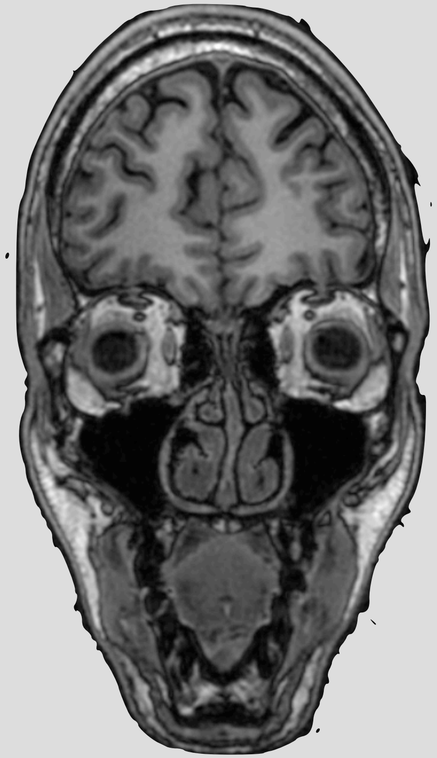
EE16B
Designing Information Devices and Systems II

Lecture 1A
Intro, EECS16A review, Caps

Instructors

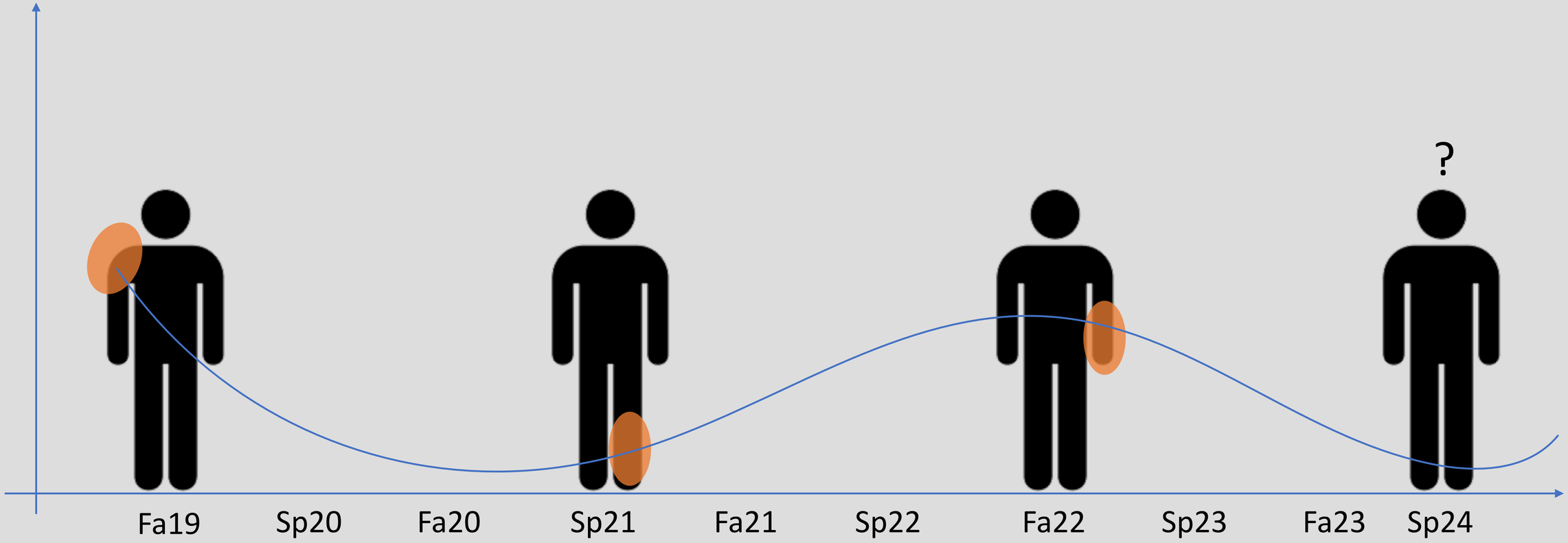
Prof. Jean-Paul (JP) Tennant
jptennant@berkeley.edu

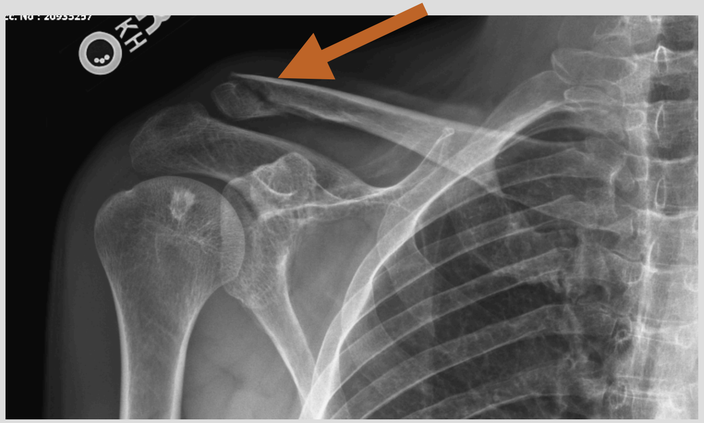
Prof. Miki Lustig
mikilustig@berkeley.edu



Office Hours: right after lecture, 11:15-12 Cory 504

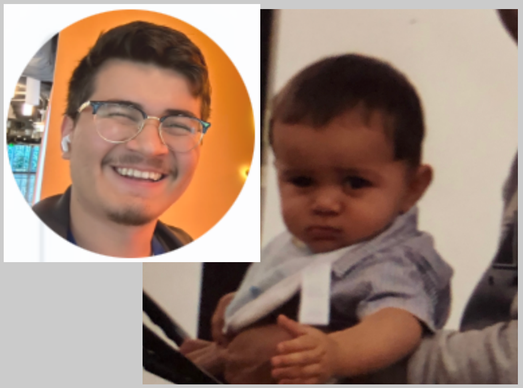
Miki’s Injury Timeline





Staff - Admin TAs

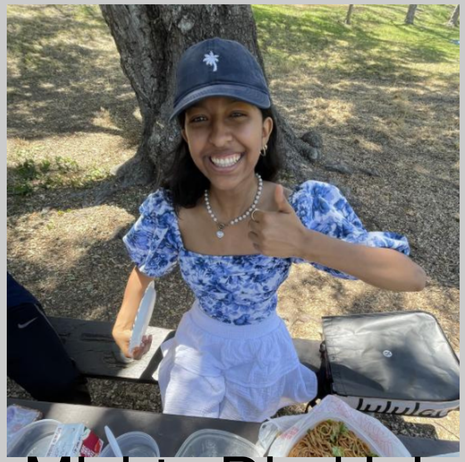
- Non-Lab:



Sebastian Arevalo

Jeshua Gustafson

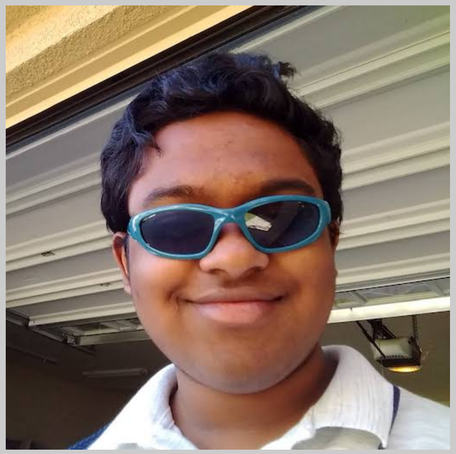
Veeryan Bhatia



Mishty Dhekial

- Lab:

Jessica Fan



Venkata Alapati

Resources

- Course Website: www.eecs16b.org
  - Policies
  - Discussion worksheets
  - Homework
  - Lab notebooks
  - Course notes
  - Calendar
  - Will announce when fully updated!

Resources

- Course Website: www.eecs16b.org
- Course Ed
  - Announcements posted there
  - Ask questions and engage with other students
  - If you have not been added, email: eecs16b-sp24@berkeley.edu

Resources

- Course Website: www.eecs16b.org
- Course Ed
- Gradescope
  - Submit HW, preLabs etc
  - If you have not been added, email: eecs16b-sp24@berkeley.edu

Course Format

- Lectures
  - Tu / Th 9:30-11:00 AM Pimentel 1
  - Topics on the course website
  - Recording on bcourses
  - If you have not been added, email:
    eecs16b-sp24@berkeley.edu

Course Format

- Lectures
- Discussions
  - Mon. (covers Th lecture) and Wed (covers Tu lecture)
  - Many sections spread out (course calendar)
  - Starts tomorrow! (Wed. 1/17/24)
  - If you have not been added, email:
    eecs16b-sp24@berkeley.edu

Course Format

- Lectures
- Discussions
- Homework
  - 1 per week, due Sat. Night
  - 1 free drop, 2 no-question-asked 3 day extension
  - Found on www.eecs16b.org

Course Format

- Lectures
- Discussions
- Homework
- Lab
  - 1 Prelab followed by 1 lab every week (typically)
  - Found on www.eecs16b.org

Course Format

- Lectures
- Discussions
- Homework
- Lab
- Office Hours / Homework Rave
  - Look at calendar
  - OH Queue: https://oh.eecs16b.org
  - Conceptual and HW aid by Faculy, TAs and Tutors.

Course Format

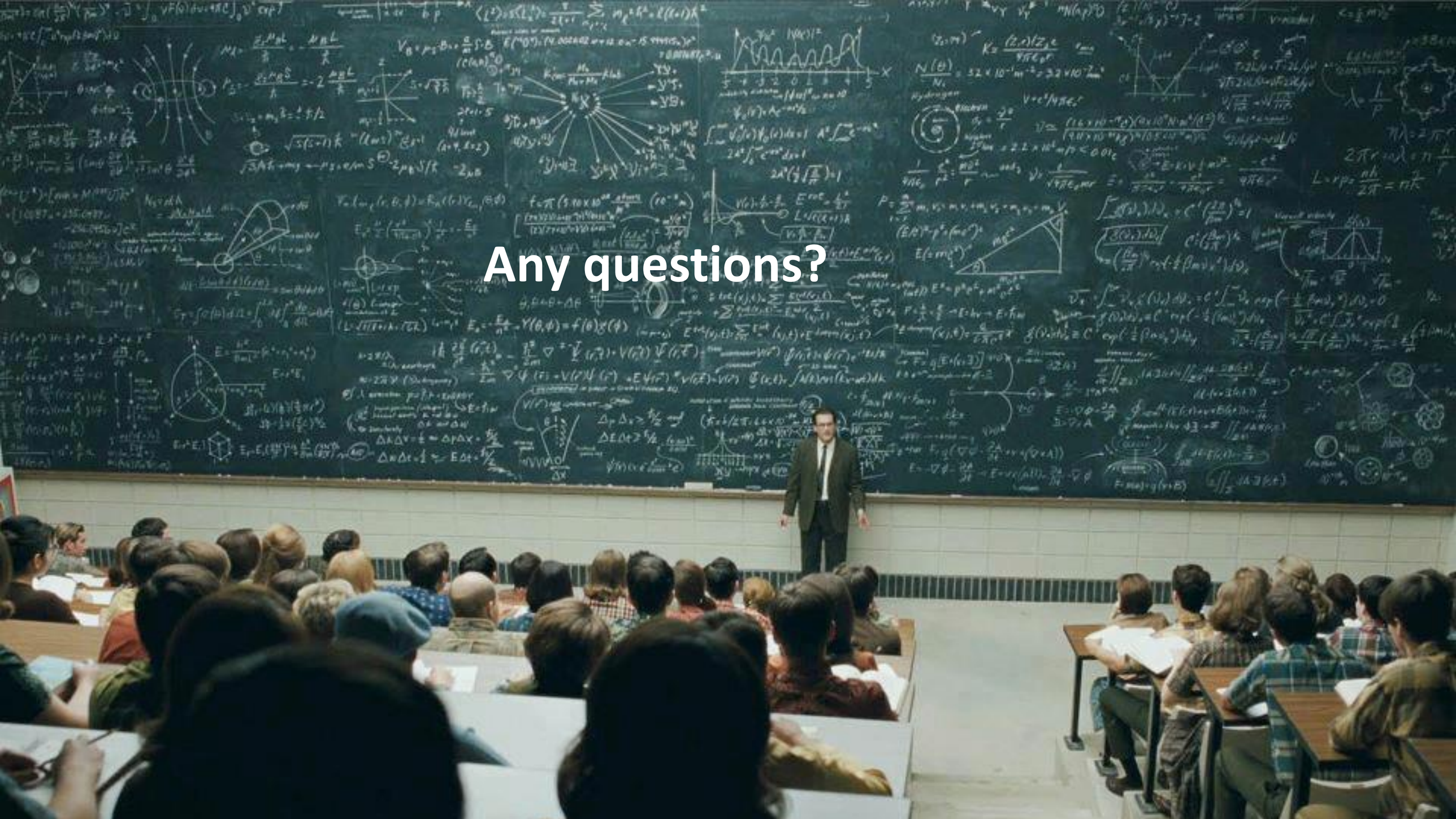
- Lectures
- Discussions
- Homework
- Lab
- Office Hours / Homework Rave
- Exams:
  - Midterm 1: TBD likely week 6-7
  - Midterm 2: TBD, likely Week 11
  - Final: Wed. 05/08/24 11:30am - 2:30PM (no conflict allowed)

Course Grading BreakDown

- Homework 10%
- Lab 20%
- Midterm 1 - 20%
- Midterm 2 - 20%
- Final - 30%

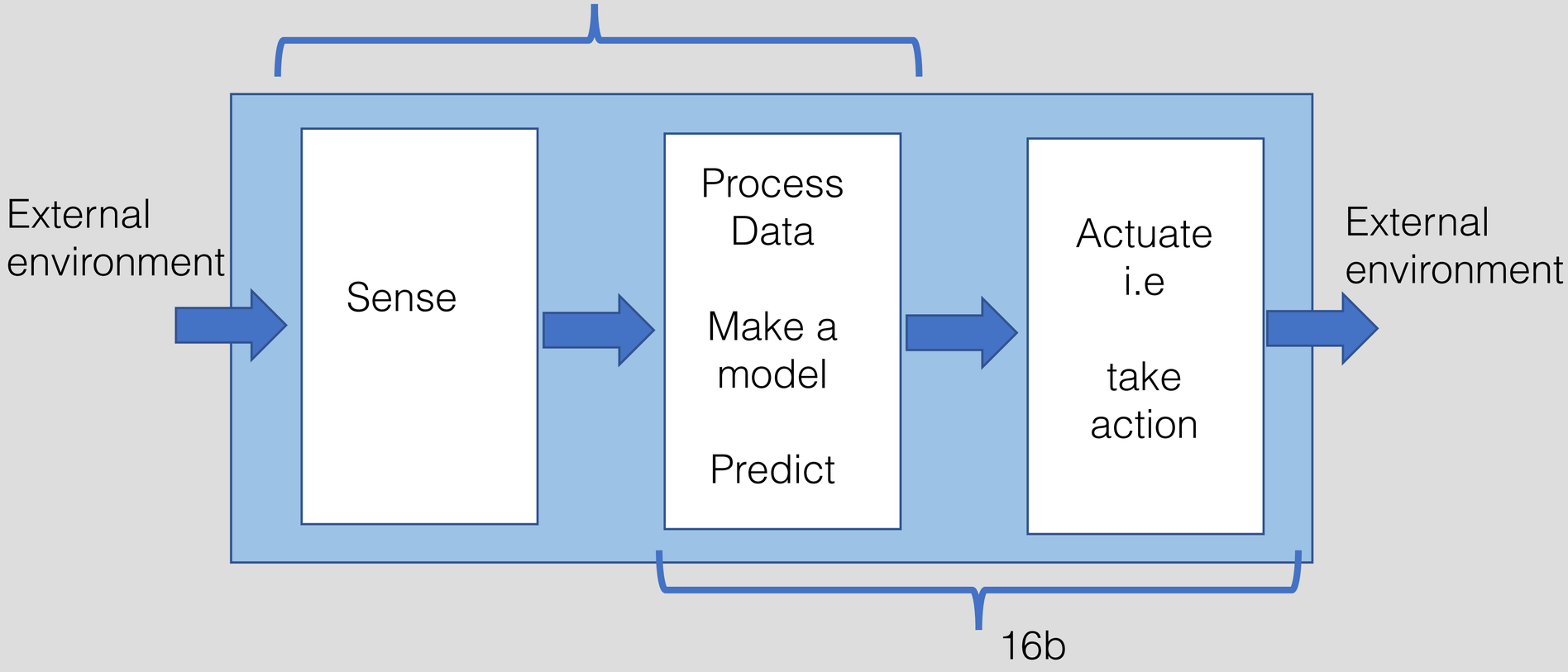
Academic Honesty

We treat all our students with utmost trust and respect, and expect students to return the same trust and respect. In EECS16B we will have ***zero-tolerance*** for academic dishonesty. There will be ***dire consequences*** for students that violate that trust and the Berkeley code of conduct. Both professors are committed to enforcing academic honesty, and ***dishonesty cases will be punished in their fullest -- no excuses or special circumstances will be considered***. Always seek help, never cheat.


Any questions?


START

Example application: self-driving cars



Learning Goals

EECS 16A

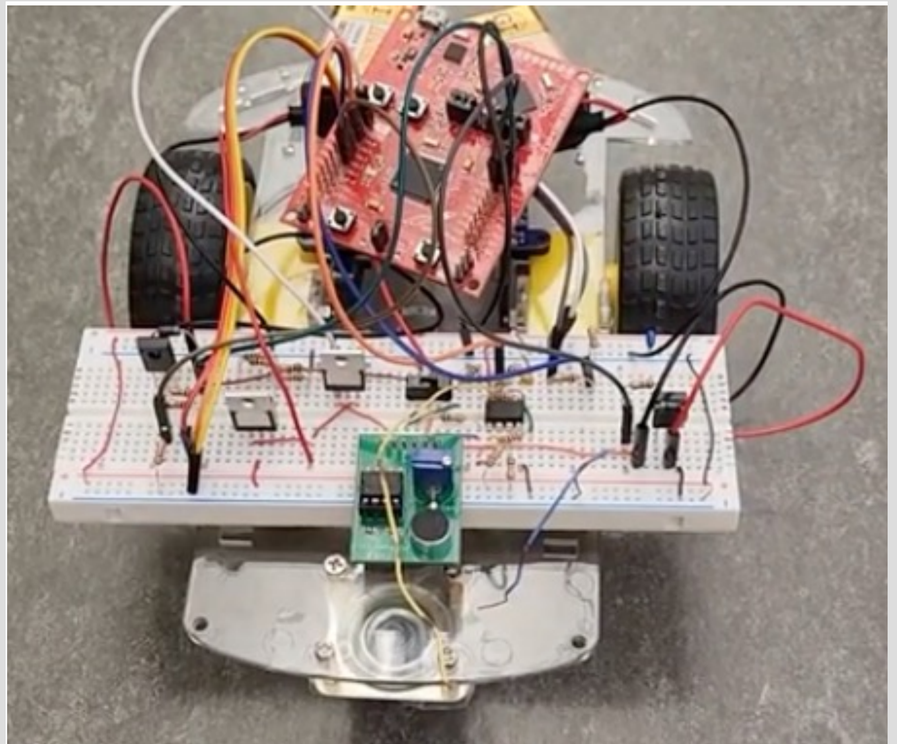
- Module 1: Introduction to systems
- Module 2: Introduction to circuits and design
- Module 3: Introduction Signal Processing and Machine Learning

EECS 16B

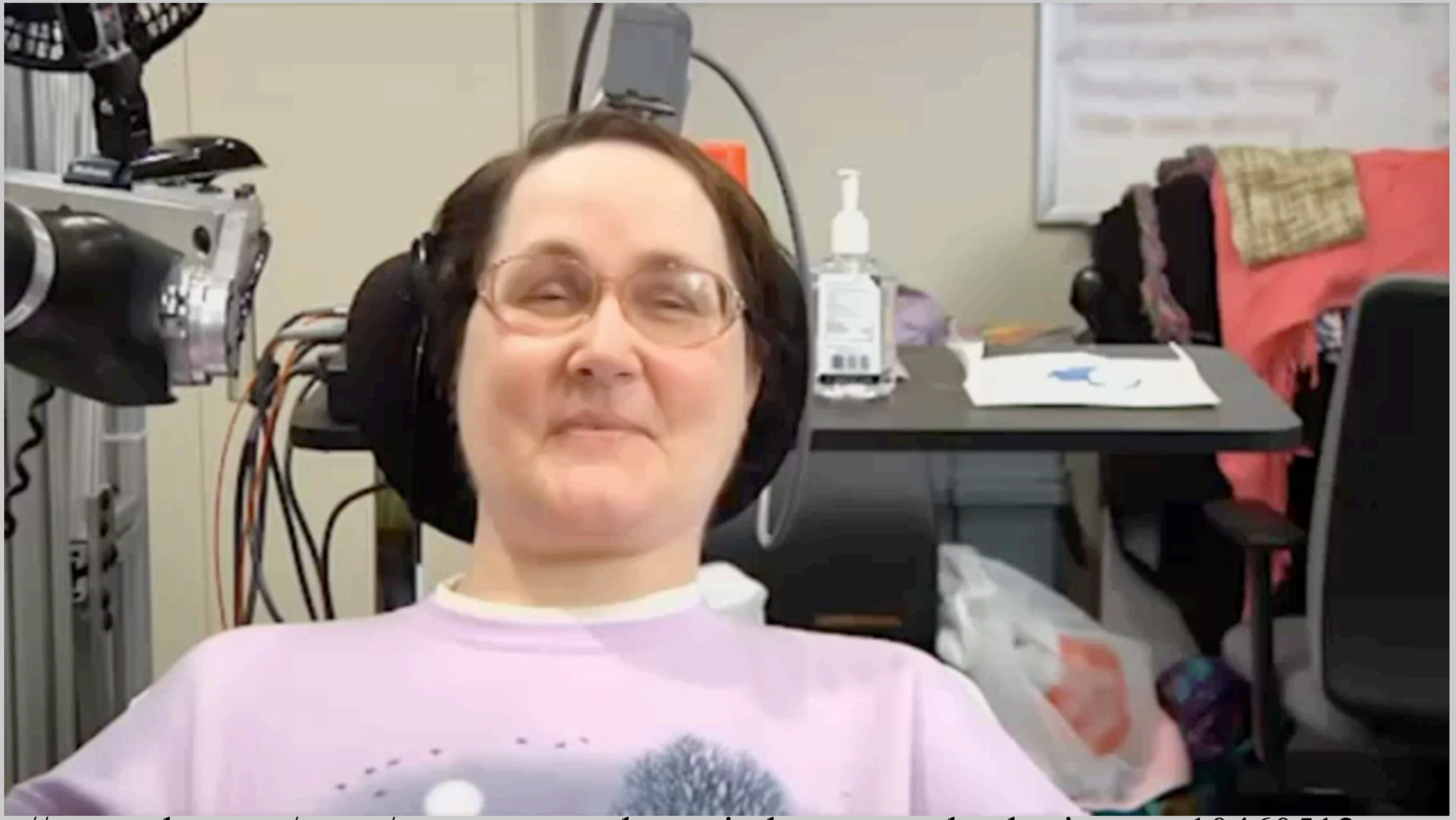
- Module 4: Advanced circuit design / analysis
  - Transients, sinusoidal inputs, filtering, Transistors and digital gates
- Module 5: Introduction to control and robotics
  - State space, feedback control, controllability
- Module 6: Introduction to data analysis, signal processing and ML
  - Advanced linear algebra, SVD, PCA

Lab

- Op-Amps
- ADC, DAC
- Motion and Speed Sensing
- Voice Sensing and Analog filtering
- System Identification
- Control
- Classification
- Integration of S1XT33N



Brain Machine Interface

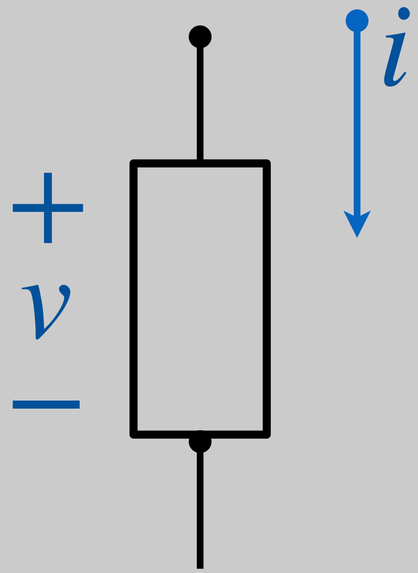


http://news.sky.com/story/woman-uses-her-mind-to-control-robotic-arm-10460512

EECS16A Assumptions:

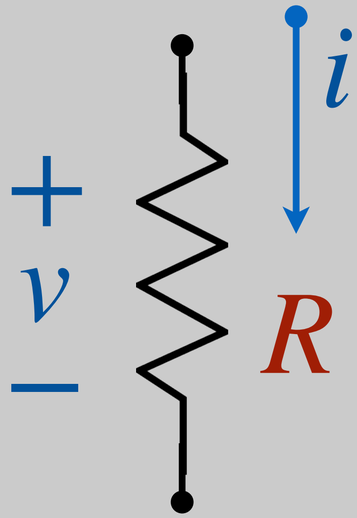
- Voltage, charge, current
- Energy, Power
- Resistors, Sources (independent + dependent)
- KCL / KVL and Nodal analysis
- Voltage / Current Dividers
- Linearity, superposition
- Norton / Thevenin equivalents
- Load / Source Resistance

Element:

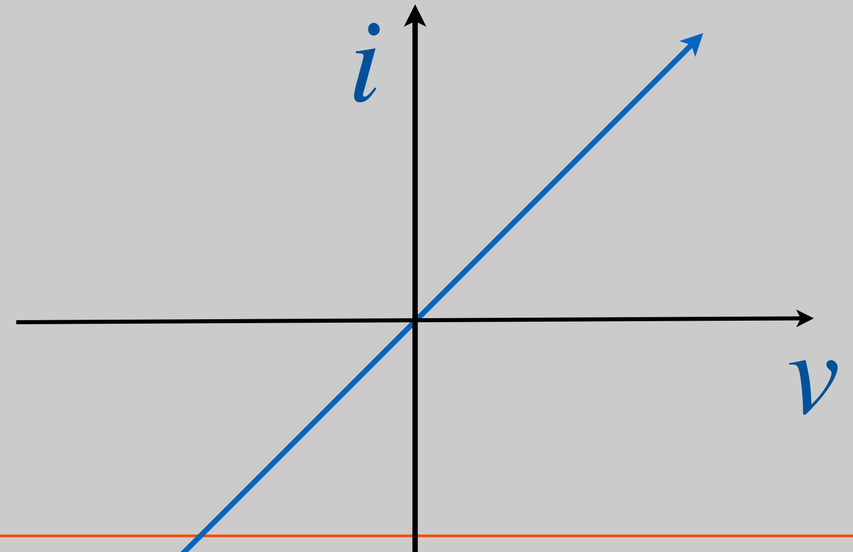


$$i[\text{Amp}]$$
$$v[\text{Volt}]$$
$$v \cdot i = P \ [Watt]$$

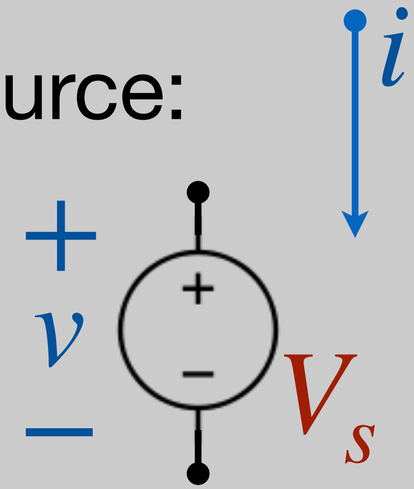
Resistor:

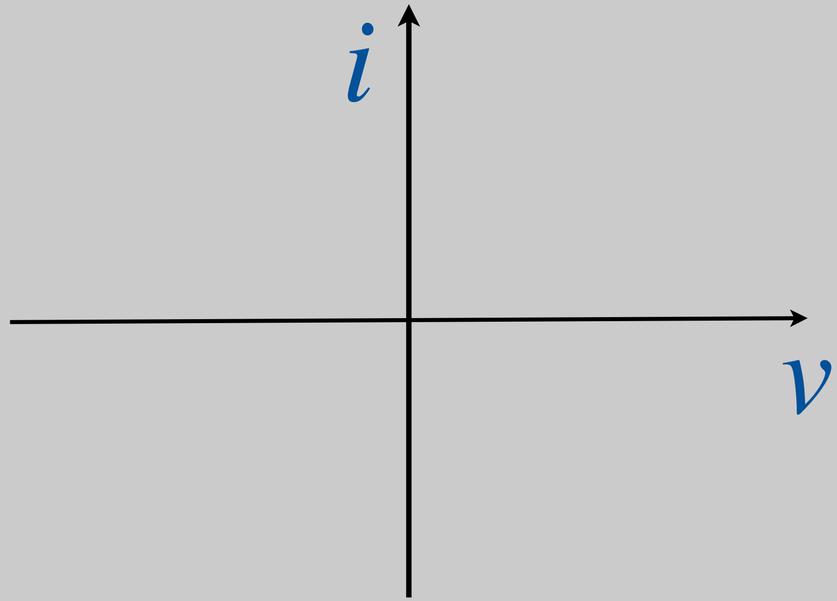


$$R[\text{Ohm}/\Omega]$$
$$v = iR$$
$$i = \frac{1}{R}v$$

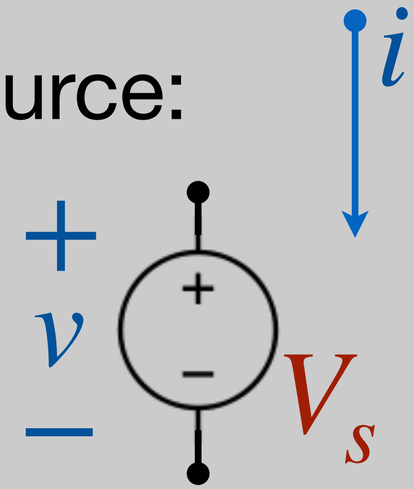


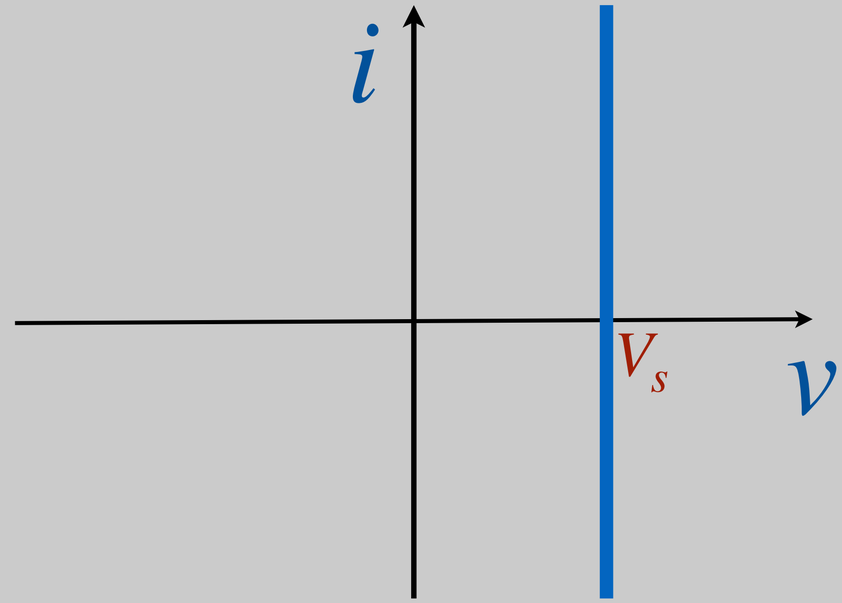
Voltage Source:



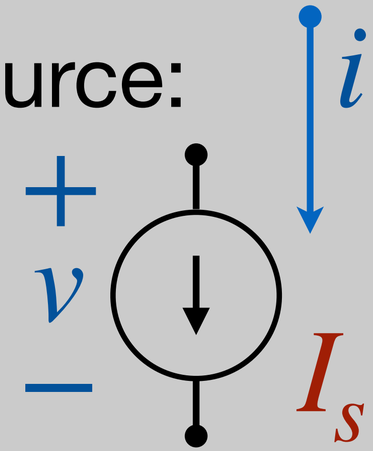


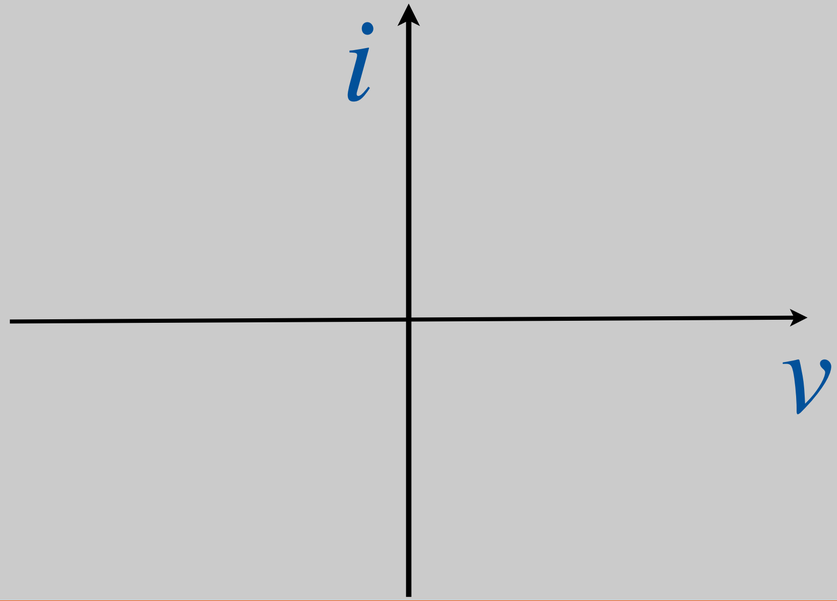
Voltage Source:



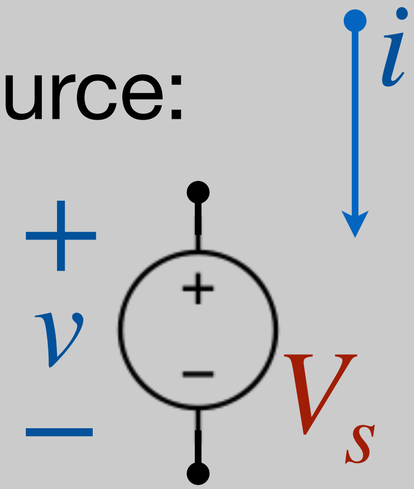


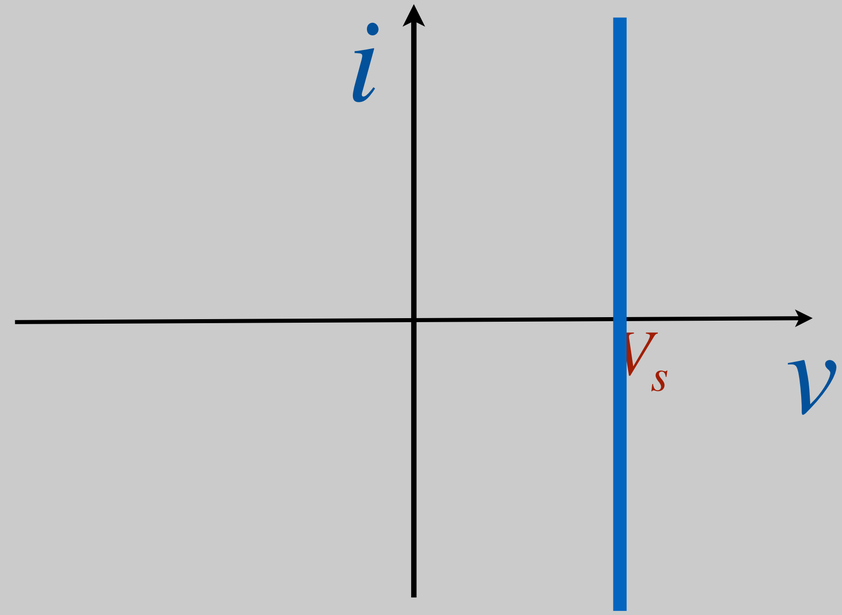
Current Source:





Voltage Source:





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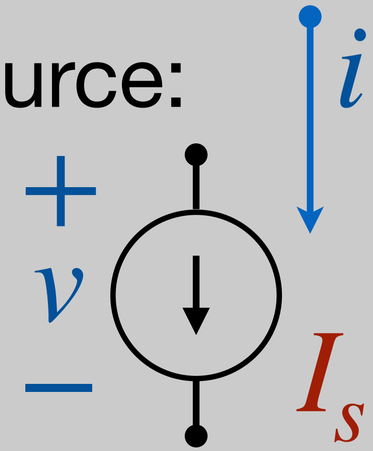
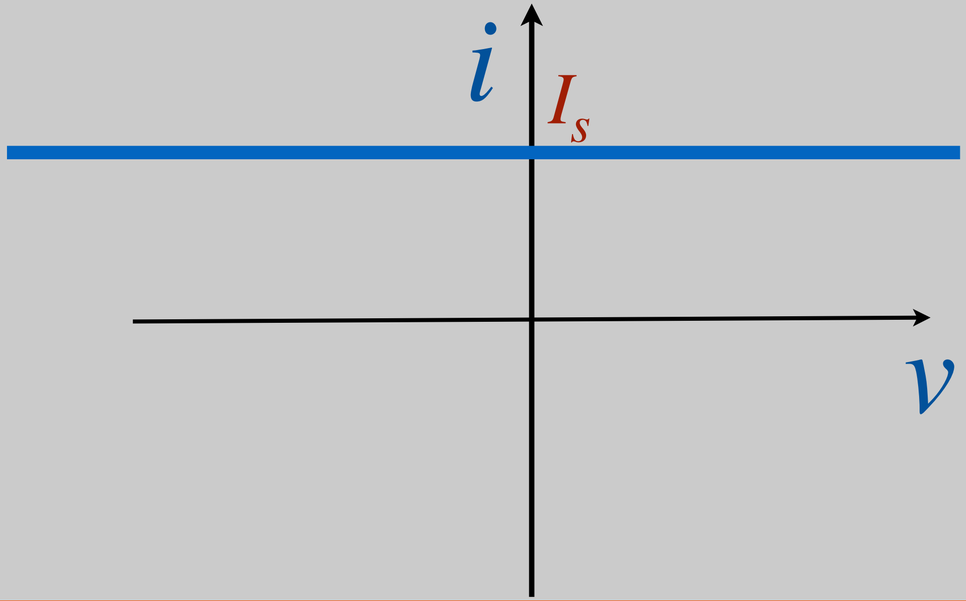
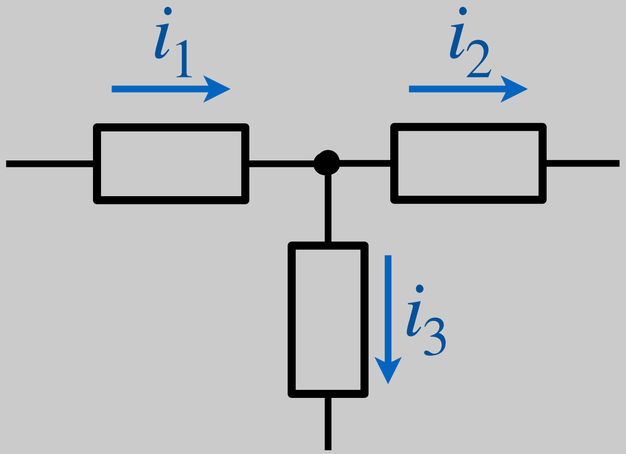




EECS16A Review

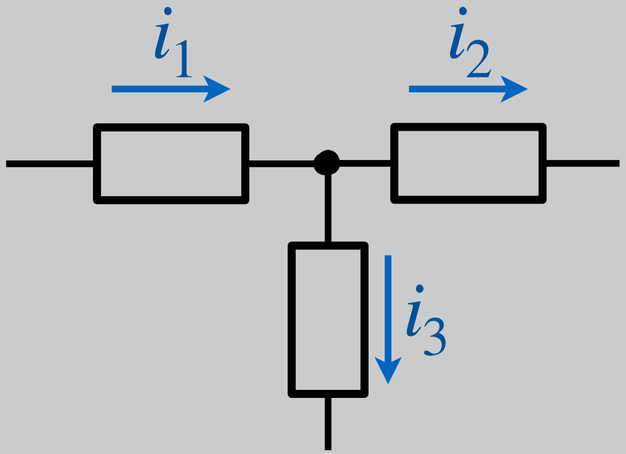
KCL:



$$\sum_N i_k = 0$$

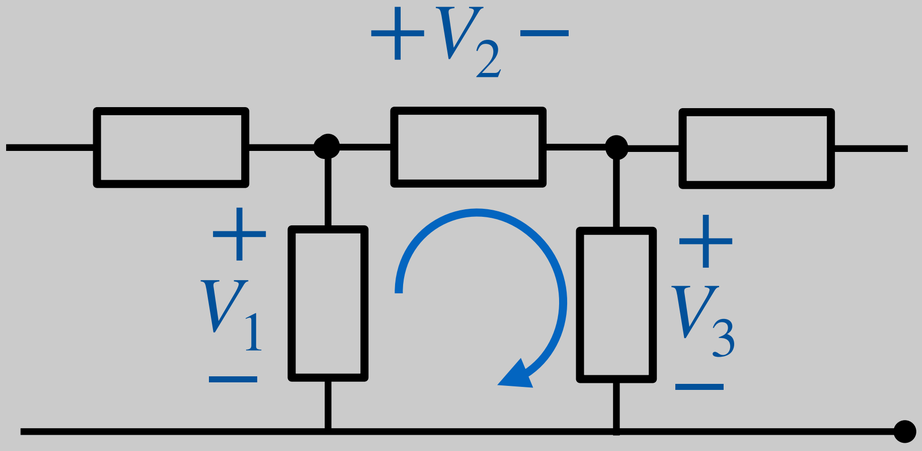
EECS16A Review

KCL:



$$\sum_N i_k = 0$$

KVL:



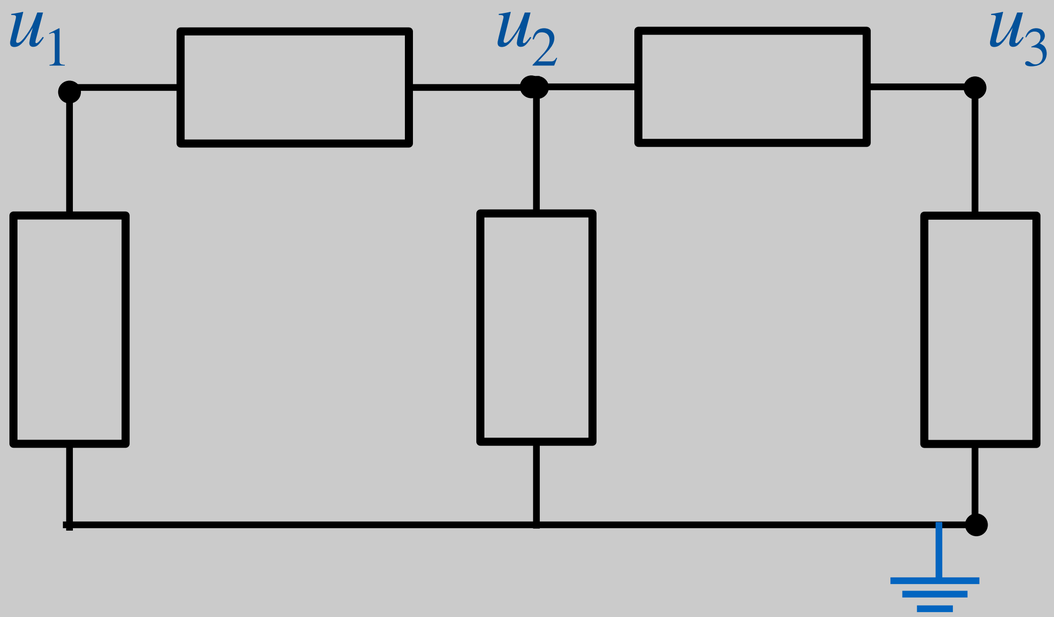
$$\sum_N V_k = 0$$

Nodal Analysis:

1. Label nodes, and assign ref
2. Label current in elements
3. Label voltages with passive sign convention

31/2. Identify unknowns, “Cheat” with shortcuts

4. Set up KCL eqn, with I-V relationship
5. Solve



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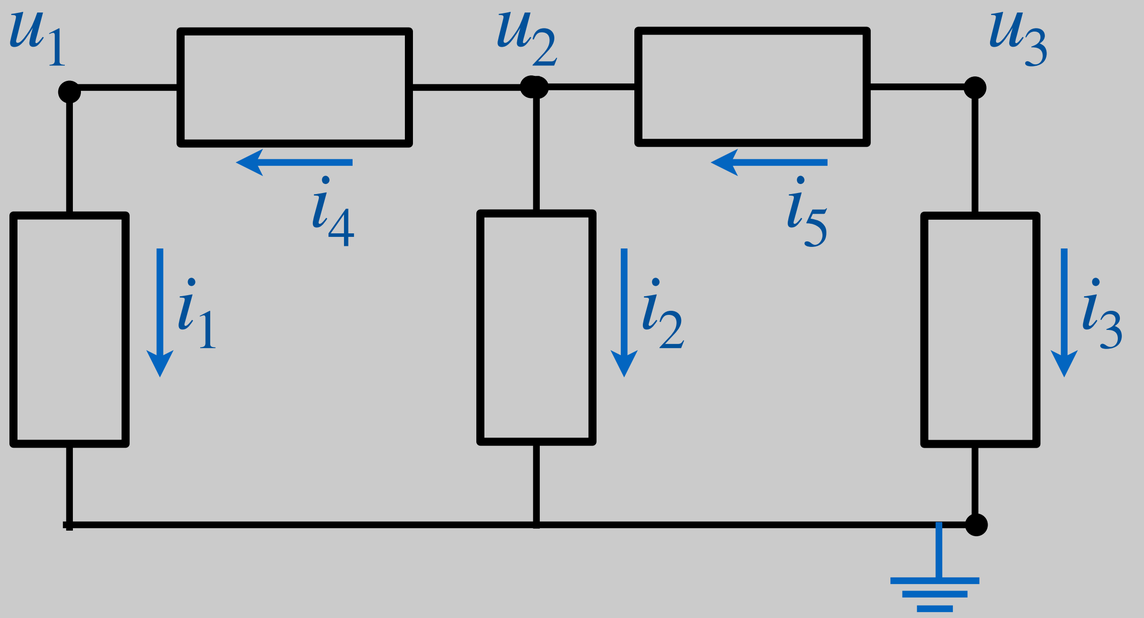

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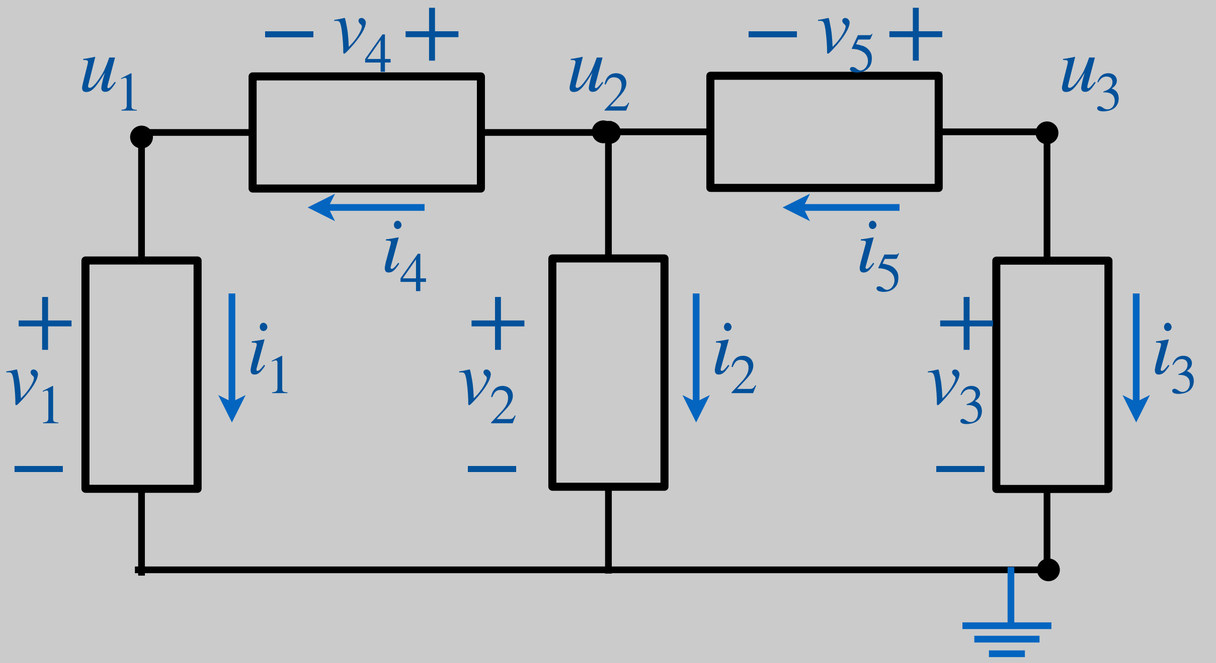

Nodal Analysis:

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2. Label current in elements
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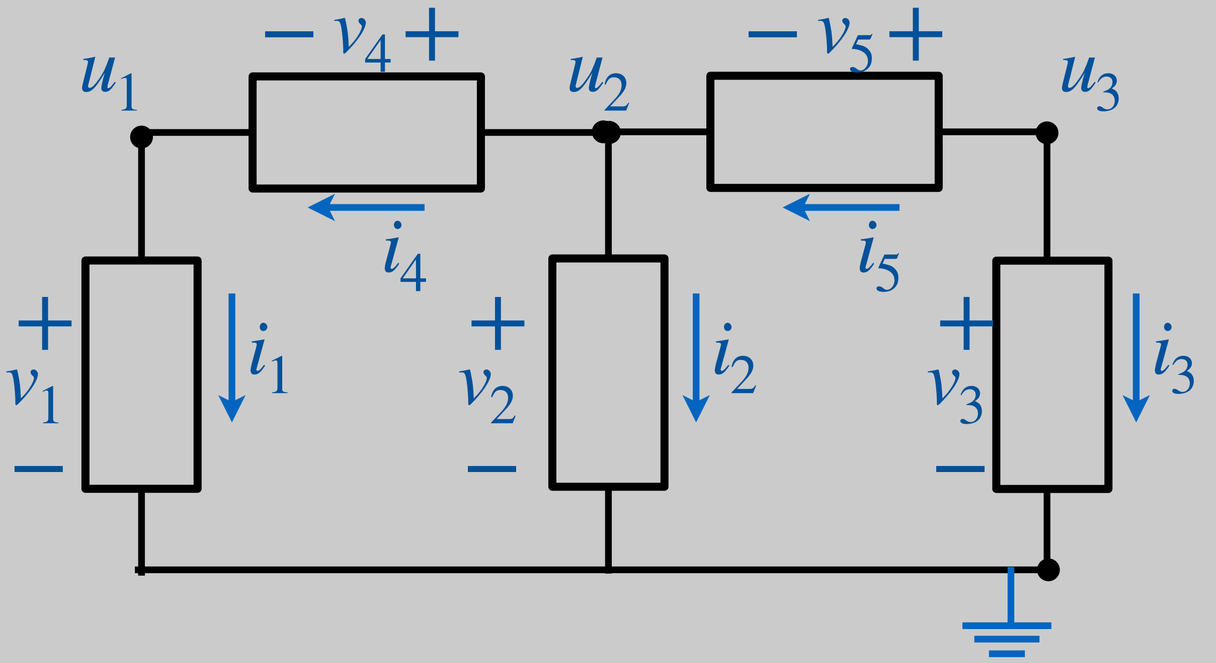
31/2. Identify unknowns, “Cheat” with shortcuts

4. Set up KCL eqn, with I-V relationship
5. Solve

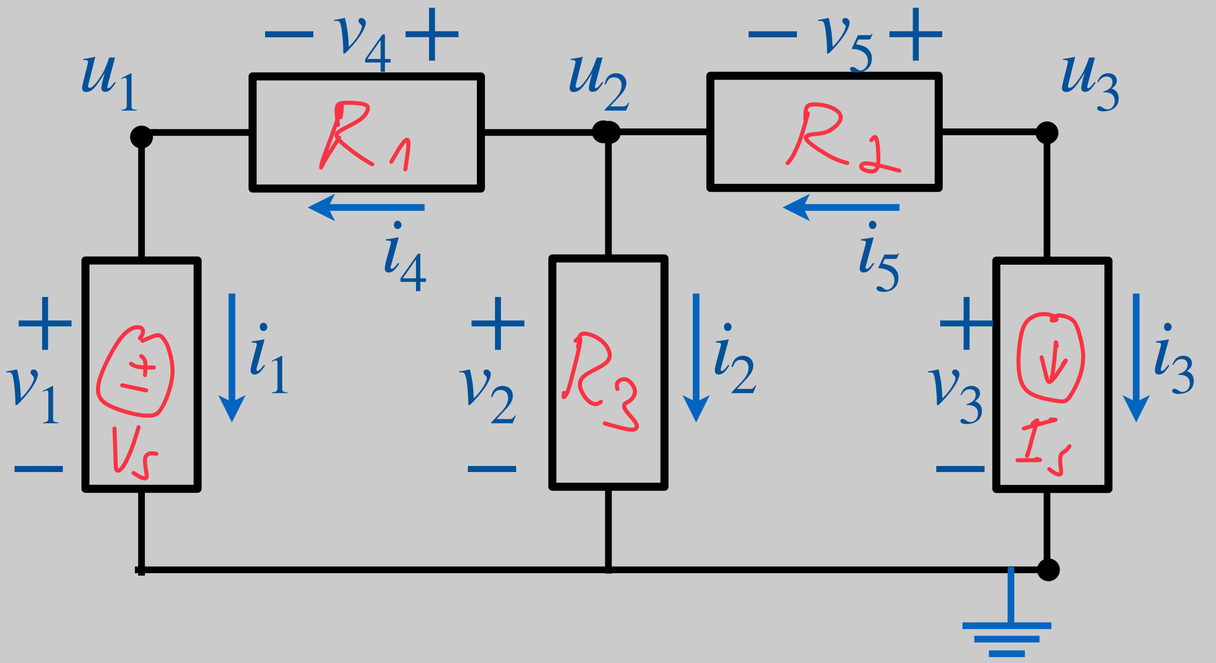


Nodal Analysis:

1. Label nodes, and assign ref
2. Label current in elements
3. Label voltages with passive sign convention

31/2. Identify unknowns, “Cheat” with shortcuts

4. Set up KCL eqn, with I-V relationship
5. Solve

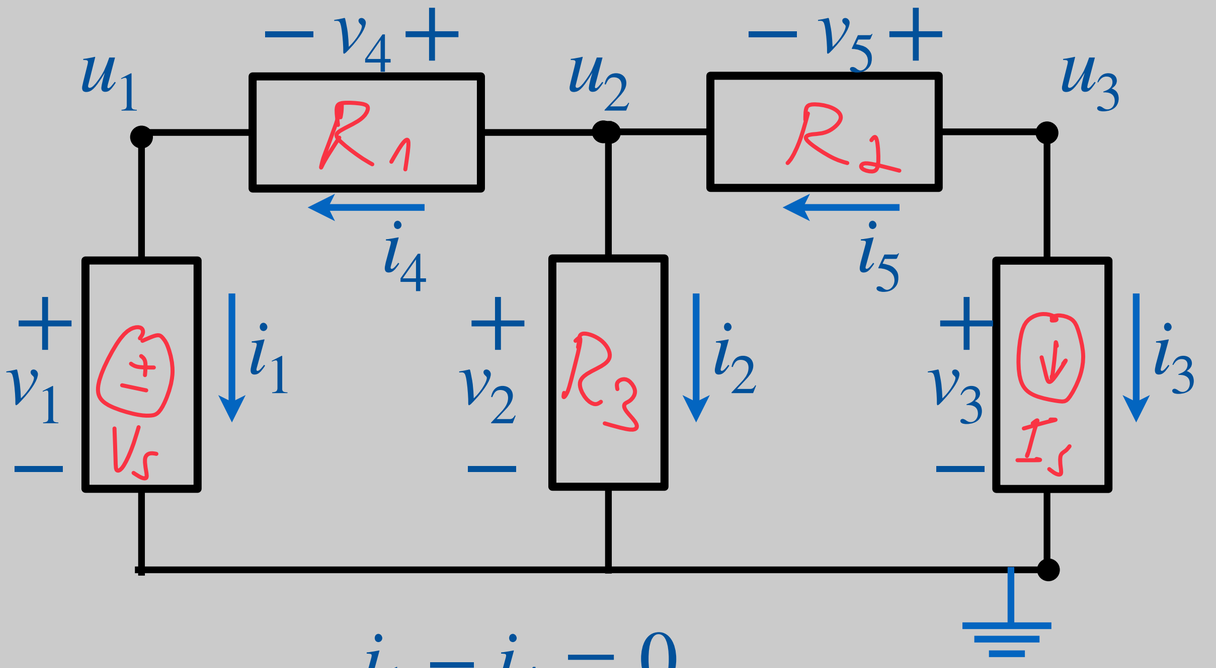


Nodal Analysis:

1. Label nodes, and assign ref
2. Label current in elements
3. Label voltages with passive sign convention

31/2. Identify unknowns, “Cheat” with shortcuts

4. Set up KCL eqn, with I-V relationship
5. Solve (for node potentials)



$$i_1 - i_4 = 0$$

$$i_2 + i_4 - i_5 = 0$$

$$i_5 + I_s = 0$$

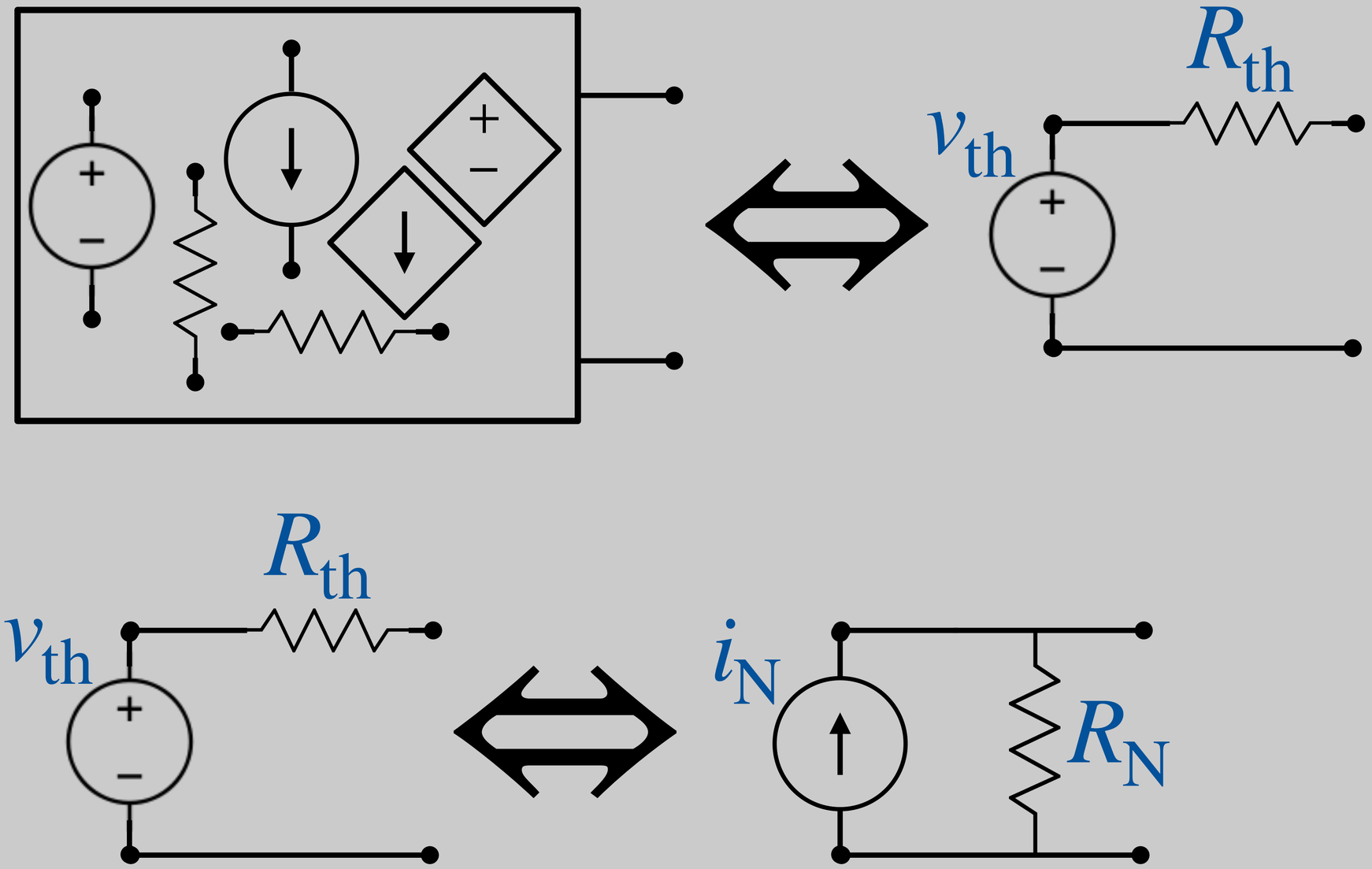
$$u_1 = V_s$$

$$u_2 - u_1 = R_1 i_1$$

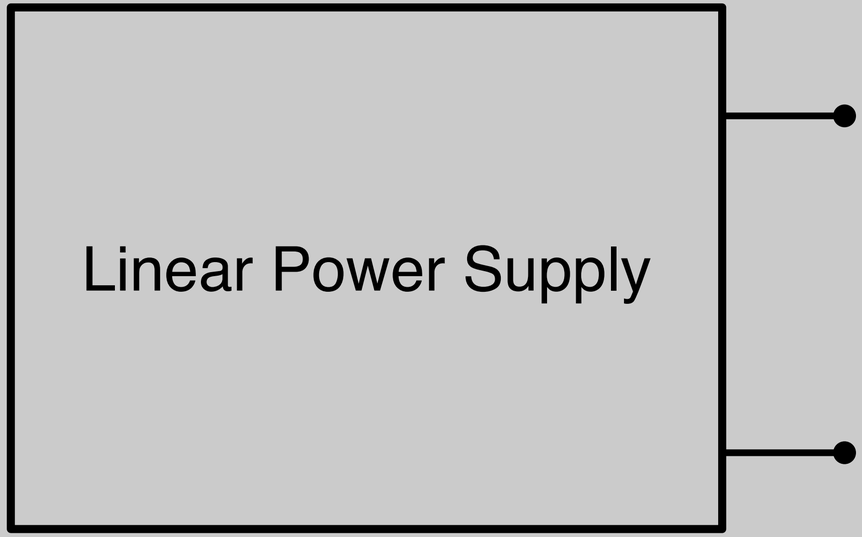
$$u_2 = R_3 i_2$$

$$u_3 - u_2 = R_2 i_5$$

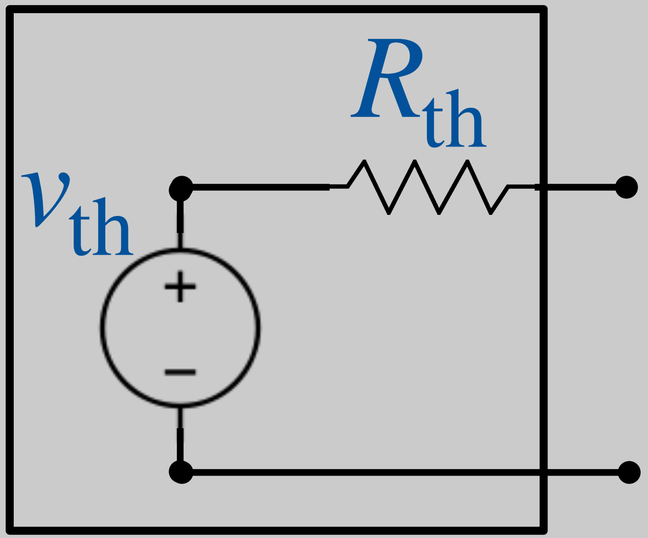
Equivalents:



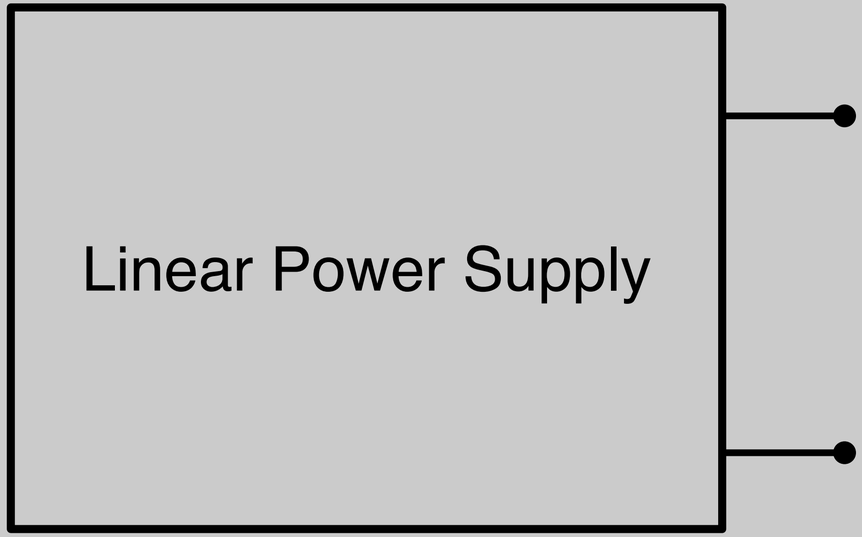
Equivalents:



Q: How to measure v_{th}, R_{th} ?



Equivalents:



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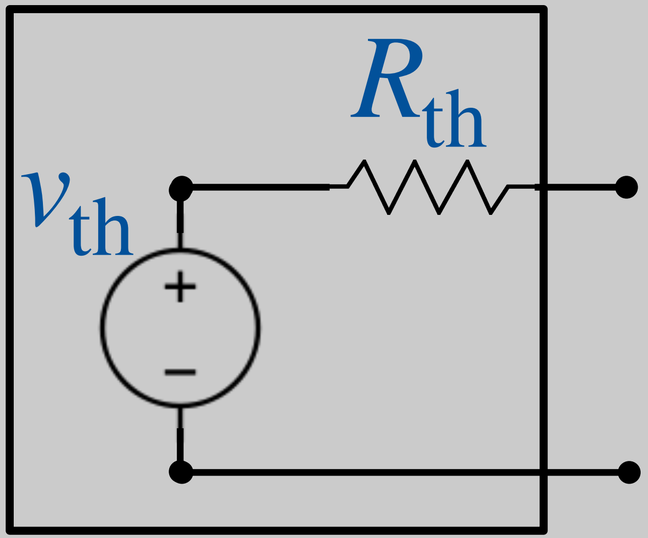
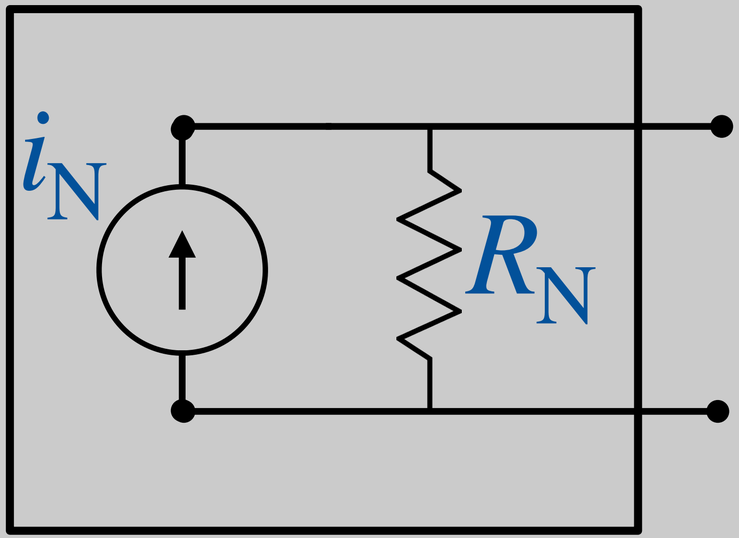
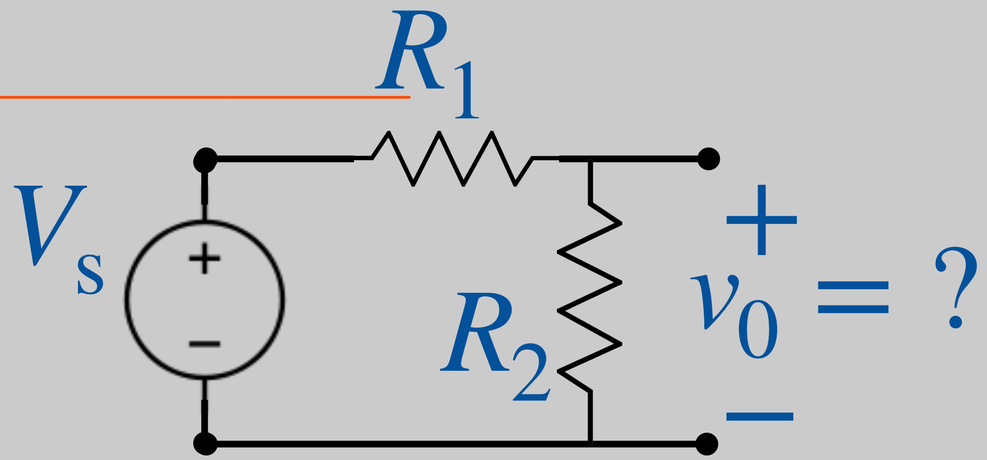


Q: What about i_{N}, R_{N} ?



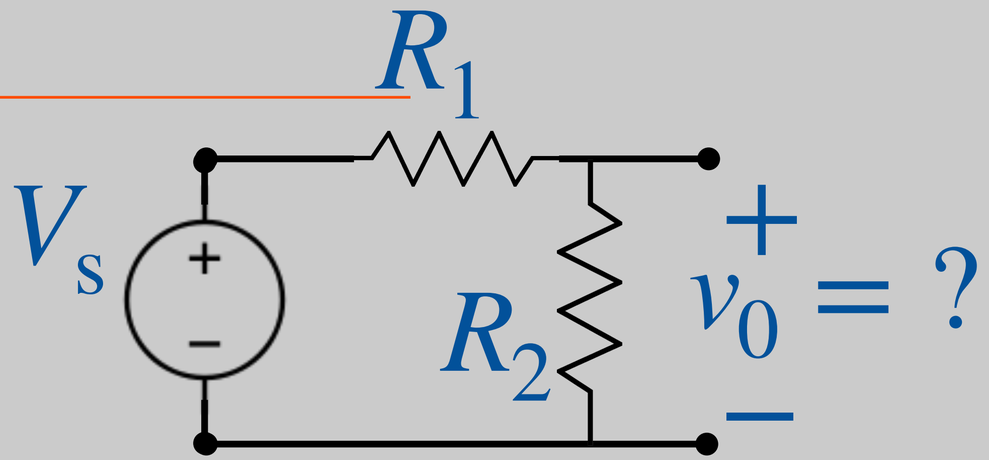
Q: How to solve?



A1: Voltage divider!

$$v_0 = \frac{R_2}{R_1 + R_2} V_s$$

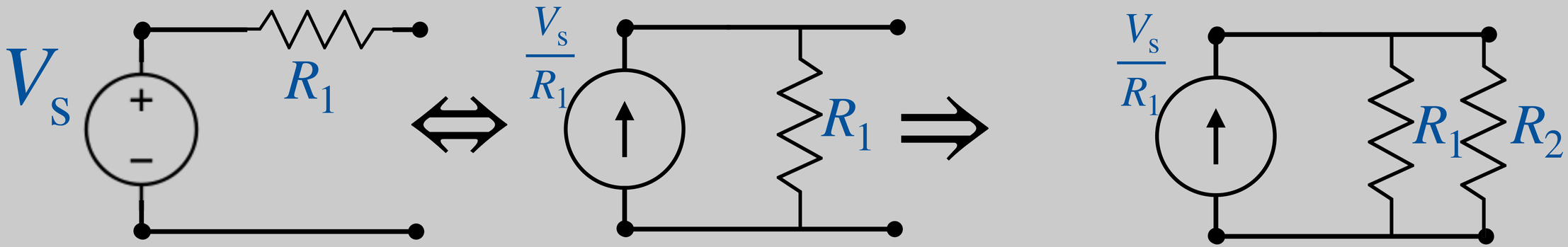
Q: How to solve?



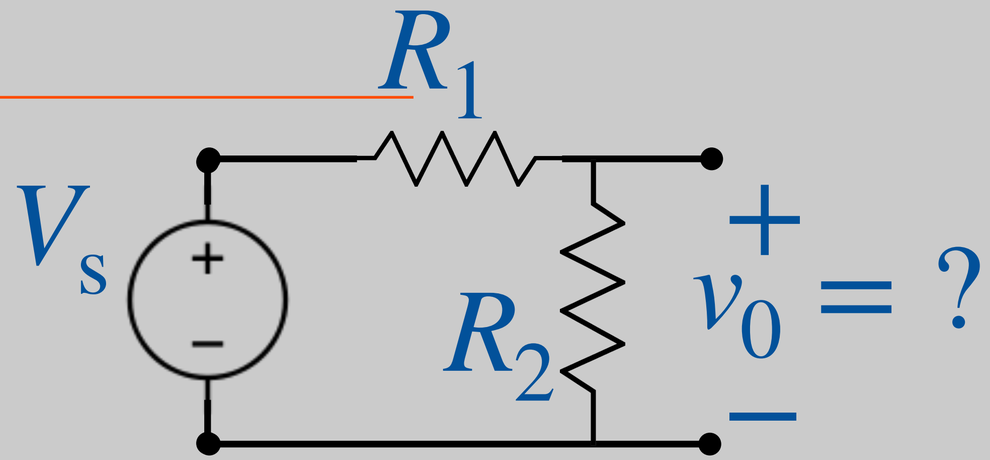
A1: Voltage divider!

$$v_0 = \frac{R_2}{R_1 + R_2} V_s$$

A2: Thevenin/Norton Eq.



Q: How to solve?



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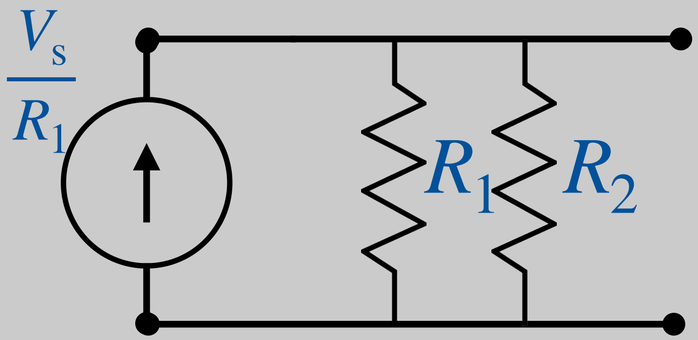
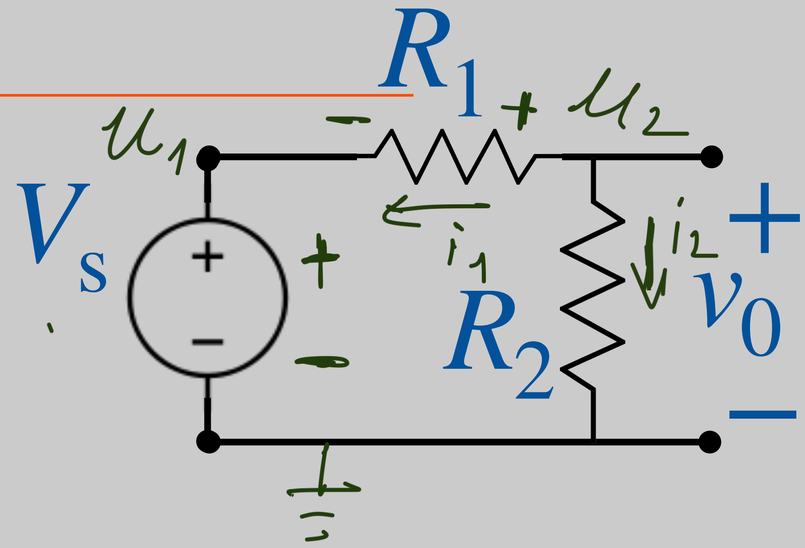


$$v_0 = \frac{V_s}{R_1} \cdot \frac{R_1 R_2}{R_1 + R2}$$

Q: How to solve?



A3: Node analysis

$$u_1 = V_s$$

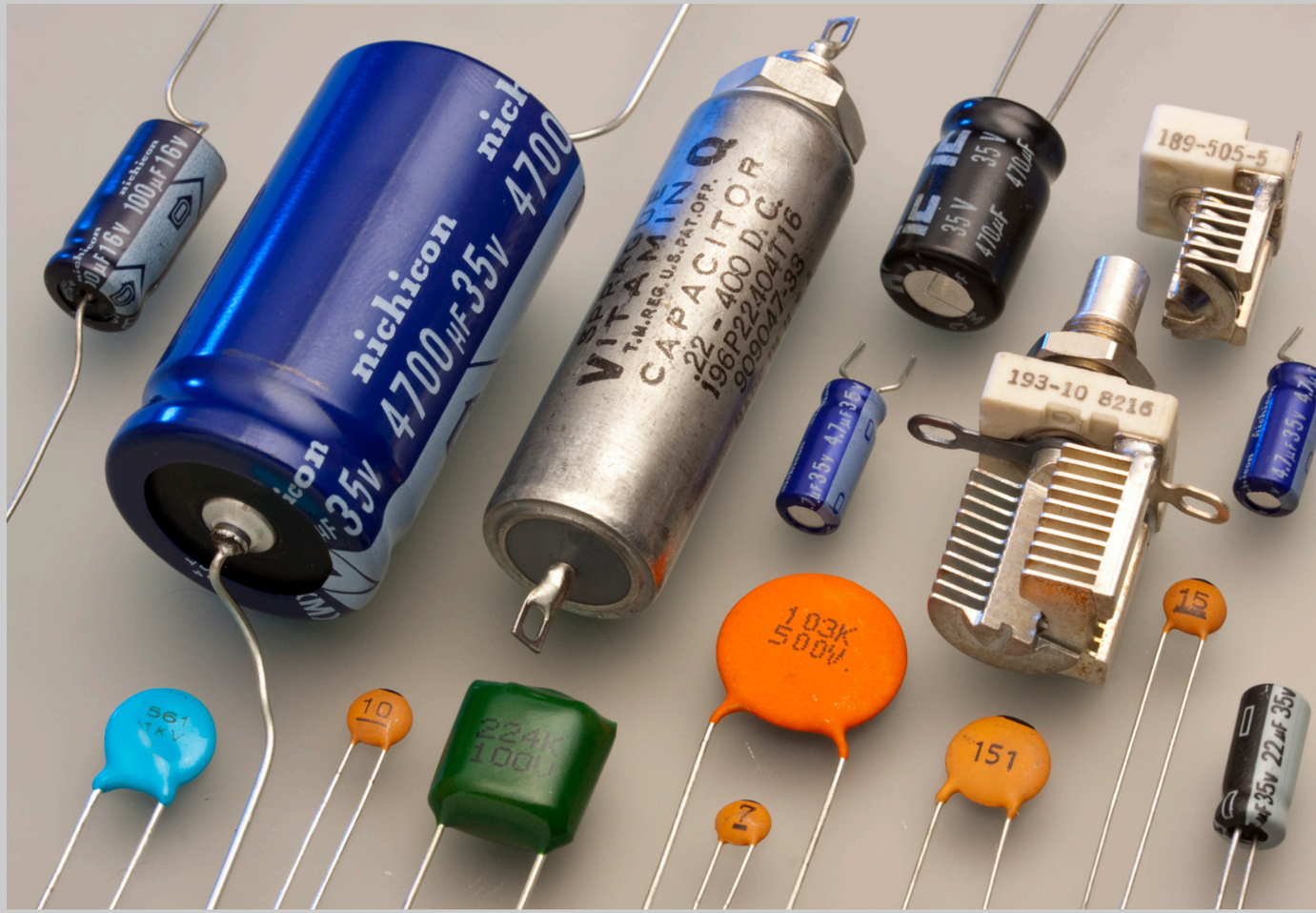
$$i_1 + i_2 = \frac{u_2 - V_s}{R_1} + \frac{u_2}{R_2} = 0$$

$$u_2 = \frac{R_2}{R_1 + R_2} V_s = v_0$$

Capacitance:

- Capacity to store charge (energy)
- Units: Farad [F]
- Components typically μF (10^{-6}), nF (10^{-9}), or pF (10^{-12})
- Parasitic capacitance pF (10^{-12})
- Power, super-caps, energy storage mF (10^{-3}) to 10s of F

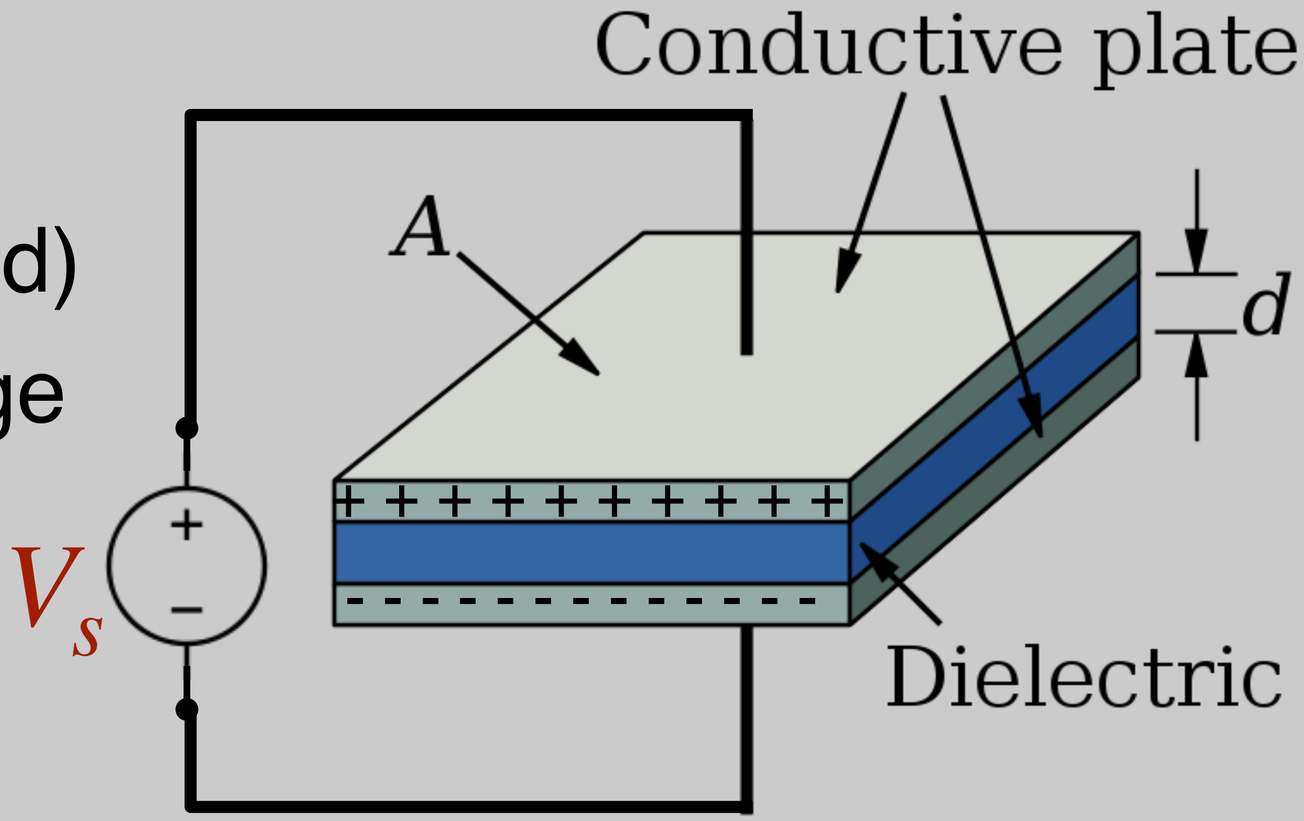
Capacitors:


nichicon
4700μF 35V
VITAMIN Q
CAPACITOR
22 - 400 D.C.
193-10 8216
189-505-5
103K
500V
224K
1000
151
561
1KV
10
7
15

Capacitors:

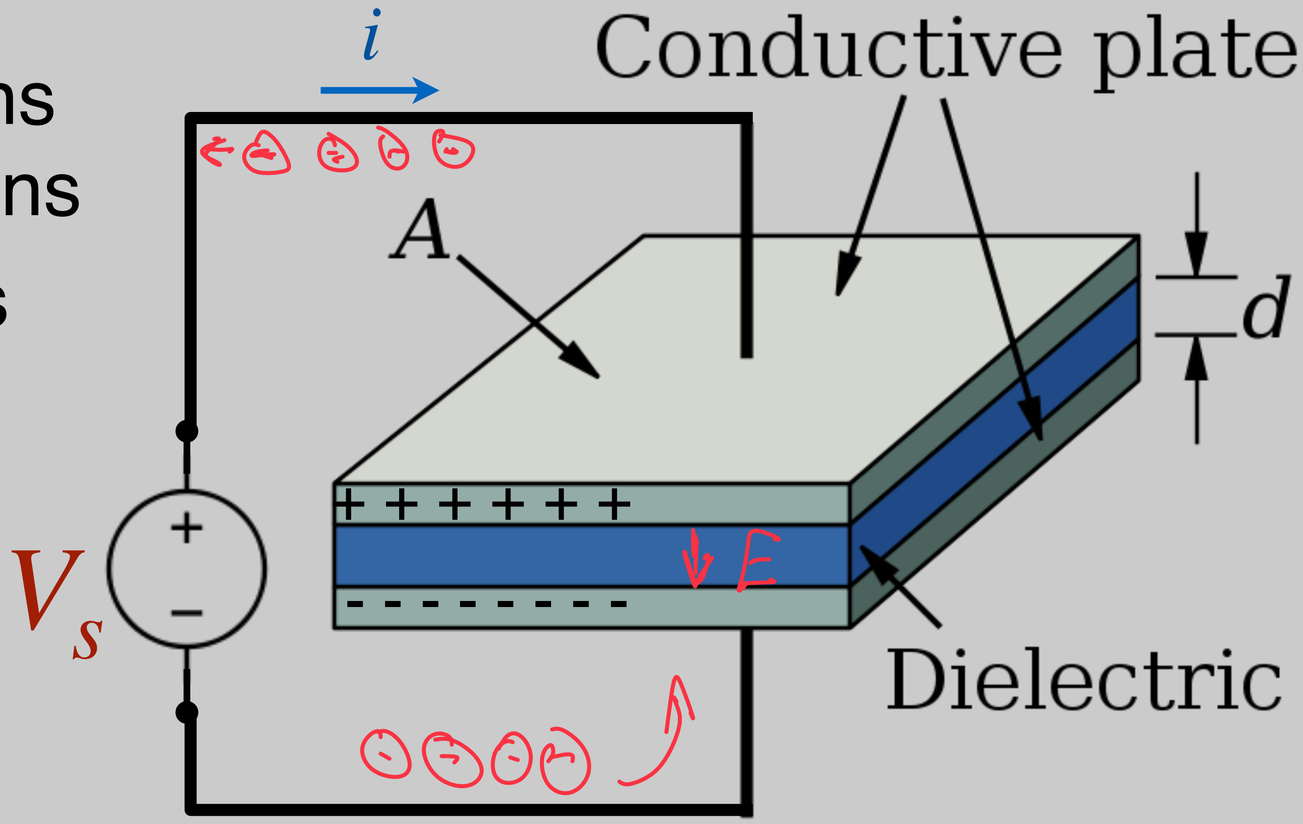
- Two conductors, separated by insulator
- Stores charge (q)
- Stores energy (in Electric field)
- Charge proportional to voltage

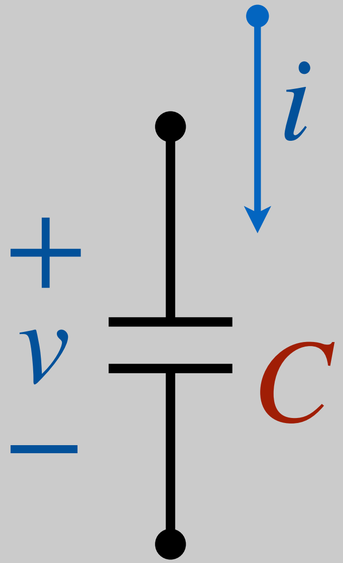
$$q = CV_c$$



- Changing voltage will cause charge to flow
- Electrons flow opposite to current
- Top plate will be depleting electrons
  Bottom plate accumulating electrons
- Electric field forms between plates
- Flow stop when potentials match

Does not flow through cap!!!!!





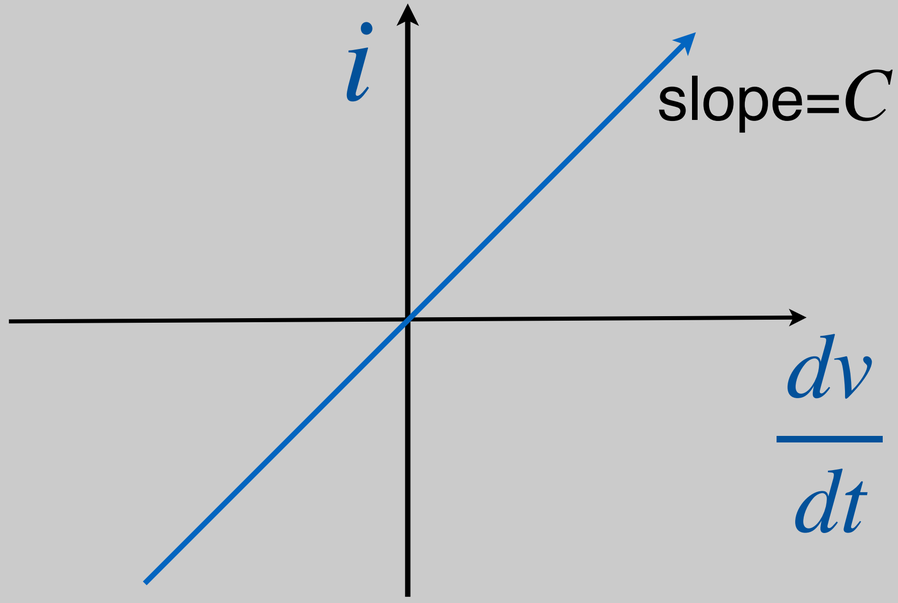
$$q = Cv$$

Time varying voltage:

$$i = \frac{dq}{dt} = C\frac{dv}{dt}$$

$$v(t) = \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau + v(t_0)$$

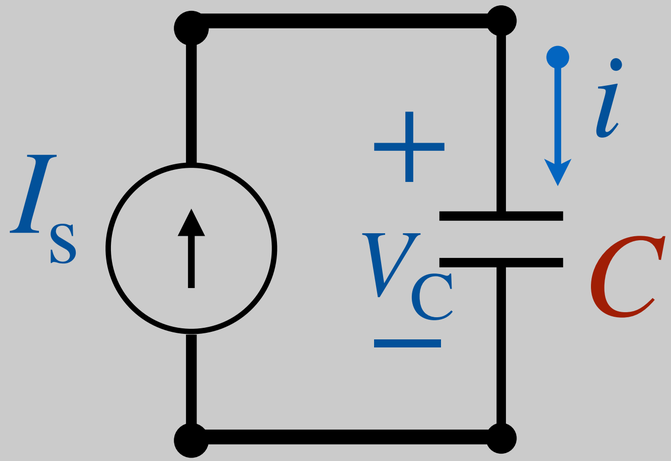
Memory!!!

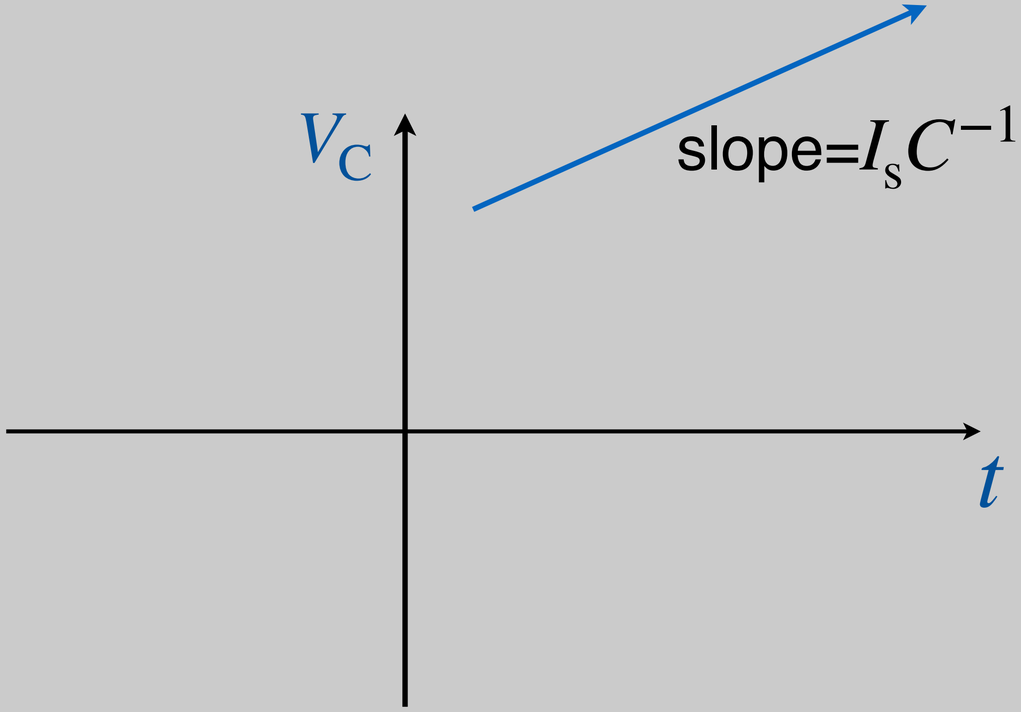


$$V_c(t) = \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau + V_c(t_0)$$

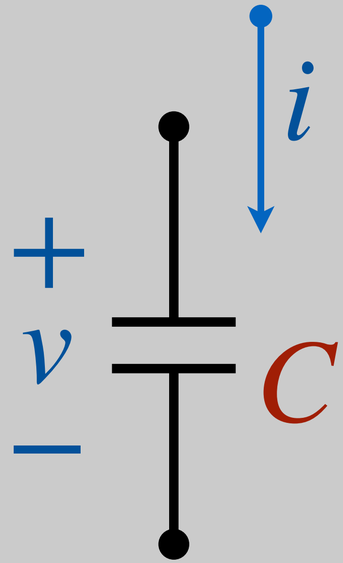
$$i(t) = I_s$$

$$\Rightarrow \quad V_c(t) = \frac{I_s}{C}t + V_c(t_0)$$





- Capacitors store energy in the electric field
- Power $p(t)$:



$$p(t) = v(t) \cdot i(t)$$

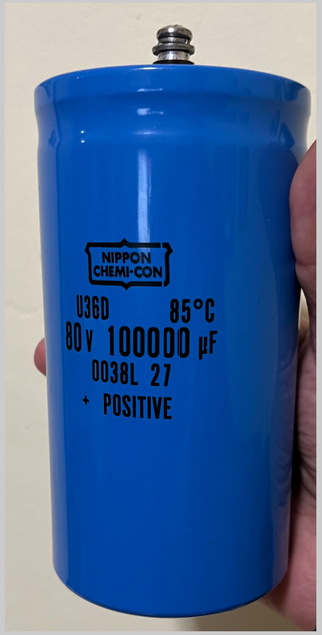
$$= v(t)\frac{Cdv(t)}{dt}$$

$$p(t)dt = Cv(t)dv(t)$$

- Energy w is integration of power:

$$w = C\int_0^V vdv = C\frac{V^2}{2}$$

Electrolytic cap



Voltage:80V

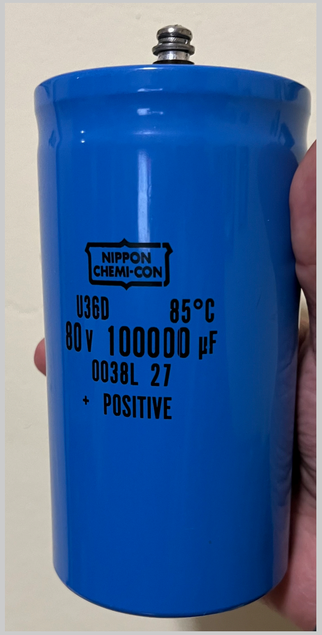
Capacitance: 0.1F

Weight: 850gr

$$w = \frac{1}{2}CV^2 = \frac{1}{2}0.1 \cdot 80^2 = 320[J]$$

$$0.375 \ [\text{kJ/Kg}]$$

Electrolytic cap



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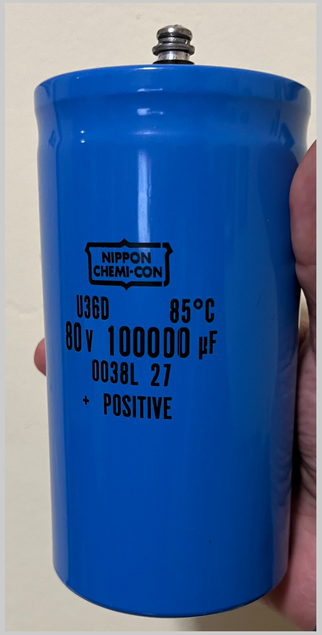
Super-Capacitor

Voltage:3V
Capacitance: 5F
Weight: 2.1gr

$$w = \frac{1}{2}5 \cdot 3^2 = 22.5[J]$$

$$10.7 \ [\text{kJ/Kg}]$$

Electrolytic cap



Voltage:80V
Capacitance: 0.1F
Weight: 850gr

$$w = \frac{1}{2}CV^2 = \frac{1}{2}0.1 \cdot 80^2 = 320[J]$$

$$0.375\ [\text{kJ/Kg}]$$

Super-Capacitor

Voltage:3V
Capacitance: 5F
Weight: 2.1gr

$$w = \frac{1}{2}5 \cdot 3^2 = 22.5[J]$$

$$10.7\ [\text{kJ/Kg}]$$

LiPo Battery

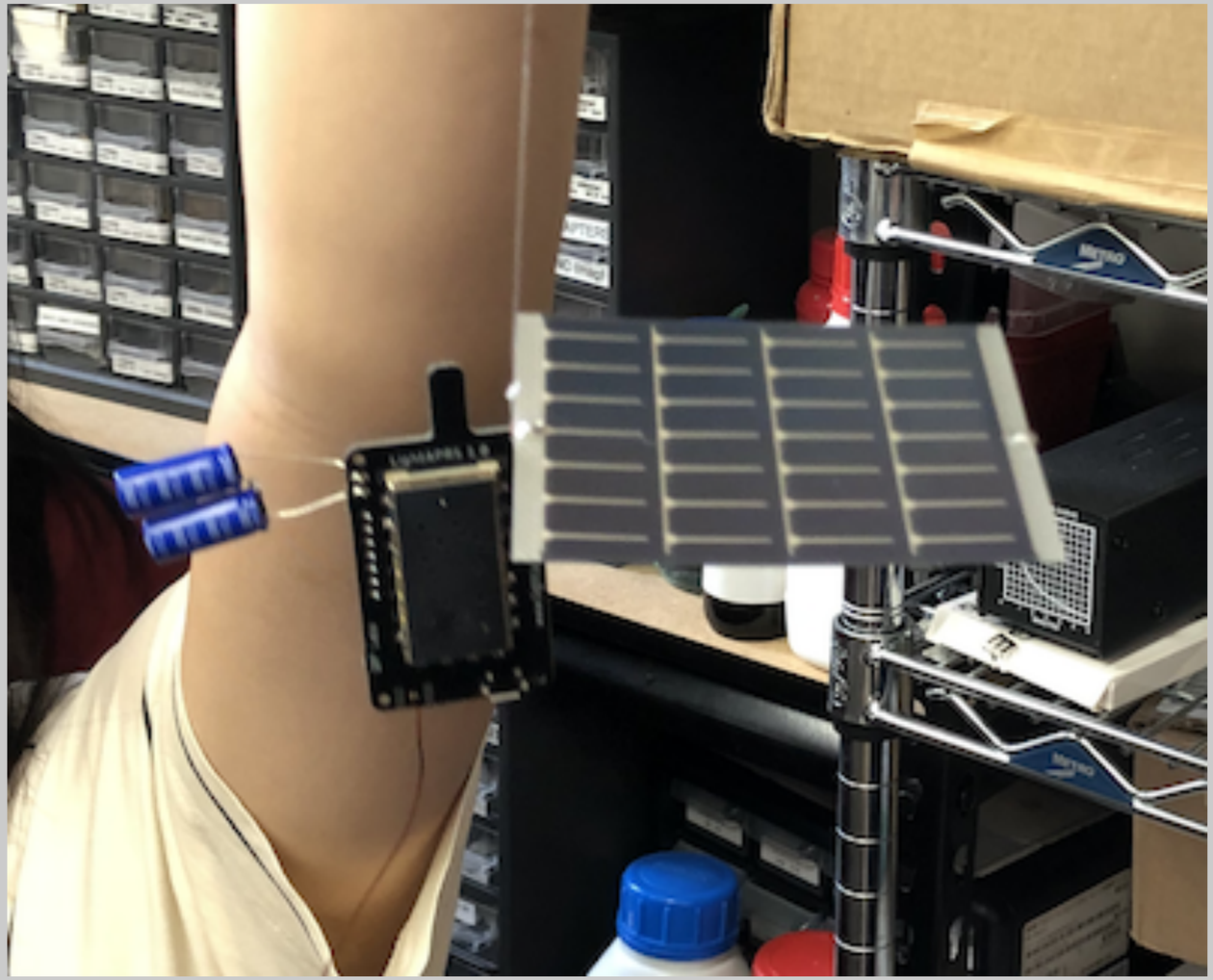
Voltage:15.2V
2800mA/h
Weight: 320gr

$$w = Ah \cdot V \cdot 3600$$

$$w = 2.8 \cdot 15.2 \cdot 3600 = 153.2[\text{kJ}]$$

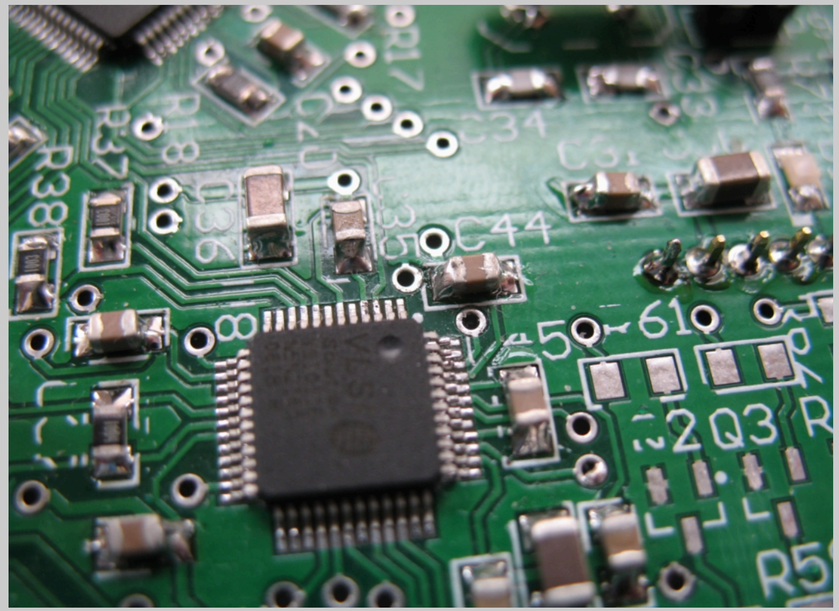
$$478.75\ [\text{kJ/Kg}]$$

Supercap for low-power devices

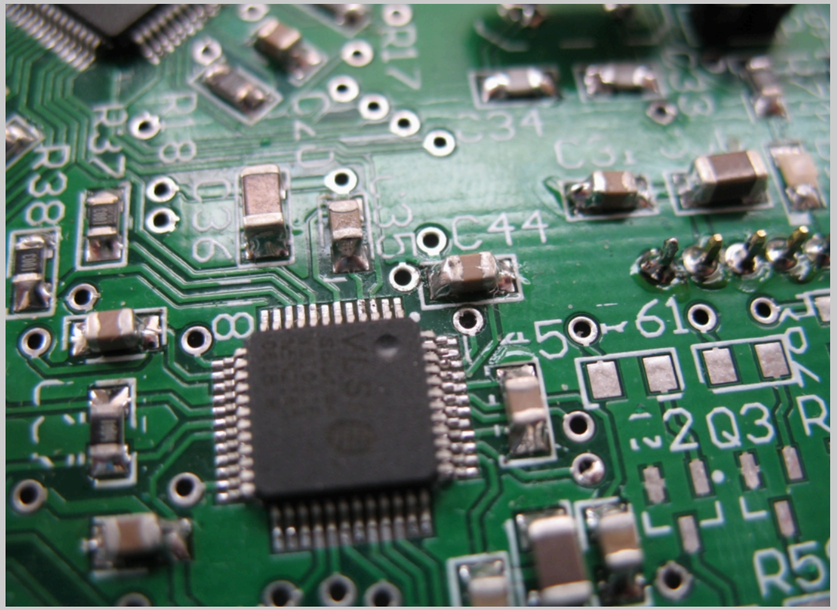


EECS16A Review

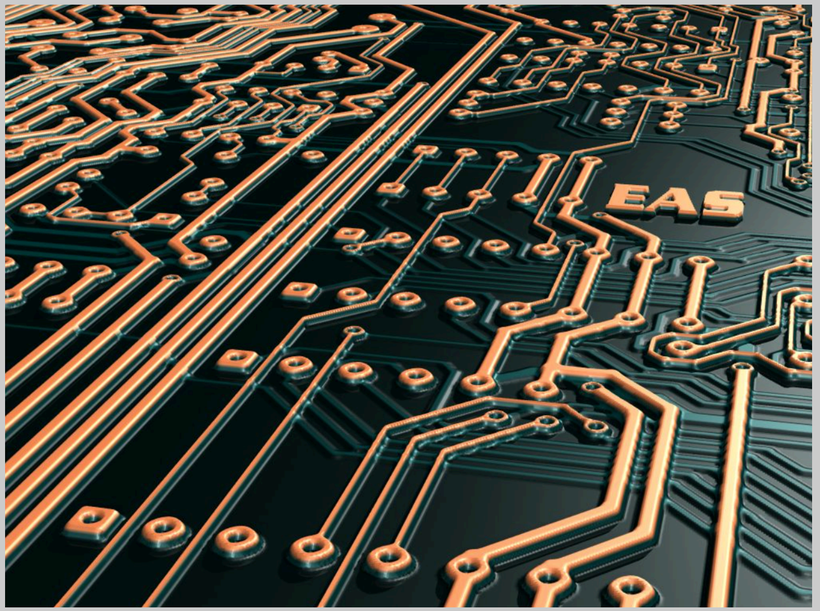
- Intentional capacitors:
  - Essential components in modern electronics
  - Energy storage, filtering, memory



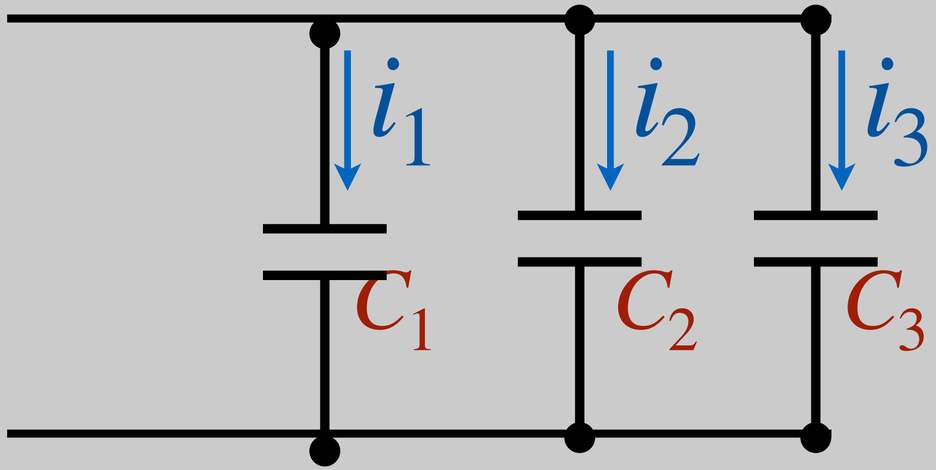
- Intentional capacitors:
  - Essential components in modern electronics
  - Energy storage, filtering, memory



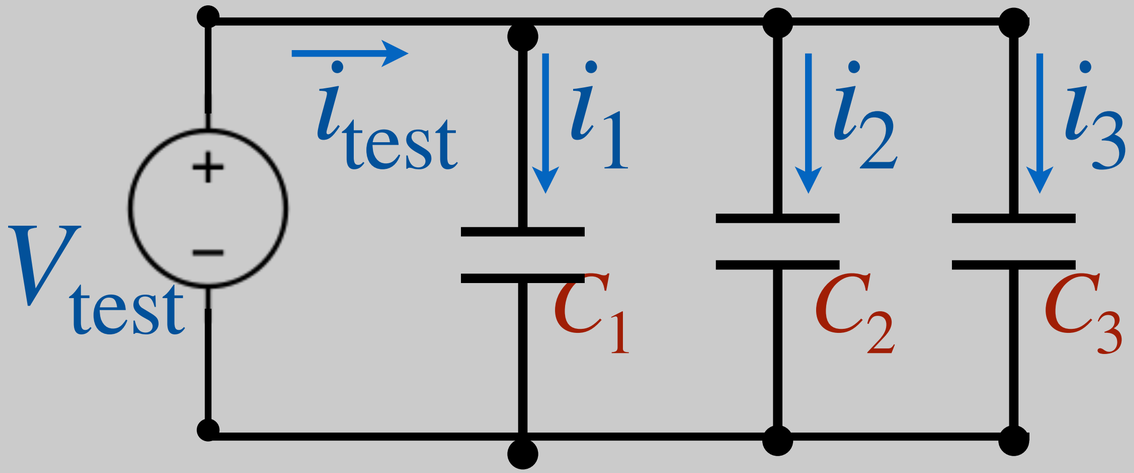
- Unintentional (parasitic)
  - Any close traces with dielectric between becomes a cap!



Parallel Capacitors:



Parallel Capacitors:

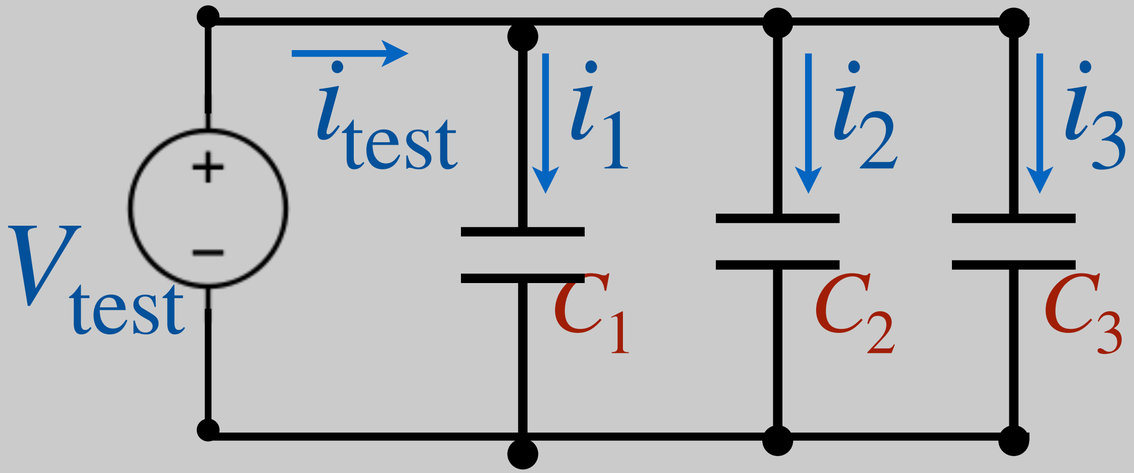


$$i_{\text{test}} = i_1 + i_2 + i_3$$

$$C_{\text{eq}}\frac{dV_{\text{test}}}{dt} = C_1\frac{dV_{\text{test}}}{dt} + C_2\frac{dV_{\text{test}}}{dt} + C_3\frac{dV_{\text{test}}}{dt}$$

$$C_{\text{eq}} = C_1 + C_2 + C_3$$

Parallel Capacitors:



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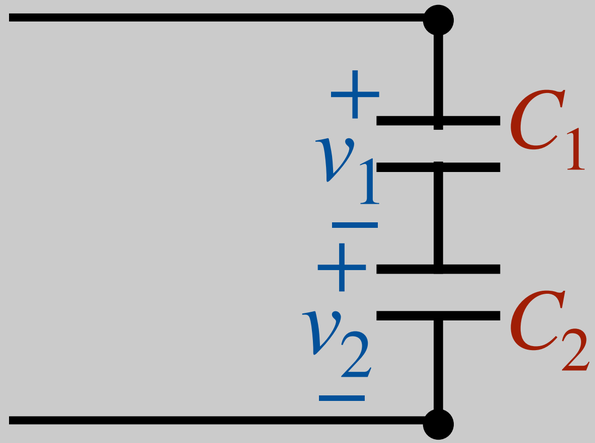
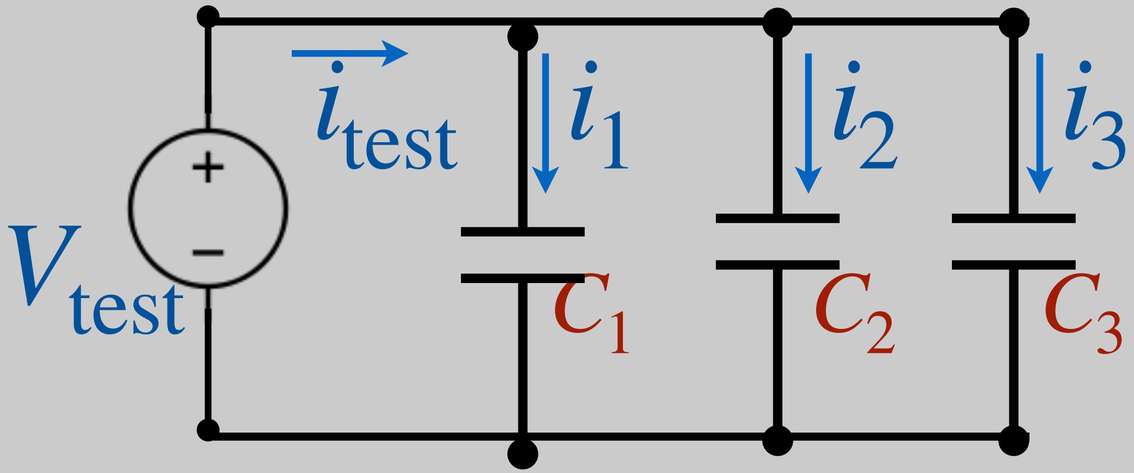
$$C_{\text{eq}} = C_1 + C_2 + C_3$$

Series Capacitors:



Parallel Capacitors:



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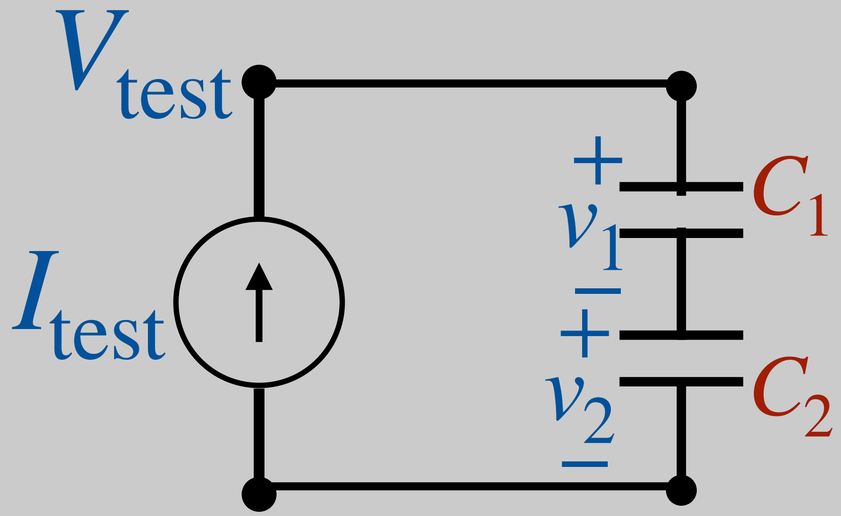
Series Capacitors:



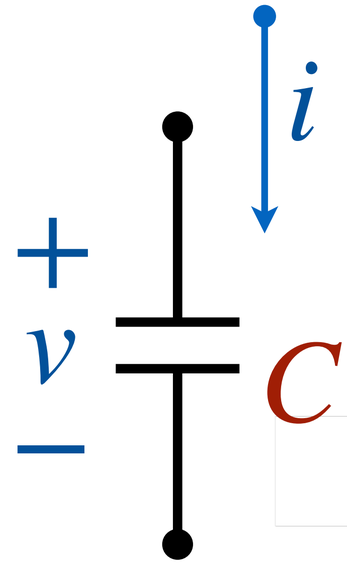
$$i_{\text{test}} = C_{\text{eq}}\frac{dV_{\text{test}}}{dt} = C_{\text{eq}}\frac{dV_1}{dt} + C_{\text{eq}}\frac{dV_2}{dt}$$

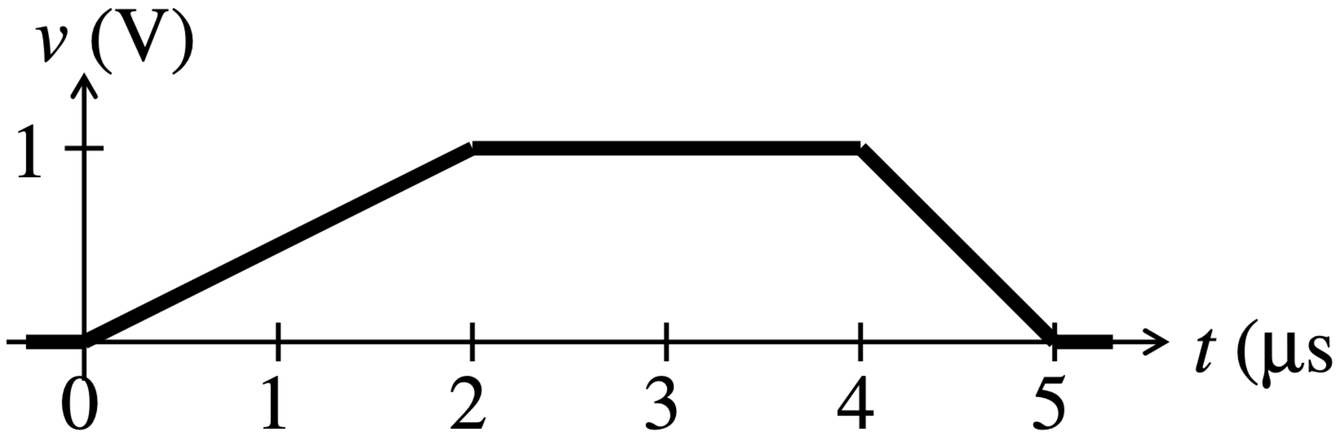
$$i_{\text{test}} = C_{\text{eq}}\frac{i_{\text{test}}}{C_1} + C_{\text{eq}}\frac{i_{\text{test}}}{C_2}$$

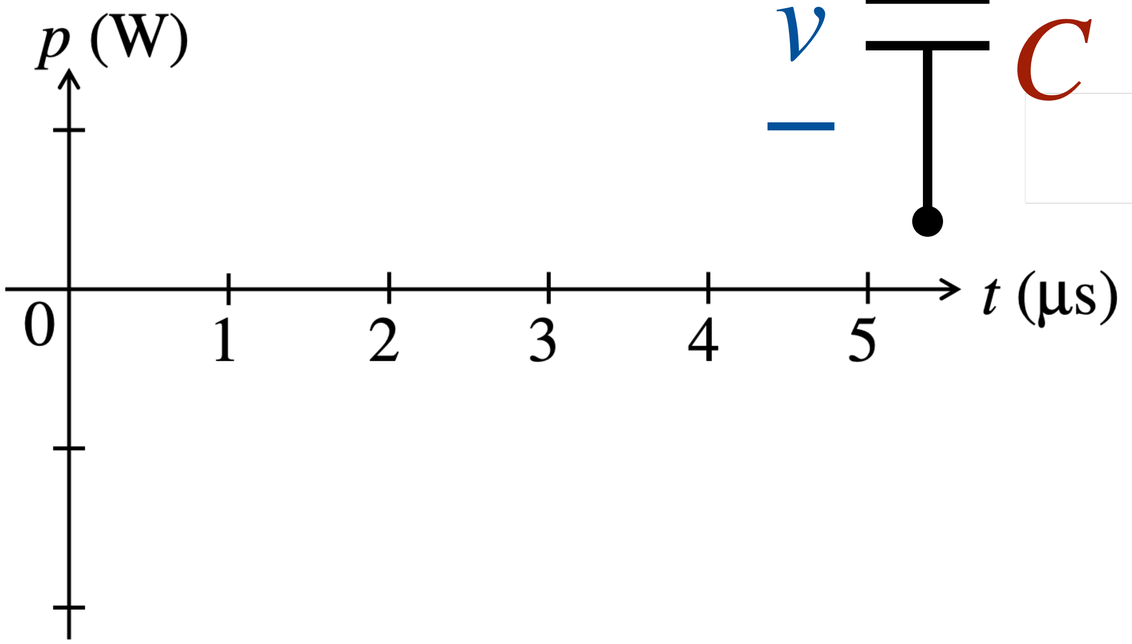
$$\frac{1}{C_{\text{eq}}} = \frac{1}{C_1} + \frac{1}{C_2}$$

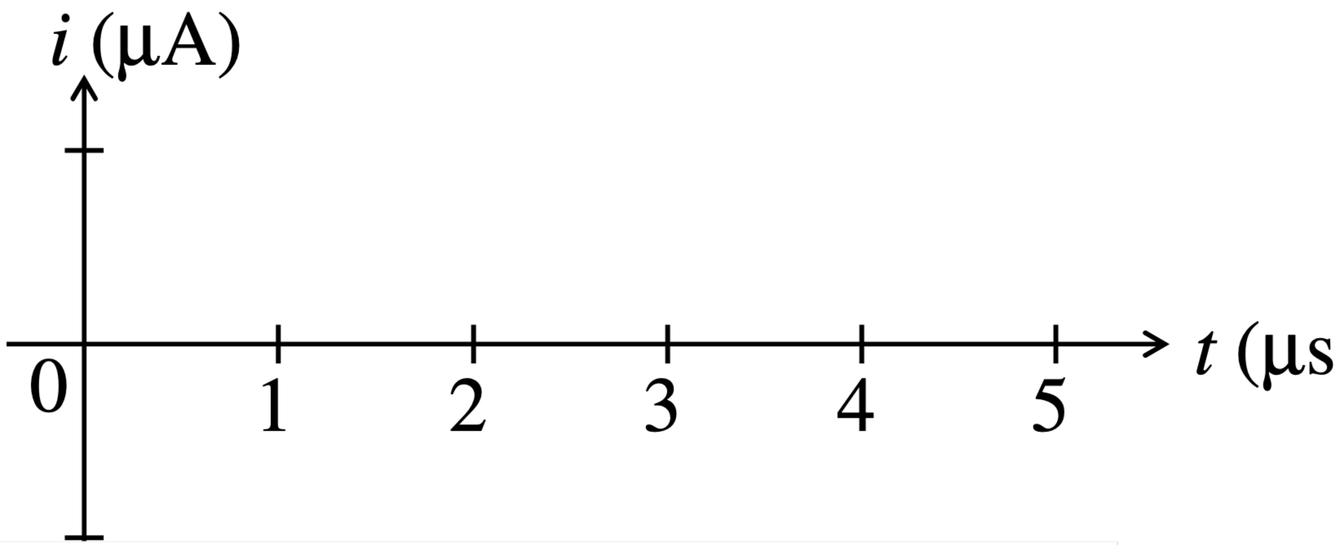
EECS16A Review

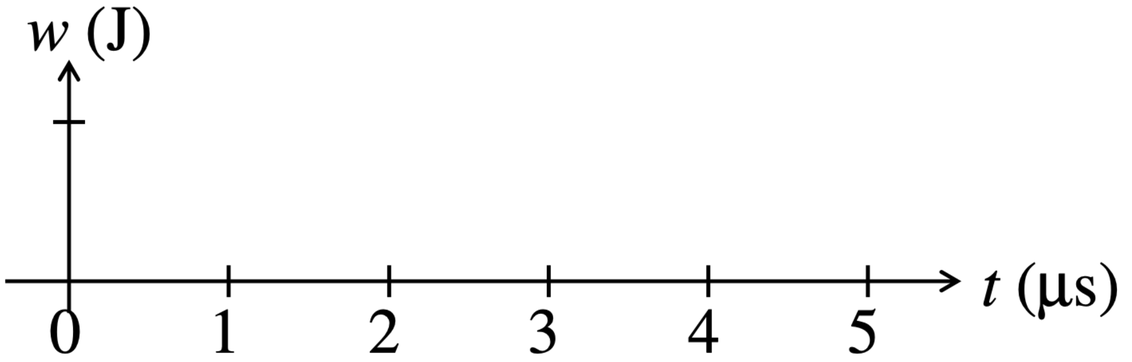
$$i = C\frac{dv}{dt}$$





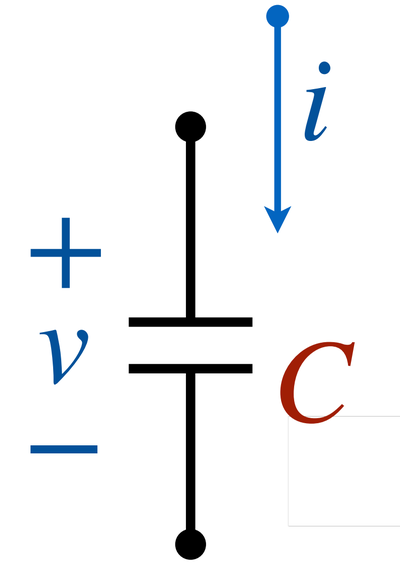


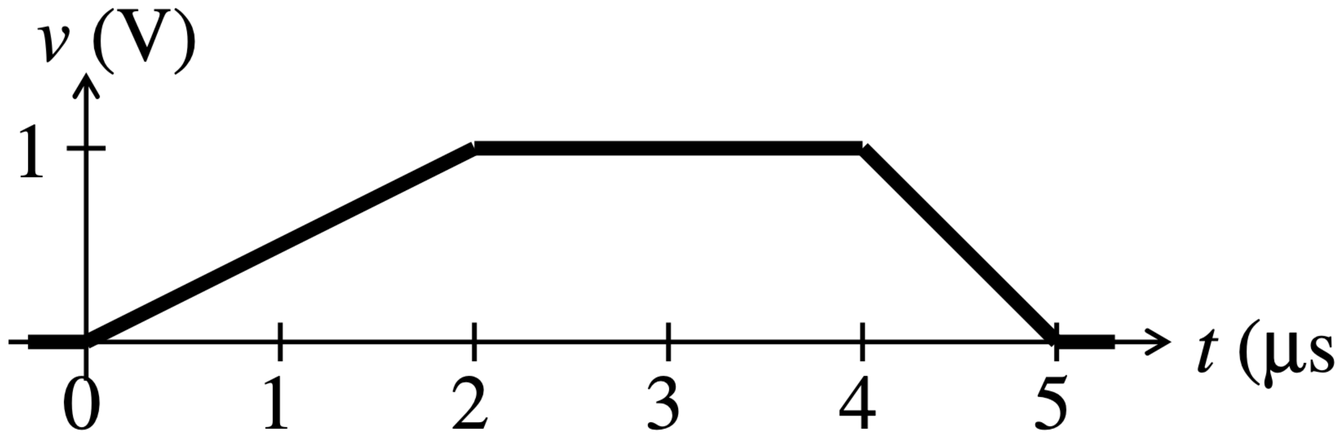


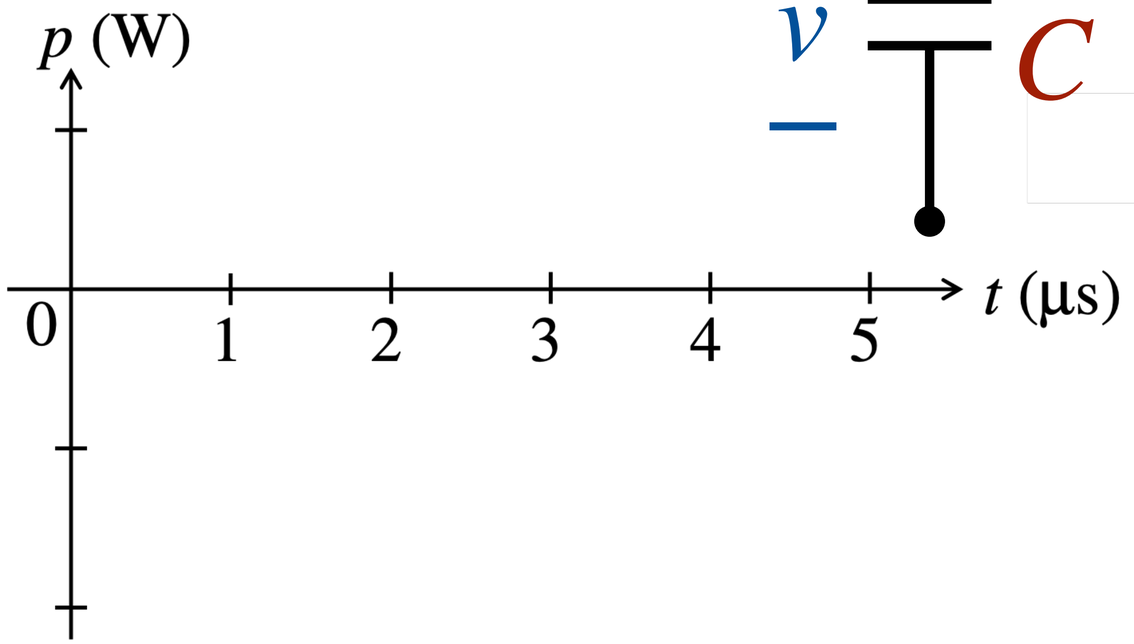


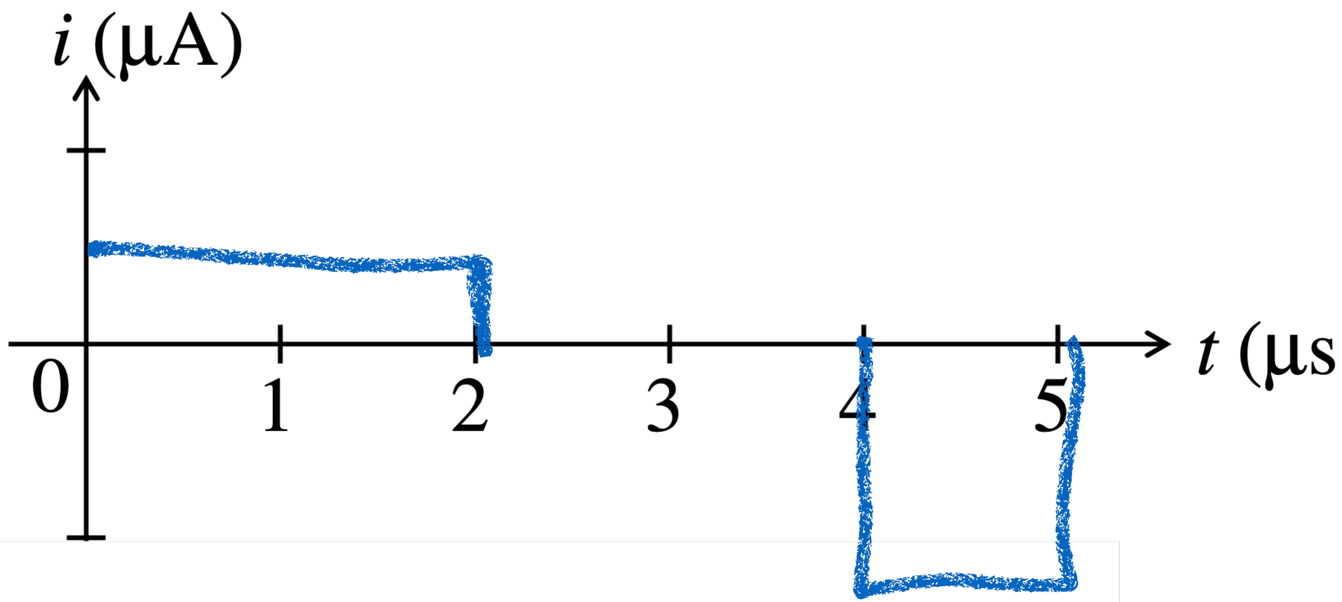
EECS16A Review

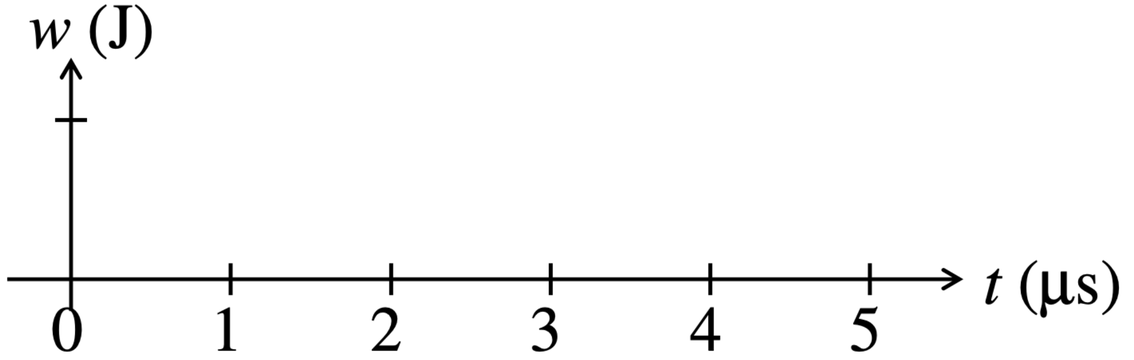
$$i = C\frac{dv}{dt}$$





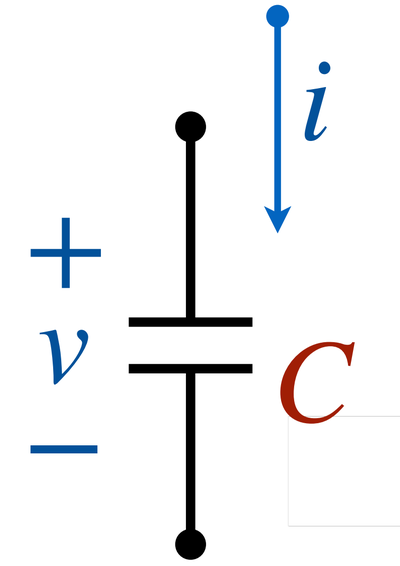


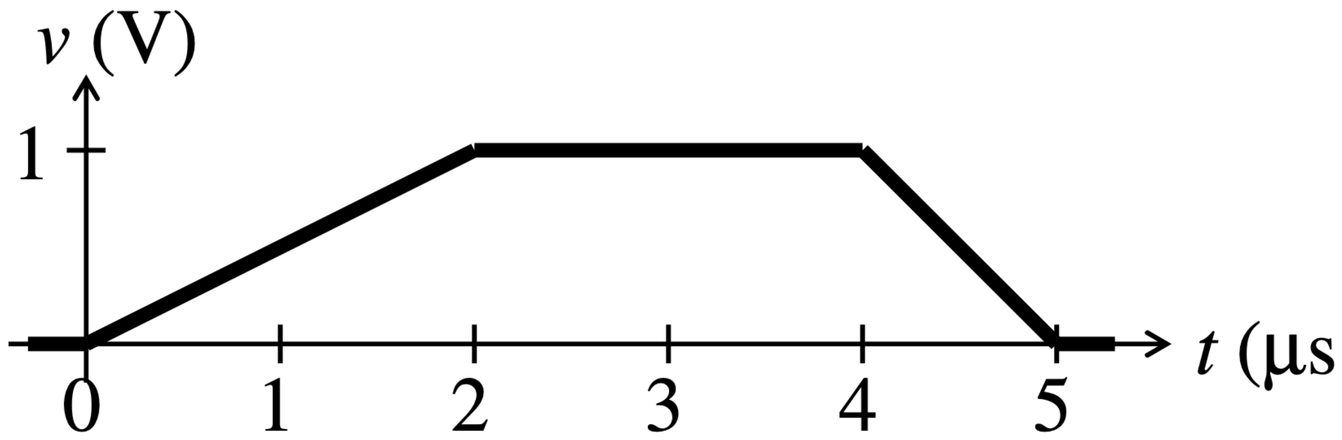


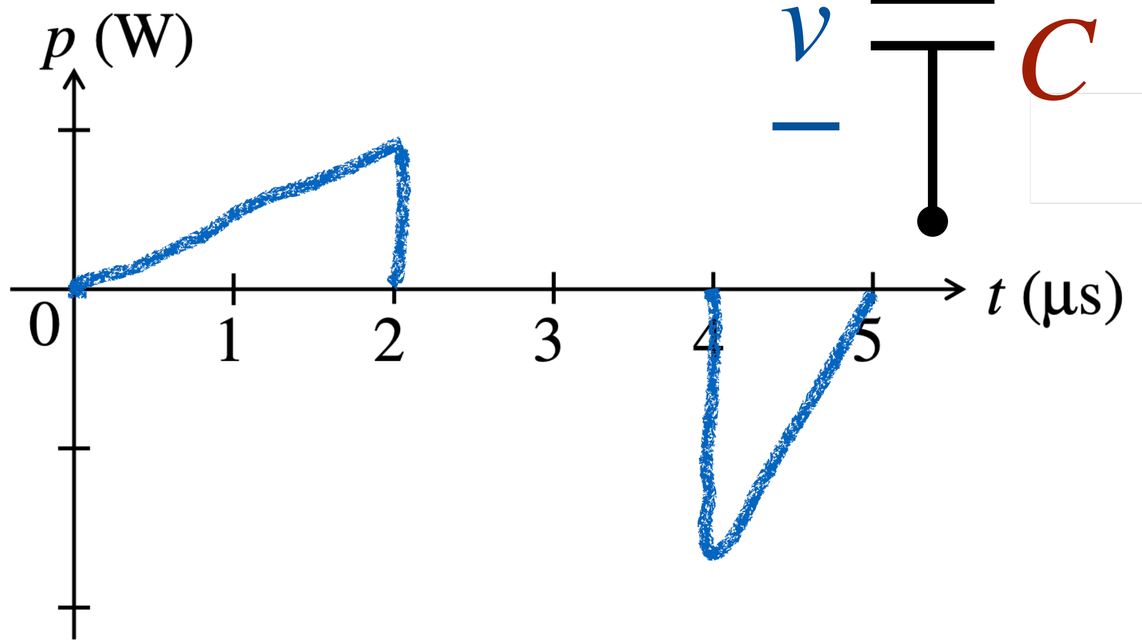


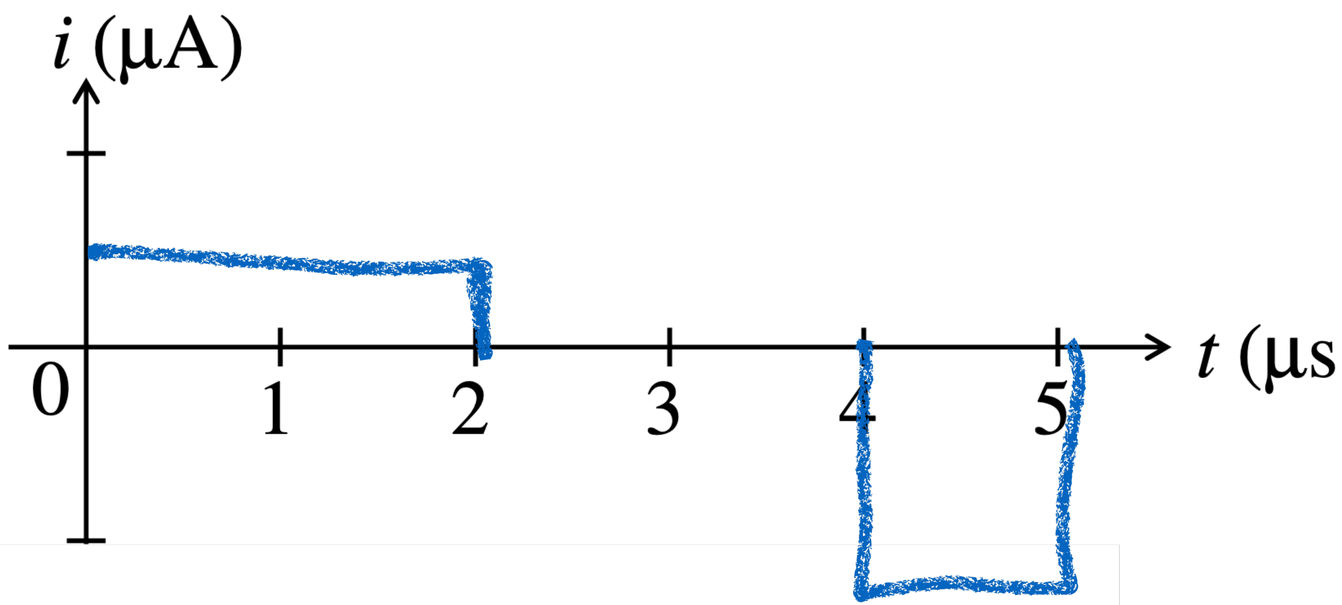
EECS16A Review

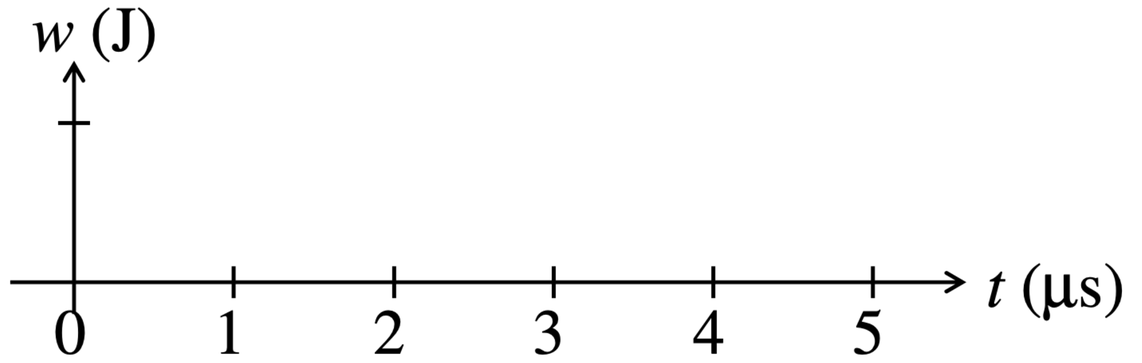
$$i = C\frac{dv}{dt}$$





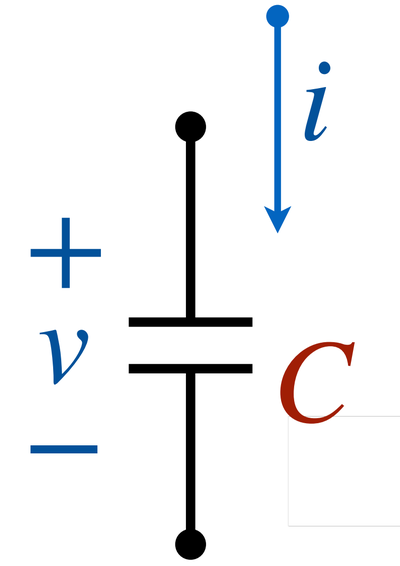


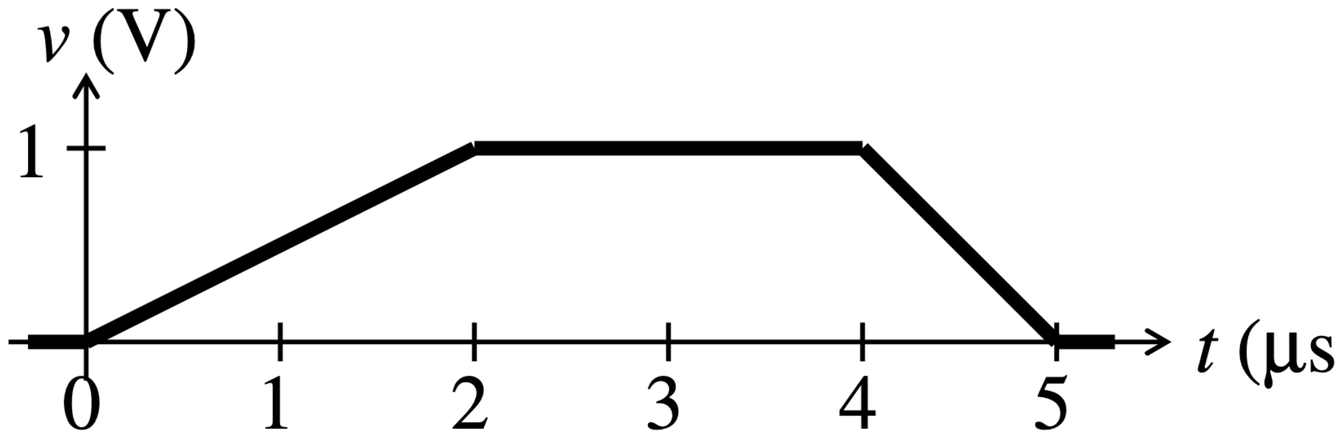


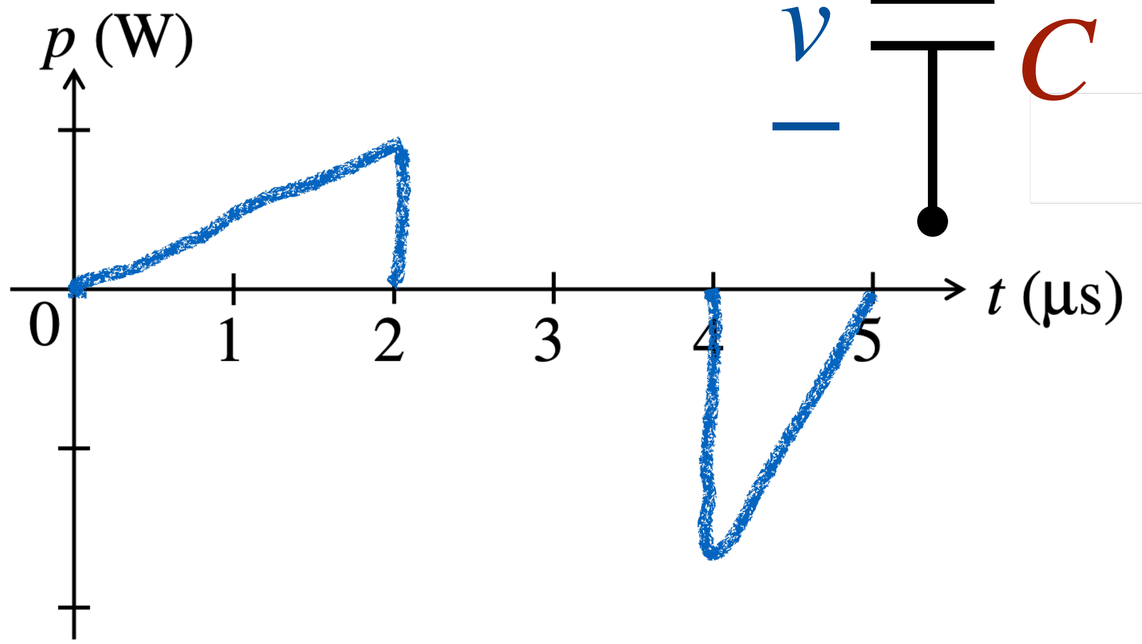


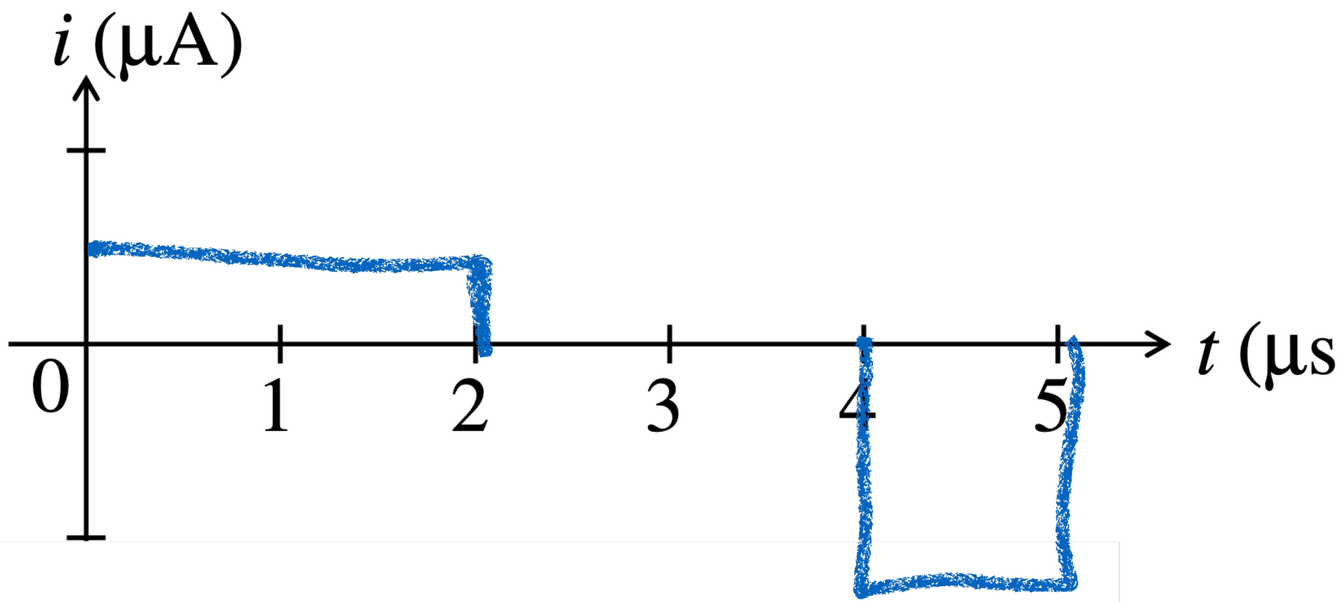
EECS16A Review

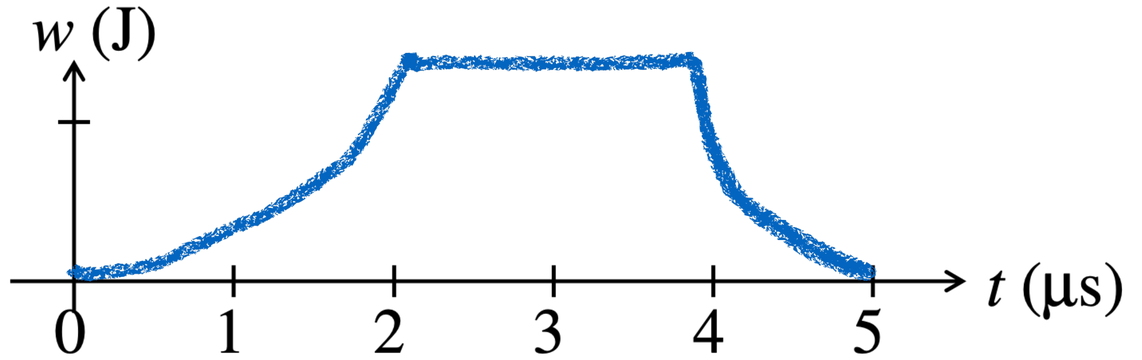
$$i = C\frac{dv}{dt}$$

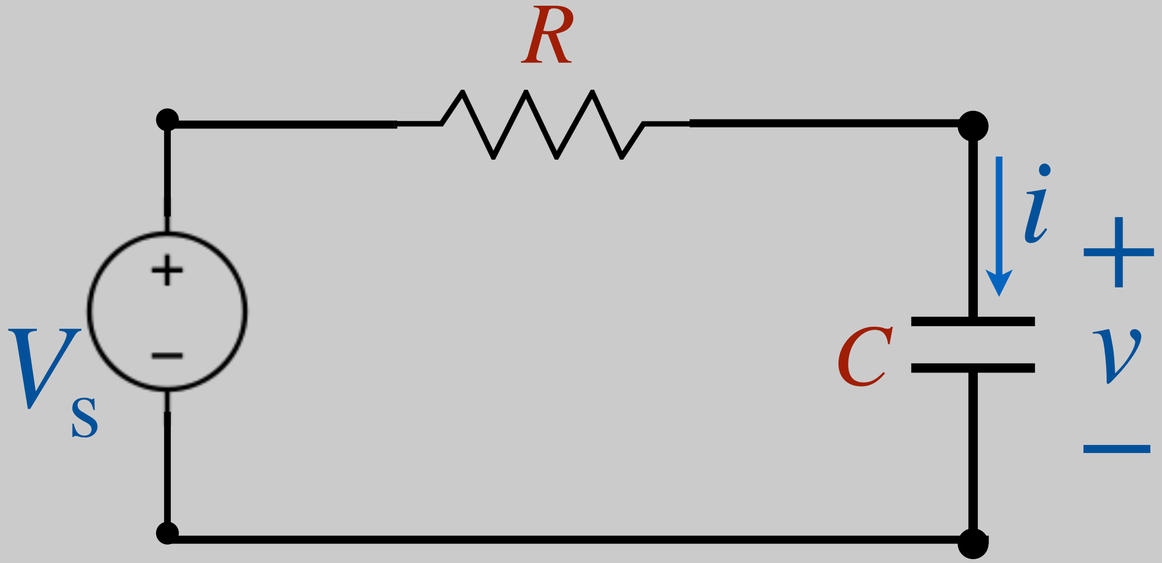


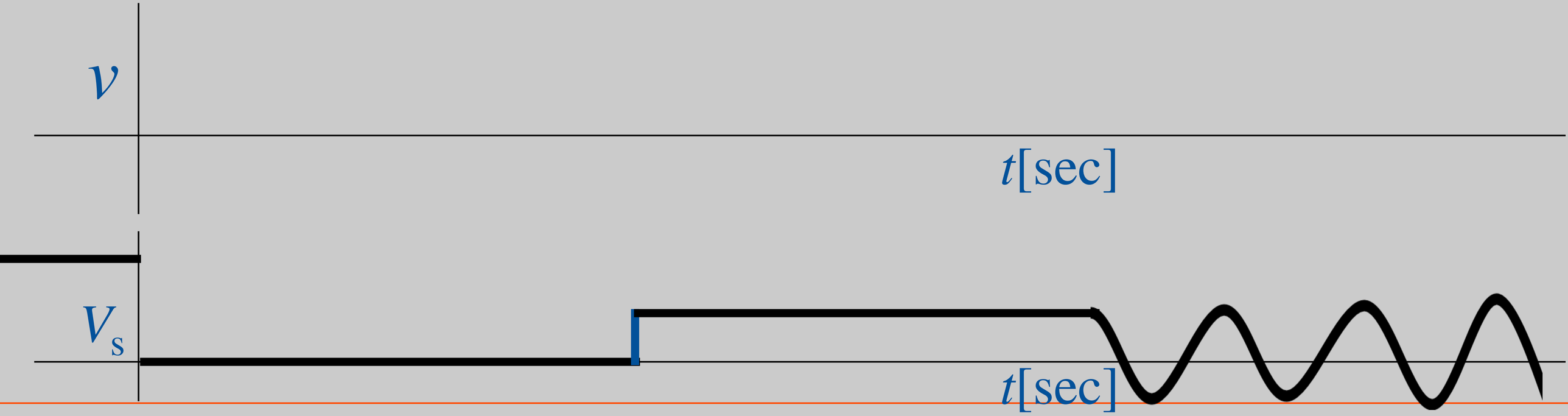









R
i
+
v
−
C
+
−
V_s


v
t[sec]
V_s
t[sec]