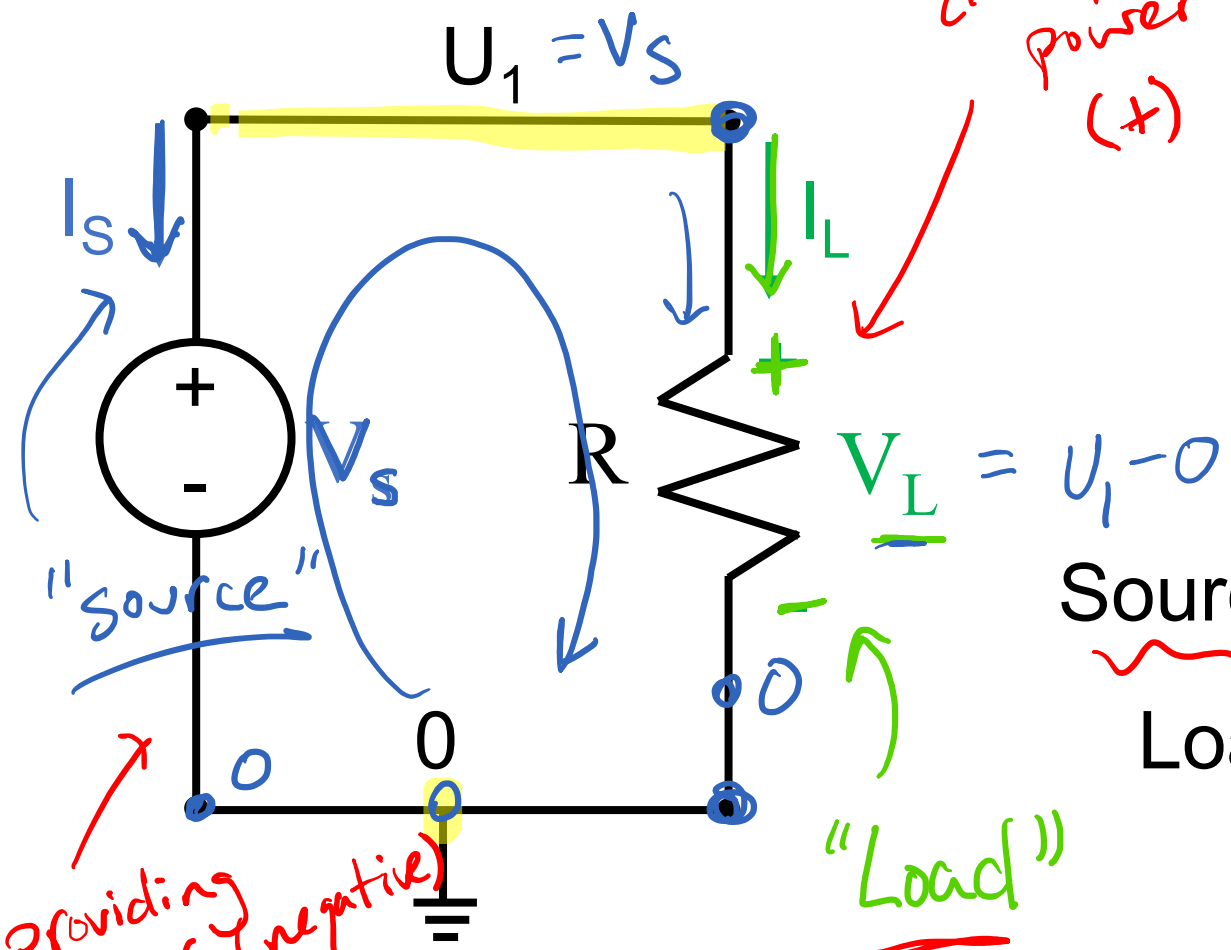


$$\text{Power} = I_R V_R = 0$$



$$\text{Power} = V_{OC} \cdot I_{OC} = 0$$

Example



KCL: $I_S + I_L = 0$

$-I_S = I_L$

KVL: $V_S - V_L = 0$

$V_S = V_L = U_1 - 0$

Source Power: $P_S = I_S V_S$

Load Power: $P_L = I_L V_L$

$= I_L V_S$

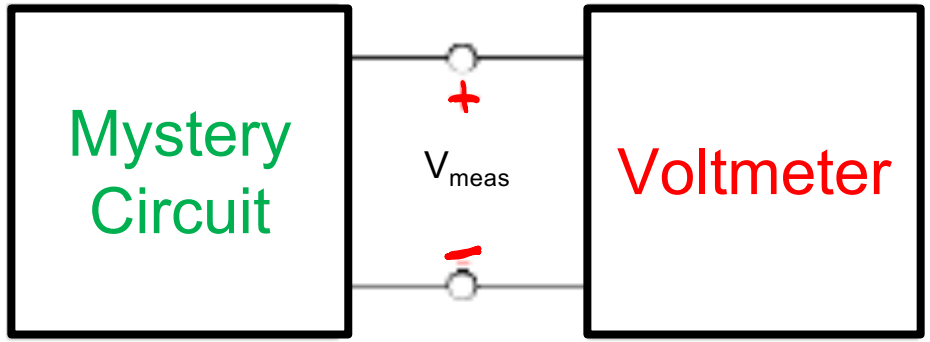
How are these related?

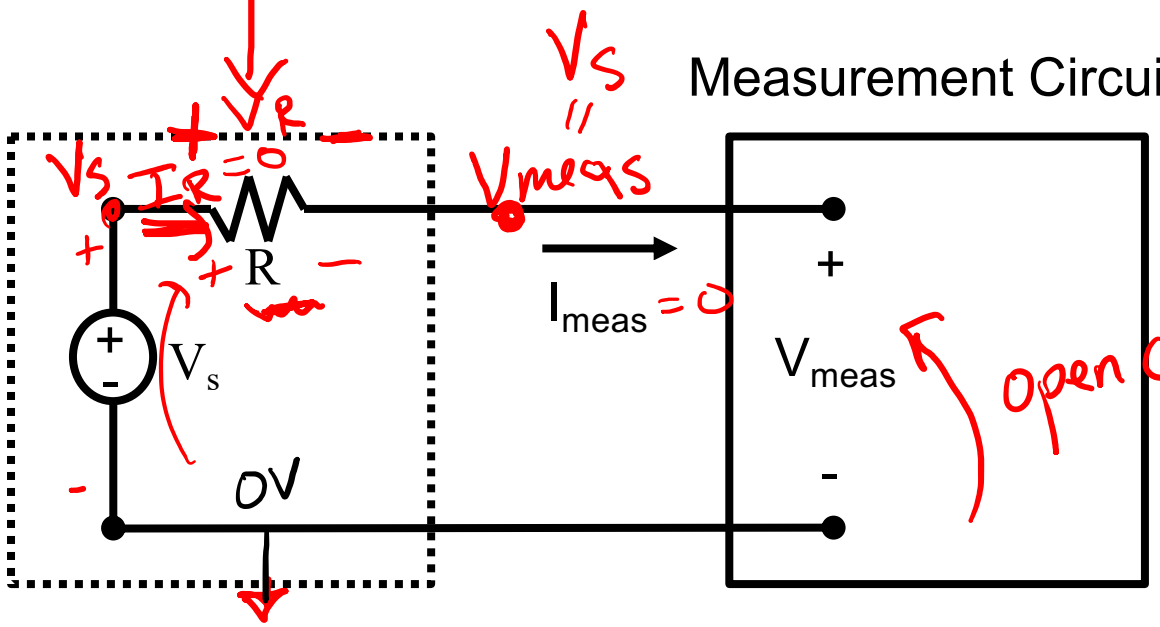
* conservation of energy

* $P_L = -I_S V_S = -P_S$

equal and opposite!

How to measure Voltage?





Goal: $V_{meas} = V_S$

KVL: $V_S - V_R - V_{meas} = 0$

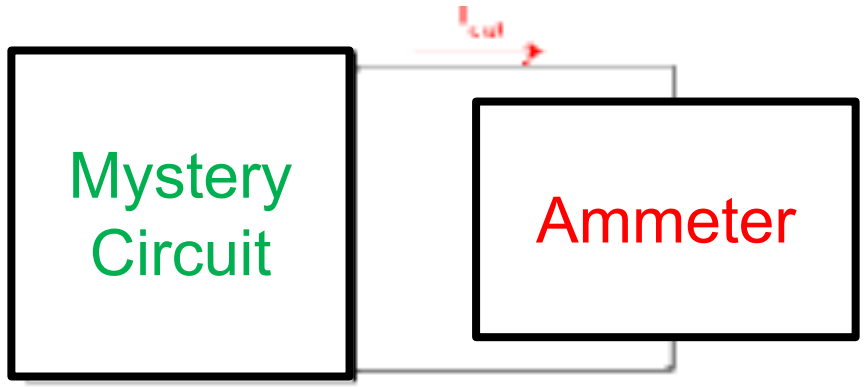
$V_S - V_R = V_{meas}$

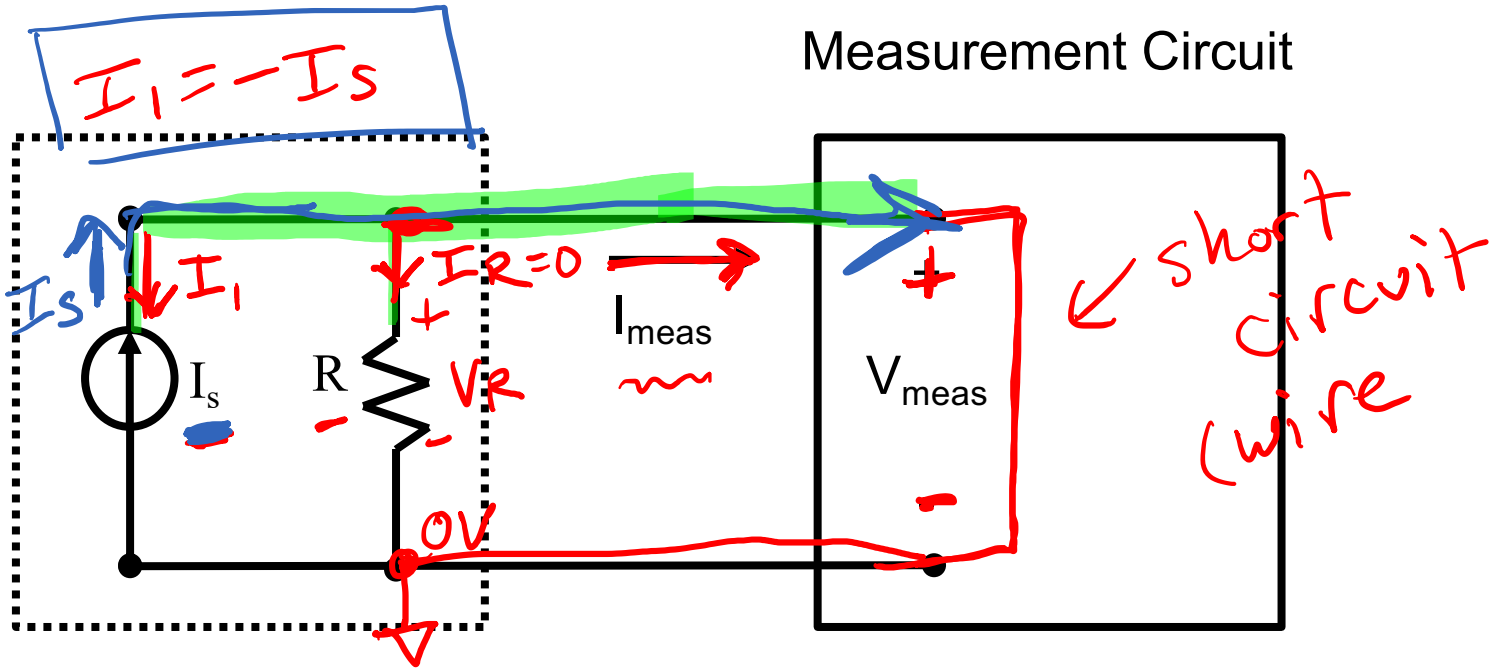
← open circuit! $*V_R = 0$

$V_R = I_R R = 0$

$I_R = 0$

How to measure Current?





Goal: $I_{meas} = I_S$

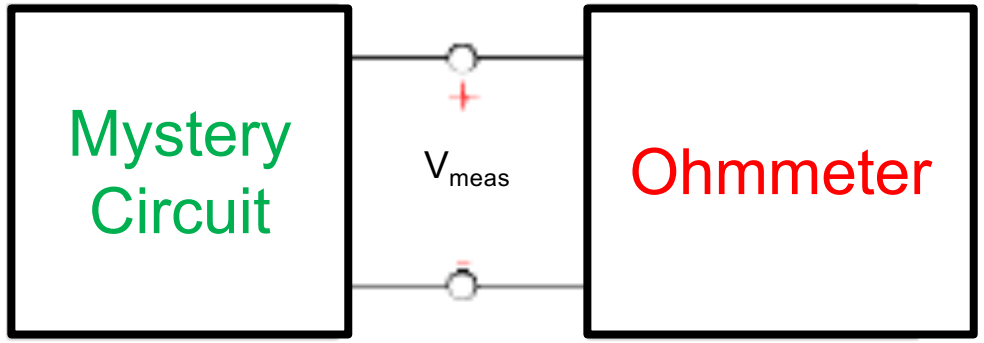
KCL: $I_S = I_R + I_{meas}$

$I_R = 0$

$V_R = I_R R = 0$

$V_R = 0$

How to measure Resistance?

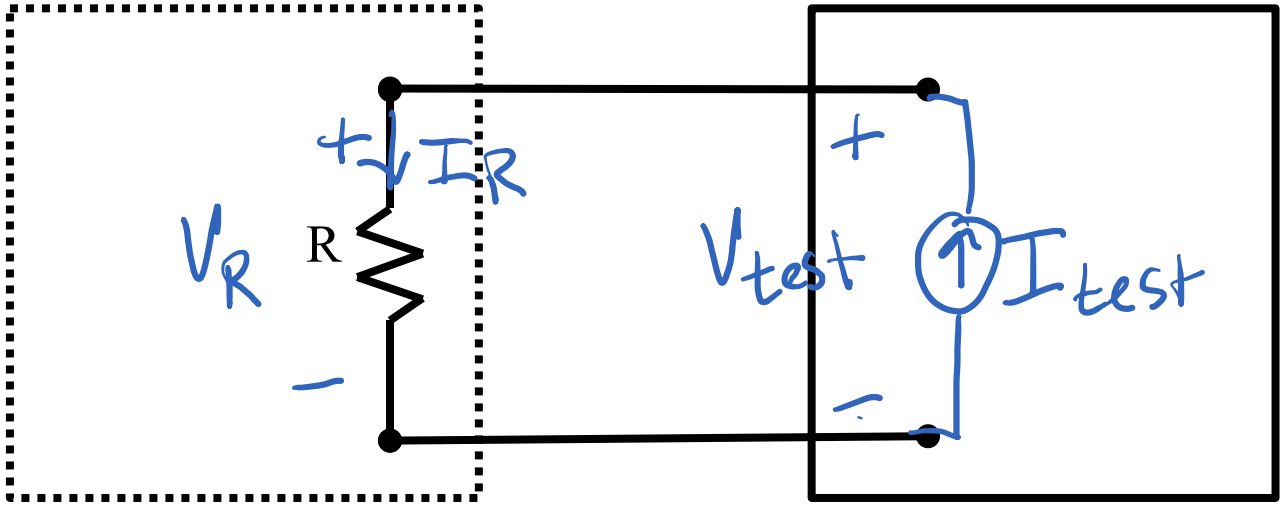


Ohm's Law

$V_R = I_R R$

$R = V_R / I_R$

Measurement Circuit



$R = V_{test} / I_{test}$

Demo!