Welcome to 6.200!

https://circuits.mit.edu/S26

Jeffrey H. Lang

Rm 10-176

Ext 3-4687

lang@mit.edu

STAFF

Lecturer	Prof. Jeffrey Lang
Lab Instructor	Prof. Samantha Coday
Recitation Instructor	Adam Hartz
Teaching Assistant	Timmy Bui
Teaching Assistant	Ed Chen
Teaching Assistant	Katrina Jander
Lab Assistants	Too Many To List
Demo Wizard	David Otten
Course Website	circuits.mit.edu/S26

TODAY

- Basic information concerning 6.200 “mechanics”
- What is 6.200 about?
- Why take 6.200?
- Lumped-element modeling
- One-port electronic devices and *i*-*v* characteristics
- Network/circuit assembly and analysis overview
- Electronic circuit analogies

SCHEDULED EVENTS

- Lectures: TR at 11-12 AM in 2-190
- Recitations: W at 12-1, 1-2 and 2-3 PM in 26-204
- Labs: R at 2-5, F at 10-1, and F at 2-5 in 34-501 with nanoquizzes during the first 15 minutes
- *We will assign recitation and lab hours via the 6.200 website*
- Open Lab Hours: Sundays 5-8 PM, Mondays 7-10 PM and Thursdays 9-11 AM all in 34-501
- Instructor Office Hours: TBA
- Evening Quizzes: 7:30-9:30 PM on Wednesdays 3/11 and 4/22 in 50-340 (Walker)
- Final Exam: scheduled by the Registrar

ASSIGNMENTS

- Homework:
  - out Tuesdays via the 6.200 website
  - due the following Monday at 10 PM
  - answered and graded via the 6.200 website as soon as possible
- Prelabs:
  - out every week along with homework via the 6.200 website
  - due before the Thursday/Friday lab two days later
- Labs: 3 hours every Thursday or Friday with nanoquizzes during the first 15 minutes
- Evening Quizzes: 7:30-9:30 PM on 3/11 and 4/22 in 50-340 (Walker)
- Final Exam: scheduled by the Registrar
- Grading details, lateness policy and collaboration policy are on the 6.200 website

RESOURCES

- Textbook: *Foundations of Analog and Digital Circuits*, Agarwal and Lang, Elsevier
- Textbook on reserve in Barker Library
- HKN tutoring program via https://hkn.mit.edu
- Instructor office hours TBD
- Open Lab Hours: Sundays 5-8 PM, Mondays 7-10 PM and Thursdays 9-11 AM all in 34-501
- 6.200 staff
- Staff emails: 6.200-help@mit.edu and 6.200-personal@mit.edu

PLEASE DO SOON

- Go to https://circuits.mit.edu/S26/section_signup and enter preferences for recitation and lab times. This is due today at 5 PM.

- The pre-lab for this week can be found within the first problem set (PS00) which is available through the 6.200 calendar on our website homepage. As part of the pre-lab complete the following two tasks.

  – EHS Electrical Safety Awareness – Course EHS00509 at https://web.mit.edu/training/my_training.html

  – Undergrad lab safety sheet acknowledgement form at https://eecs-ug.scripts.mit.edu:444/safety/index.py/6.200

6.002 IS ALL ABOUT …

- Electronic devices and circuits:

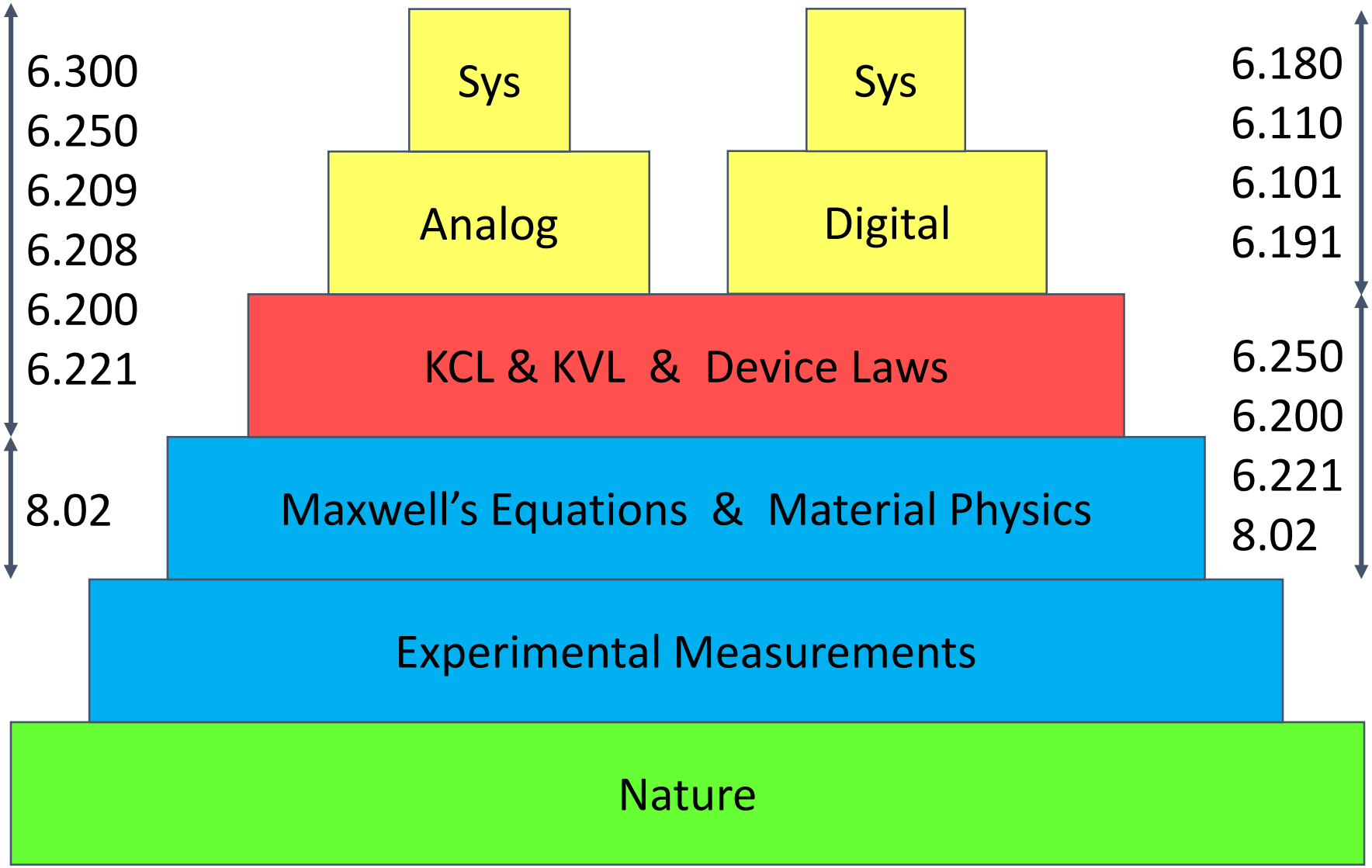
  Modeling → What makes a good model? How does abstraction fit in?
  Analysis → What does "it" do and how/why does "it" work?
  Design → What is a good design and how is one found?
  Applications → (Analog) Signal processing and signal electronics
  Energy processing and power electronics
  Interfacing to the "real (analog) world"
  Lab Experience → Making electronics real … and learning by doing

- Managing complexity:

  Physical complexity … individual complexity
  Dimensional complexity … group complexity

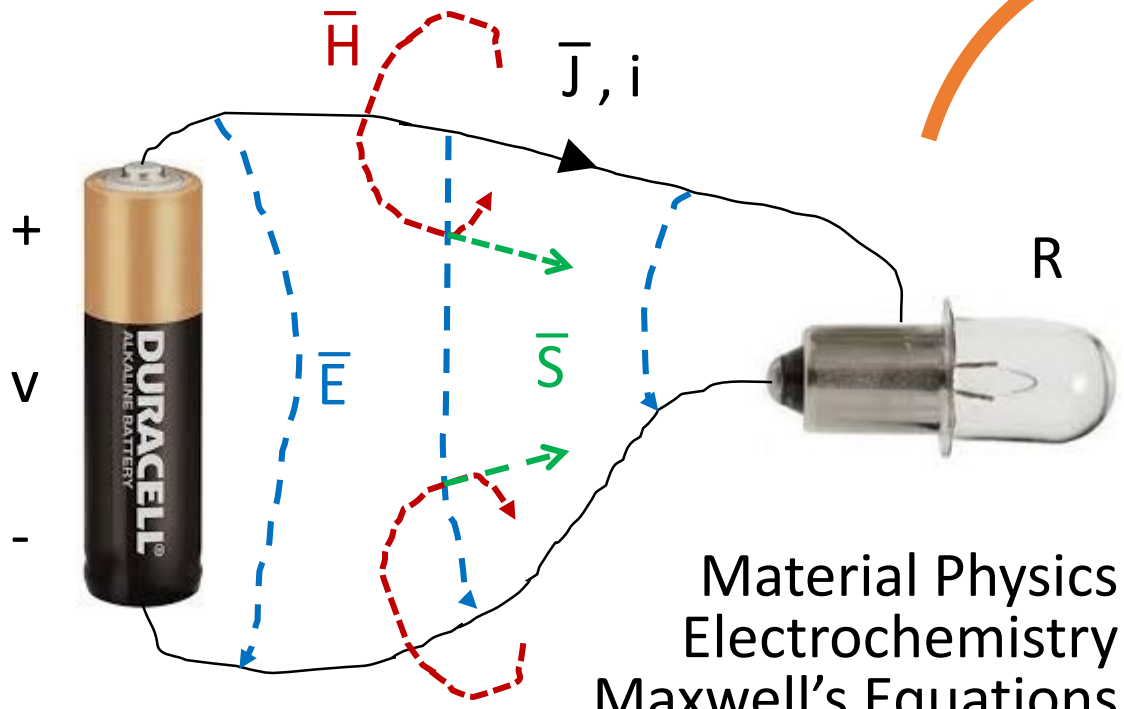
- A purposeful use of math
- A powerful language for lumped-parameter analysis and design
- Practical (theoretical and experimental) skills for UROP, internships, education, research …

SCIENCE/ENGINEERING (CIRCUITS) HIERARCHY



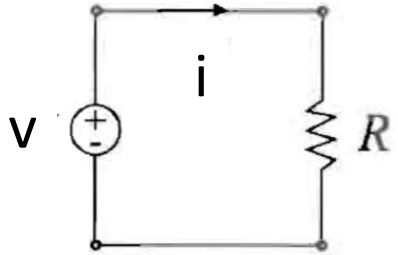
HOW TO ANALYZE A FLASHLIGHT?

Lumped-Parameter Abstraction



Material Physics
Electrochemistry
Maxwell's Equations

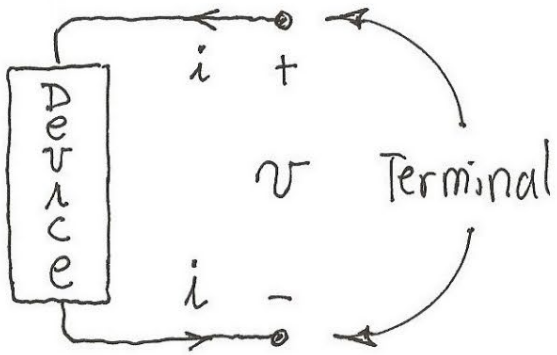
Lumped-Parameter Analysis



$v = i R$

$p = v i$

ELECTRONIC DEVICES

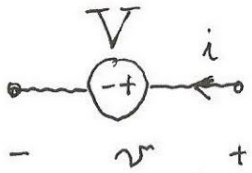


$$i = f_i(v)$$

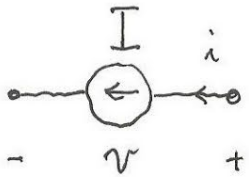
$$v = f_v(i)$$

Power In $= vi$

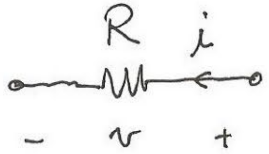
Voltage Source

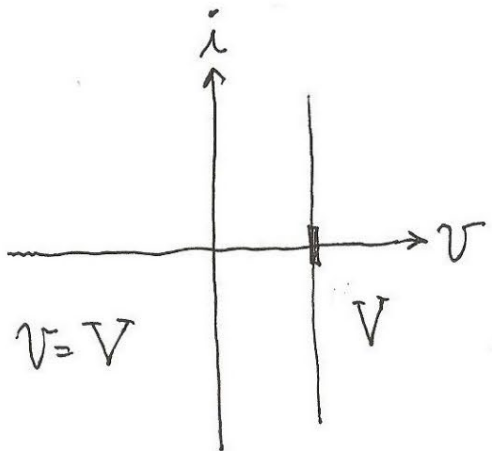


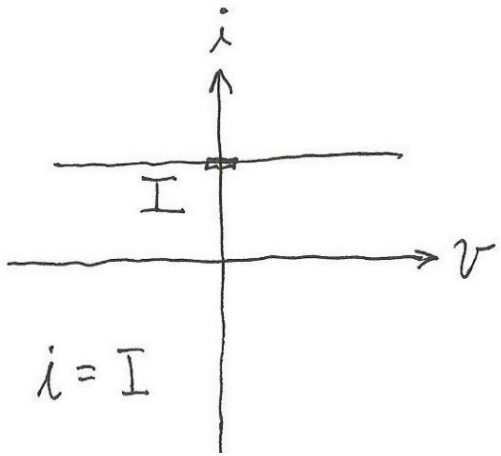
Current Source

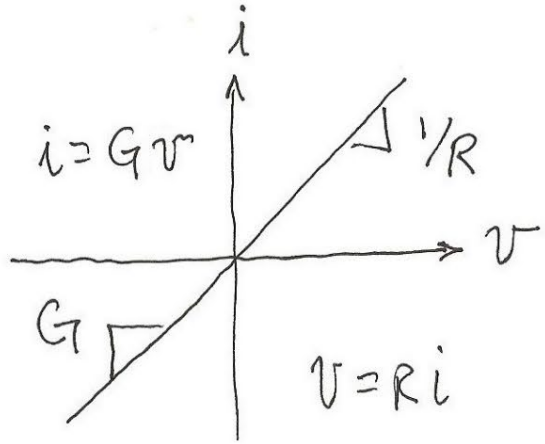


(Linear) Resistor

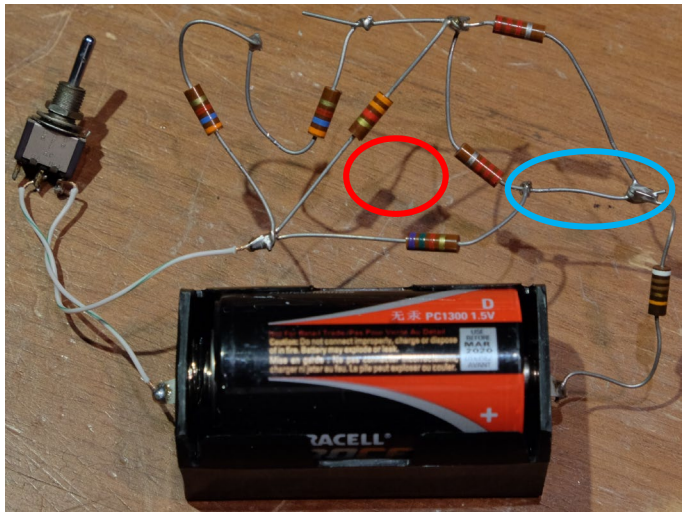


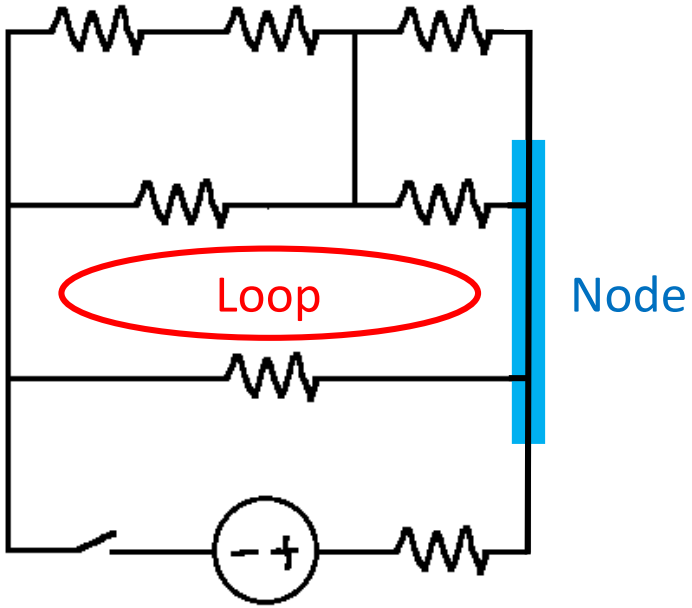






ASEMBLING & ANALYZING ELECTRONIC NETWORKS/CIRCUITS





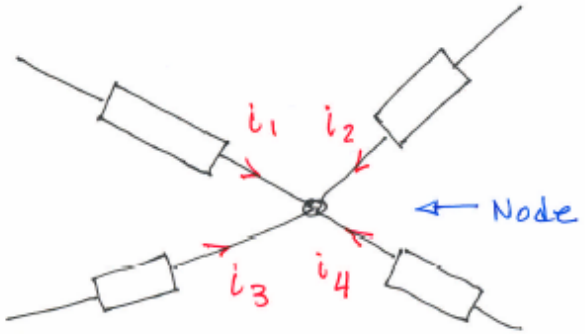
- Circuit assembly → connecting devices together at their terminals (soldering, twisting, protoboarding).
- Circuit assembly creates nodes and loops.
- Circuit assembly constrains device operation via Kirchhoff's current (KCL) and voltage (KVL) laws.
- Circuit analysis → determining all device voltages and currents, and then interpreting the voltages and currents in terms of functionality.
- Circuit voltages and currents are important; they are associated with information and power.

KIRCHHOFF'S CURRENT LAW (KCL)

$$\sum \left[\text{Branch Currents Into A Node} \right] = 0$$

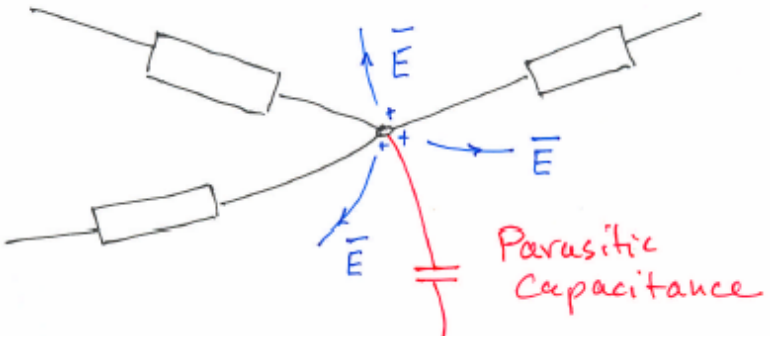
Charge Conservation

Branches At A Node



KCL

$$i_1 + i_2 + i_3 + i_4 = 0$$

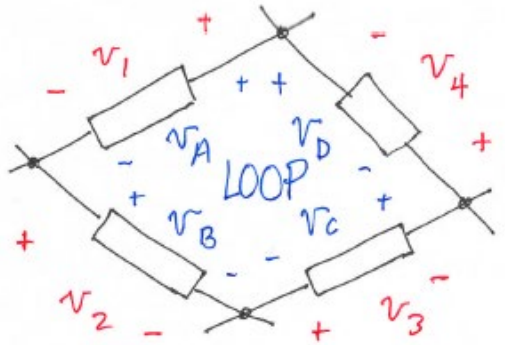


KIRCHHOFF'S VOLTAGE LAW (KVL)

$$\sum \left[\text{Branch Voltages} \right] = 0$$

Energy Conservation

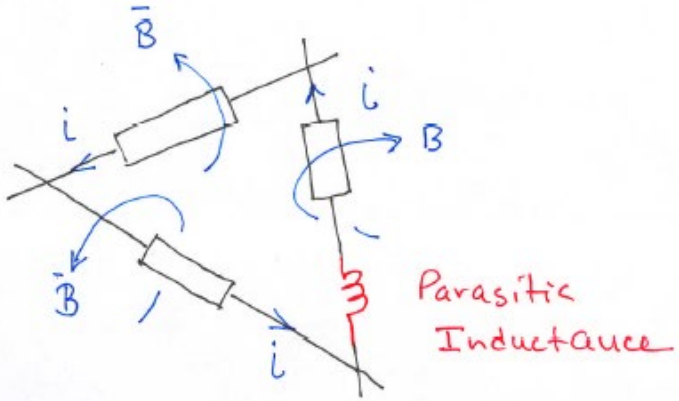
Branches Around A Loop



KVL

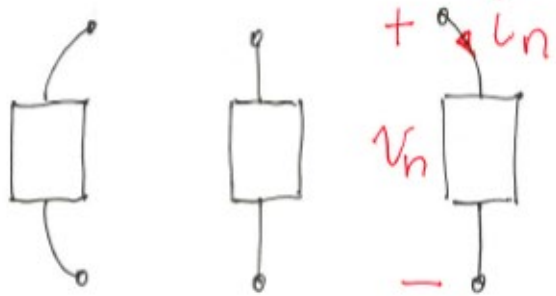
$$v_1 + v_2 + v_3 + v_4 = 0$$

$$v_A + v_B = v_C + v_D$$



CIRCUIT ANALYSIS

Circuit analysis involves the combination of device laws and connection laws.

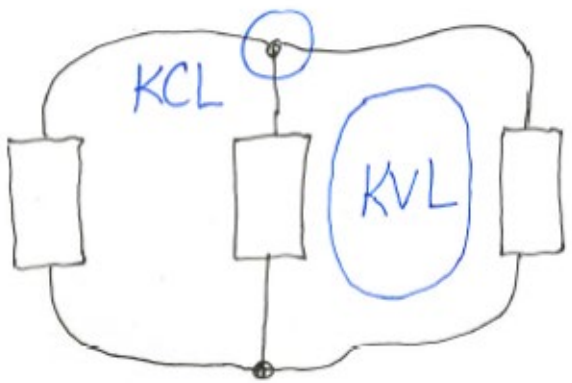


Device Laws

$i_n = f_{i_n}(v_n)$

$v_n = f_{v_n}(i_n)$

Assembly ⇓

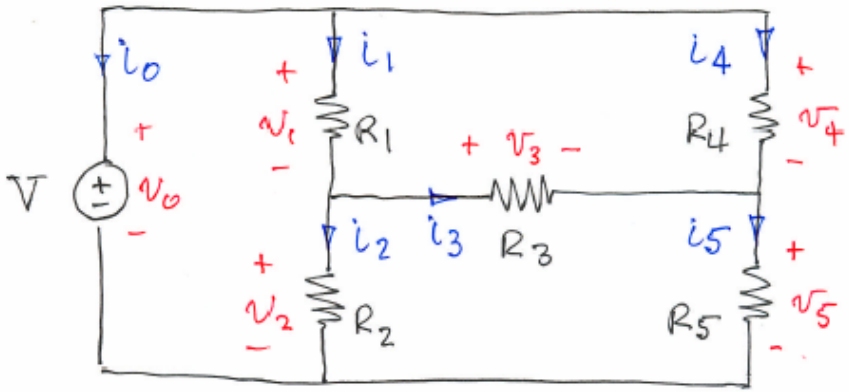


Connection Laws

KCL

KVL

CIRCUIT ANALYSIS EXAMPLE



Device Laws

$v_0 = V$

$v_1 = R_1 i_1$

$v_2 = R_2 i_2$

$v_3 = R_3 i_3$

$v_4 = R_4 i_4$

$v_5 = R_5 i_5$

KCL

$i_0 + i_1 + i_4 = 0$

$-i_1 + i_2 + i_3 = 0$

$-i_3 - i_4 + i_5 = 0$

$-i_0 - i_2 - i_5 = 0$ Redundant

KVL

$v_0 = v_1 + v_2$

$v_1 + v_3 = v_4$

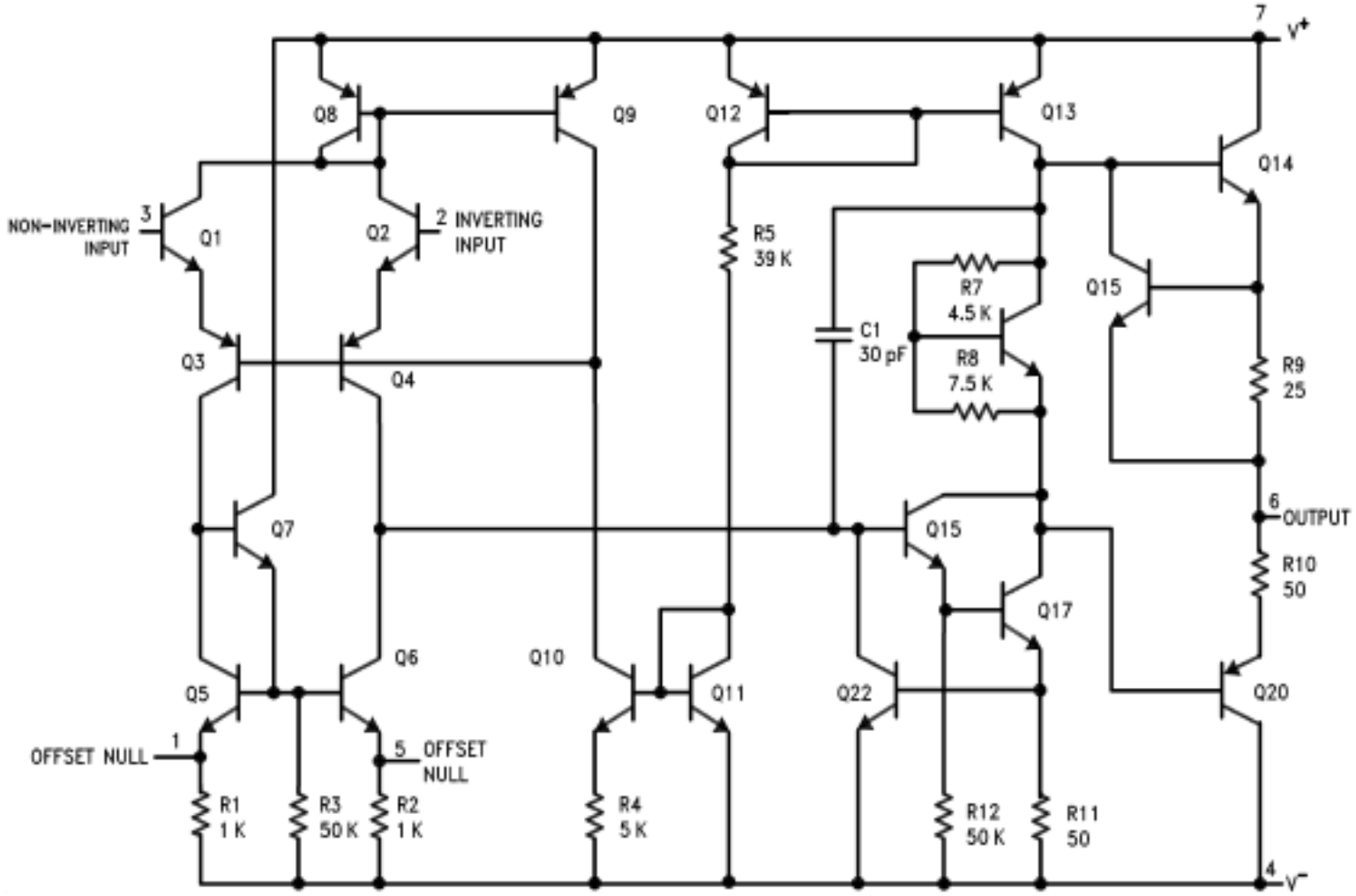
$v_3 + v_5 = v_2$

$v_0 = v_4 + v_5$ Redundant

12 Equations → Algebra → 12 Unknowns

HOW DO WE ANALYZE CIRCUITS CONTAINING MANY ELEMENTS?

741 Operational Amplifier



20 Transistors
(2 Branches Each)
10 Resistors
1 Capacitor
2 Input Voltage Sources
2 Power Supplies

55 Branches or “Devices”
110 Unknowns

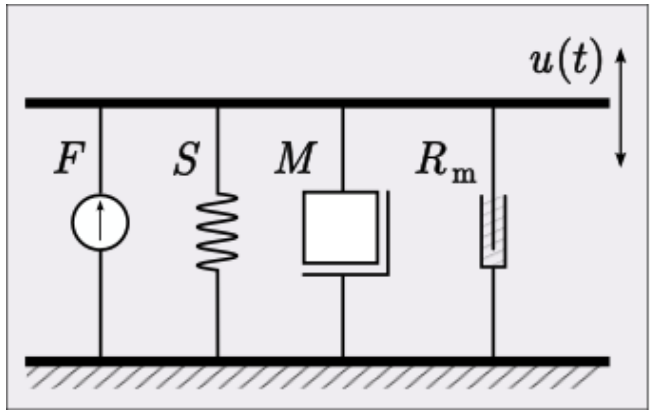
THE LANGUAGE OF ELECTRONIC CIRCUITS

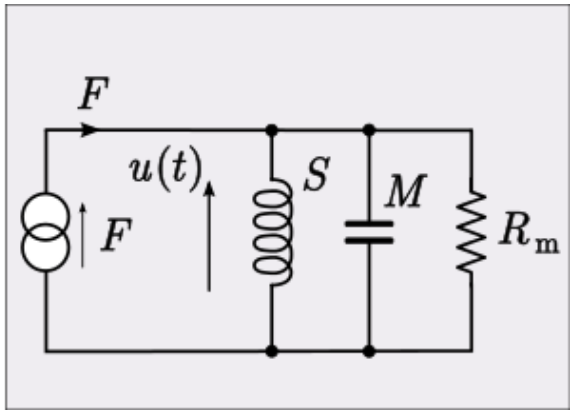
A way to model electrical systems …

… and acoustic, biomedical, fluidic, magnetic, thermal, mechanical, etc systems

A way to model/describe and analyze systems described by ODEs

MECHANICAL ↔ ELCTRICAL ANALOGS

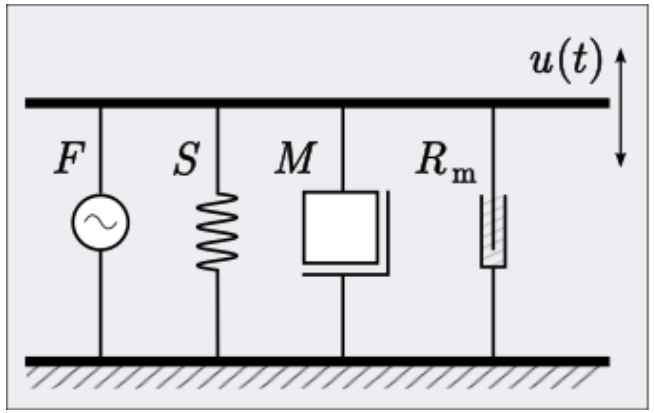


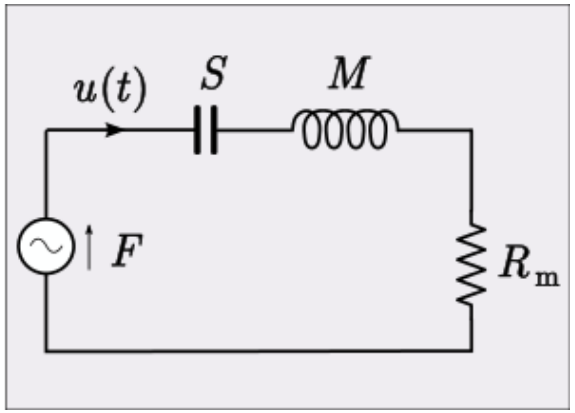


Mobility/Admittance Analogy

- Preserves through and across variables
- Preserves topology

https://en.wikipedia.org/wiki/mobility_analogy



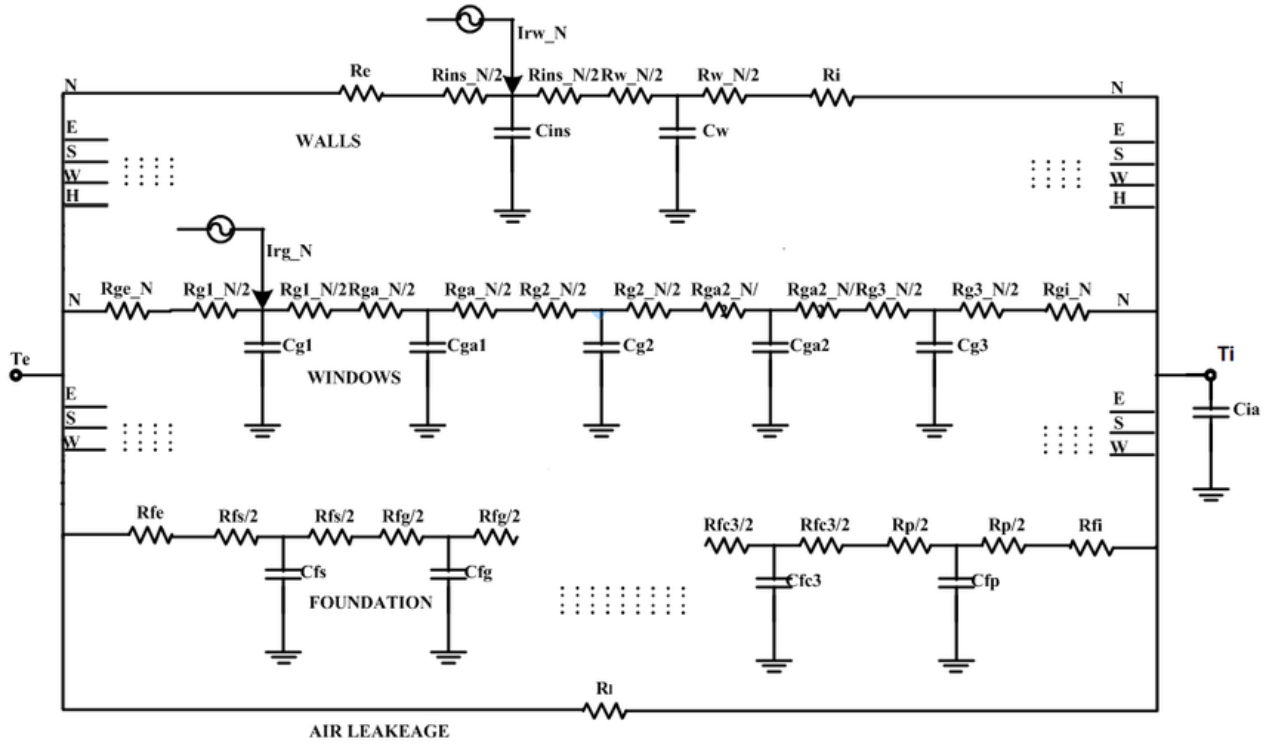


Impedance Analogy

- Preserves impedance
- Uses dual topology: nodes ↔ loops

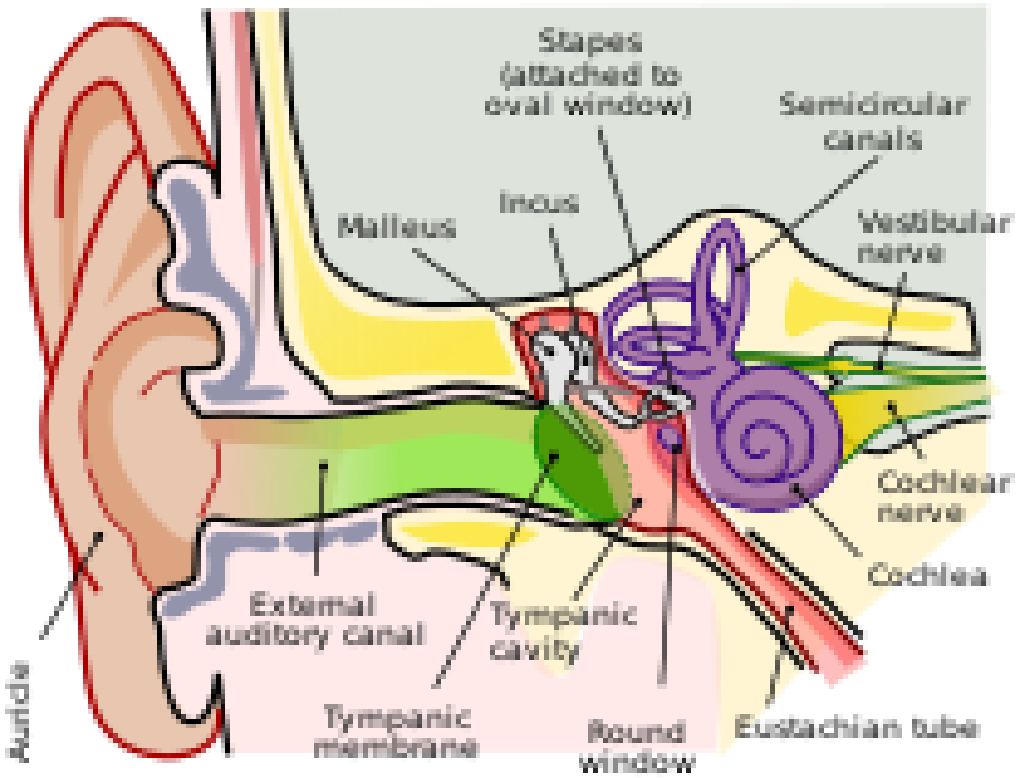
https://en.wikipedia.org/wiki/impedance_analogy

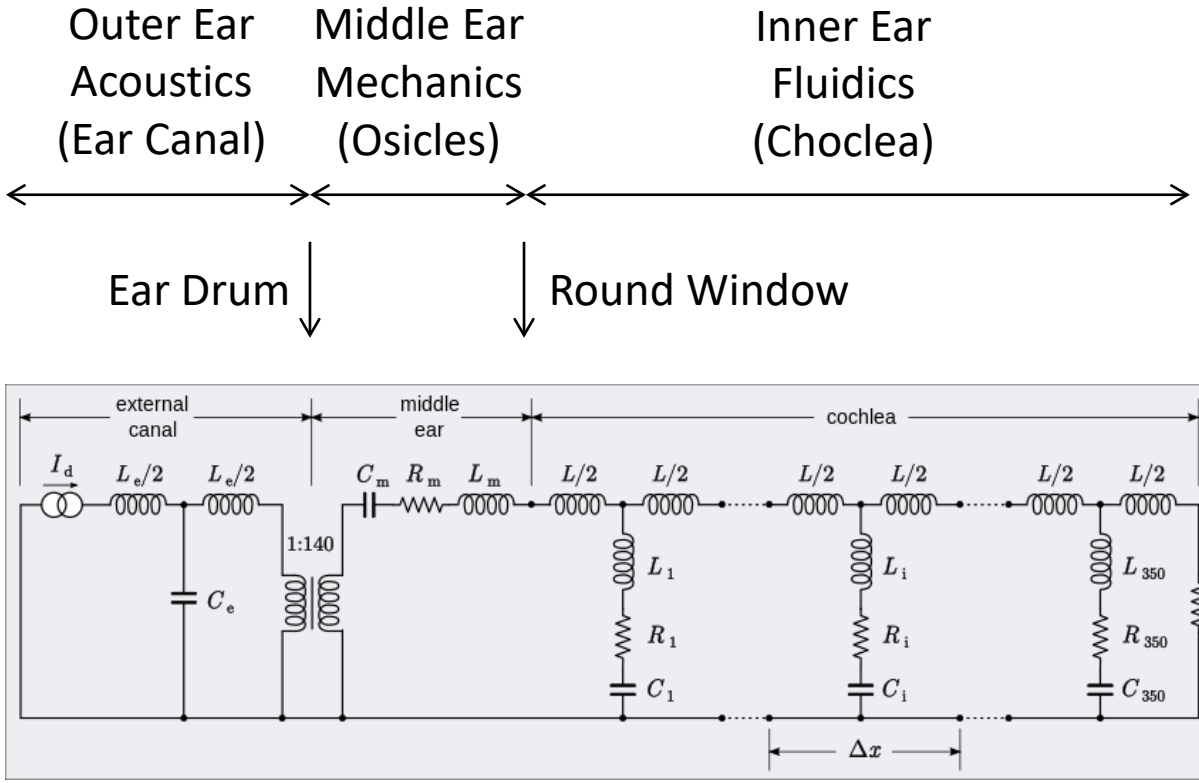
THERMAL ↔ ELECTRICAL ANALOGS



International Journal of Sustainable Building Technology and Urban Development, 4:2, 146-159, DOI: 10.1080/2093761X.2013.777682

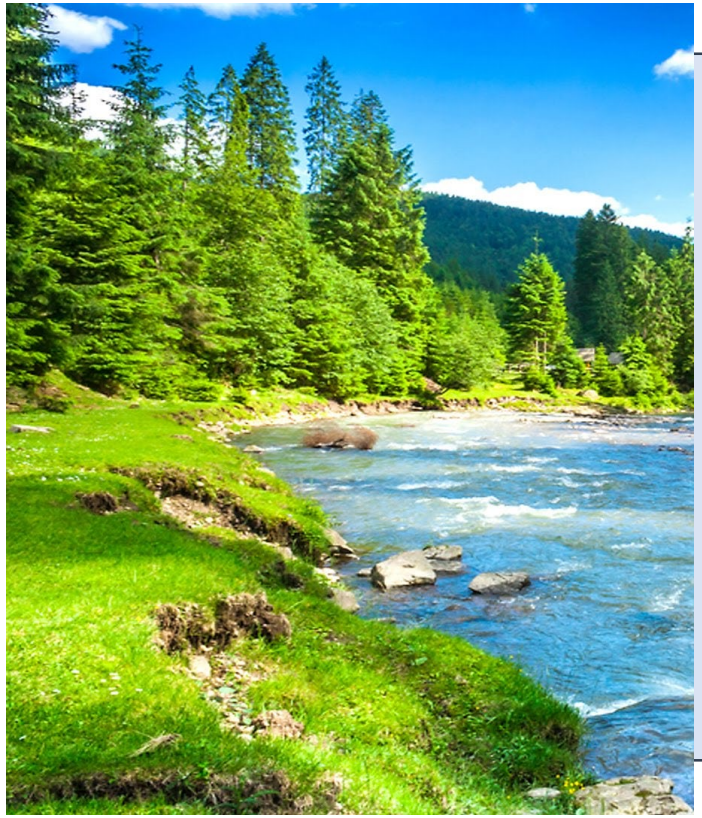
MULTIPHYSICS AUDITORY ↔ ELECTRICAL ANALOGS





https://en.wikipedia.org/wiki/impedance_analogy

6.200

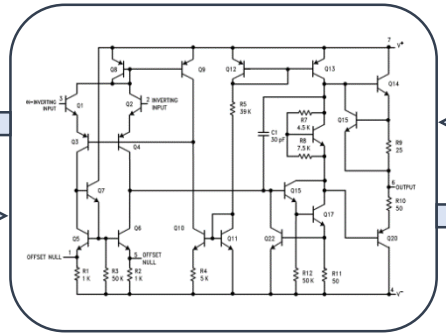


Continuous Values
Continuous Time
- Analog -

Transducers

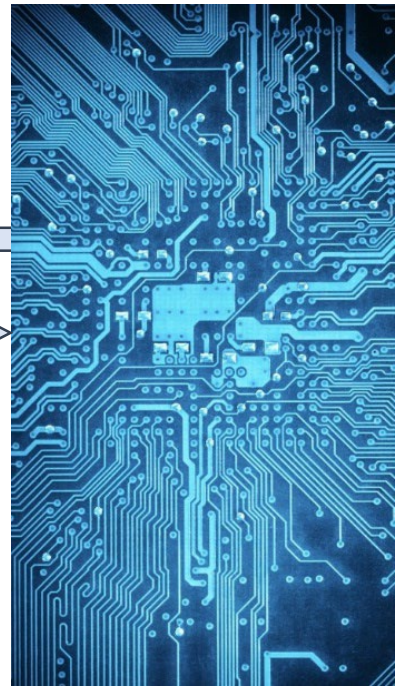
Actuators

Sensors



Analog
Electronics

Digital
Electronics



Discrete Values
Discrete Time
- Digital -