Introduction + Circuit Abstraction

Lecture 1
September 4th, 2018

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Seoul National University

***Slide credits**: Prof. Anant Agarwal at MIT*

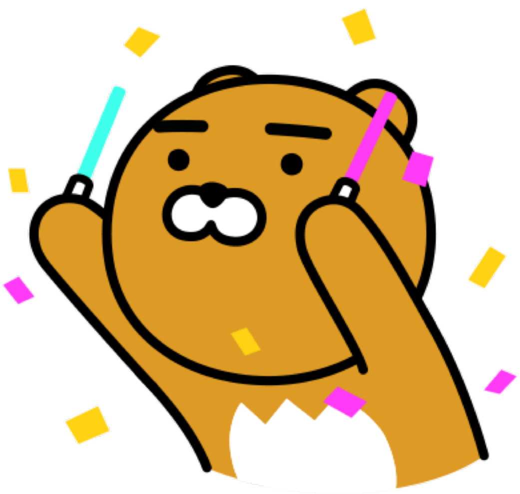
Course information

- **Schedule**
  - Lecture: 3:30 – 4:45 PM [Tue/Thu] @ #301-118

- **Instructor**
  - Jae Wook Lee (이재욱, jaewlee@snu.ac.kr)
  - Office: Engineering Building #301-506
  - Phone: 02-880-1834
  - Office Hours: 5-6 PM on Tuesdays (right after class) or by appointment

Course information: (All-star) TAs

- **Namho KIM (김남호)**
  - Email: kkjknh2@gmail.com



- **Sung Jun JUNG (정성준)**
  - Email: wjdtjdwns92@gmail.com

- **Office: SNU-Samsung Research Center (Bldg. 944-800)**
- **Phone: 02-880-1834**
- **Office Hours: TBA**

Course information: (All-star) TAs

- **Quick poll for TA office hours**
  - For which slot do you have a conflict? We will pick two with the fewest conflicts.
    - Mon 18:00 ~ 19:00
    - Tue 13:00 ~ 14:00
    - Wed 18:00 ~ 19:00
    - Thu 13:00 ~ 14:00
  - TA can answer your questions and help you understand the materials.

Course information

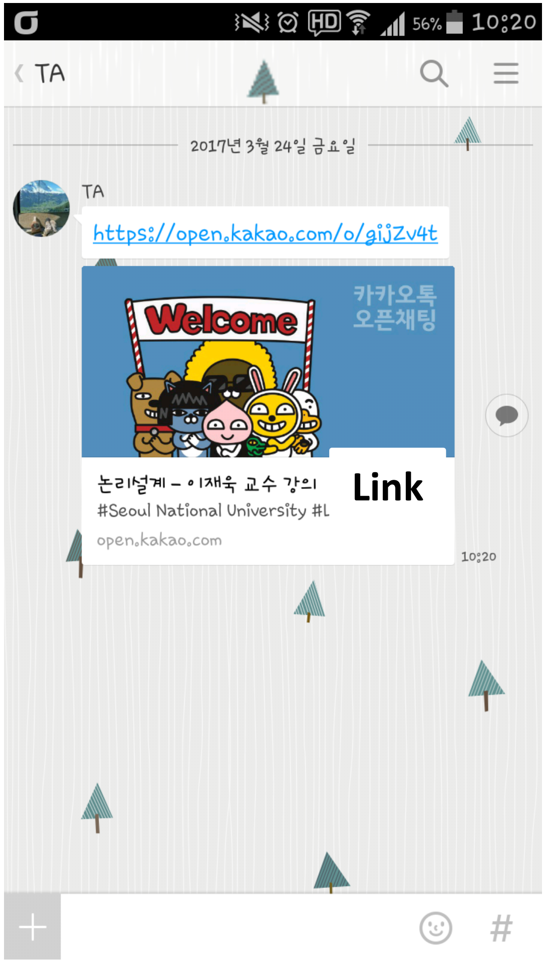
- **This is a sophomore-level course with the following prerequisites:**
  - Engineering Mathematics 1 (공학수학 1)
  - We assume you understand how to solve differential equations and the concept of complex numbers.

- **This course will be given in English (aka 영어강의).**
  - But you are welcome to ask questions in either Korean or English.

- **Course materials will be distributed through eTL.**

Course information

- **Open Kakao chat for the course**
  - We will use open chat for casual, anonymous communication.
    - Link: https://open.kakao.com/o/gSEA2GI
    - Some forbidden nicknames include professor, Prof. Lee, 이재욱 (교수), TA, 조교, 정성준, Namho Kim, etc.
  - Everyone is invited, but not required, to join.
    - Using it is completely optional
  - Primarily used for questions during the class
    - Will answer your questions outside the classroom as time permits
- **OpenChat Manual will be uploaded**



OpenChat Manual
[Hardware System Design - 2018 Spring]

2018. 3. 6

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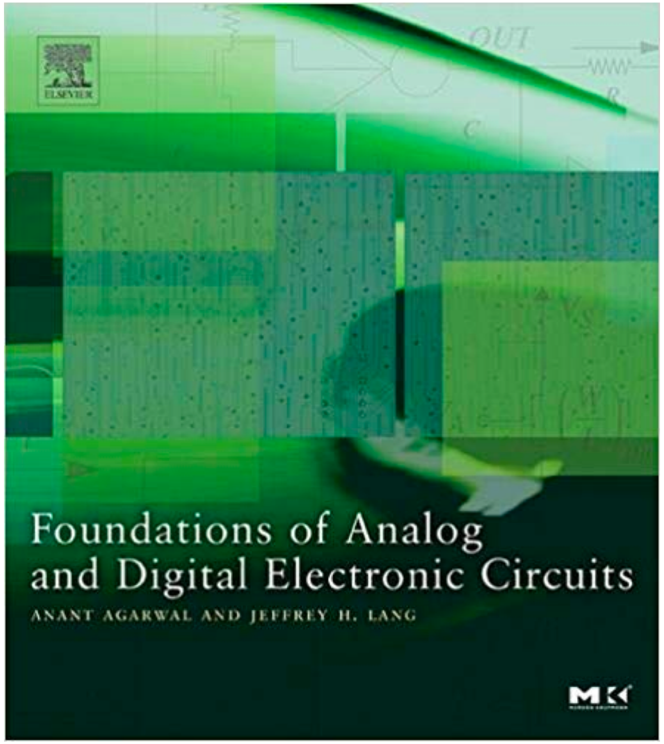
Course information: Textbooks

- **Main: Foundations of Analog and Digital Electronic Circuits [A&L]**
  - Authors: Anant Agarwal and Jeffrey H. Lang
  - Morgan Kaufmann, 2005 (1st Edition)



Outline

Textbook: Ch. 1.1-1.4, Appendix A.1-A.2

- **Abstraction**
- **Lumped Circuit Abstraction**
- **Lumped Matter Discipline**
- **Example: Deriving Kirchhoff's Laws**
- **Logistics**

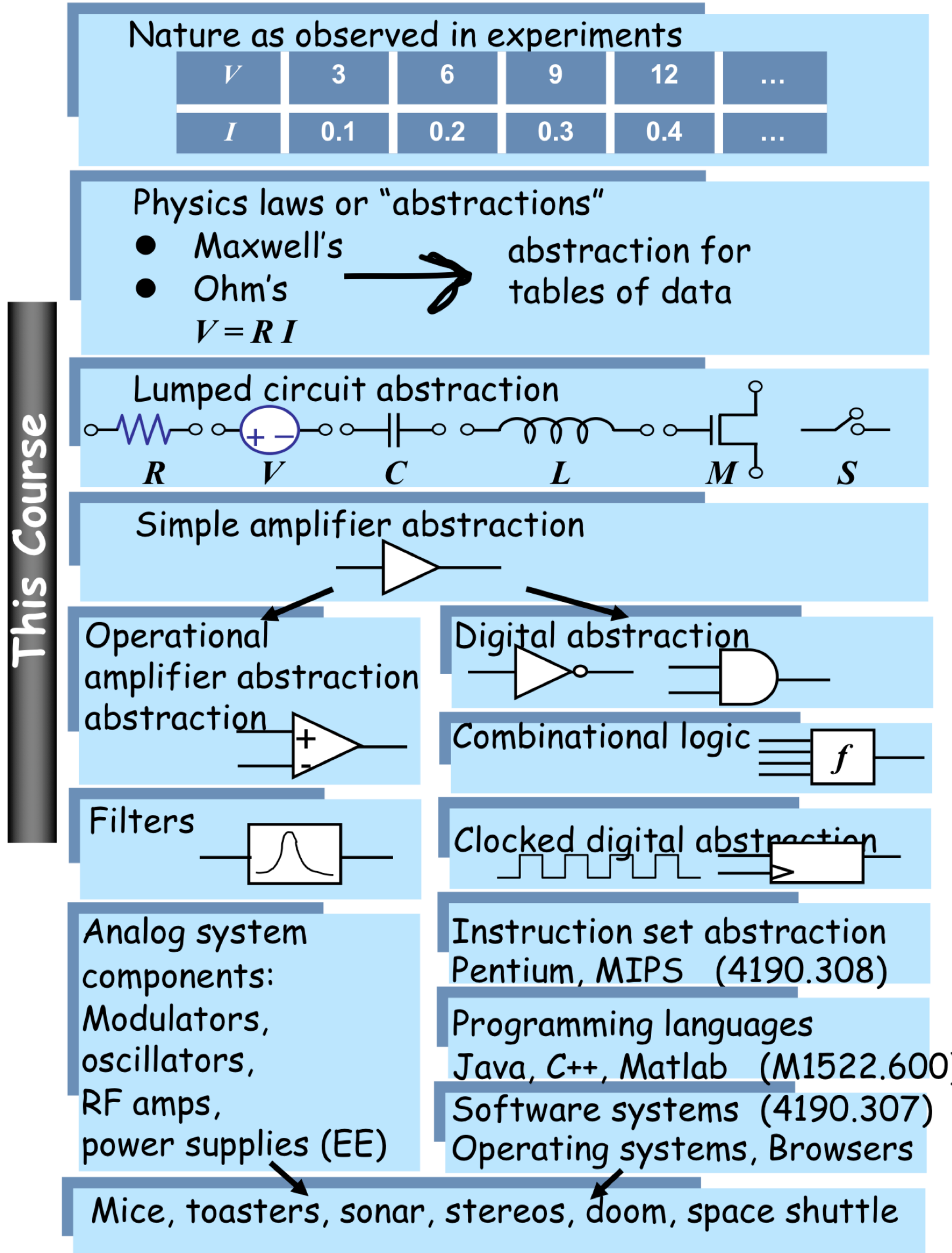
What is ….?

- **What is engineering?**
  - Purposeful use of science

- **What is this course about?**
  - Gainful employment of Maxwell's equations
  - From electrons to digital gates and op-amps

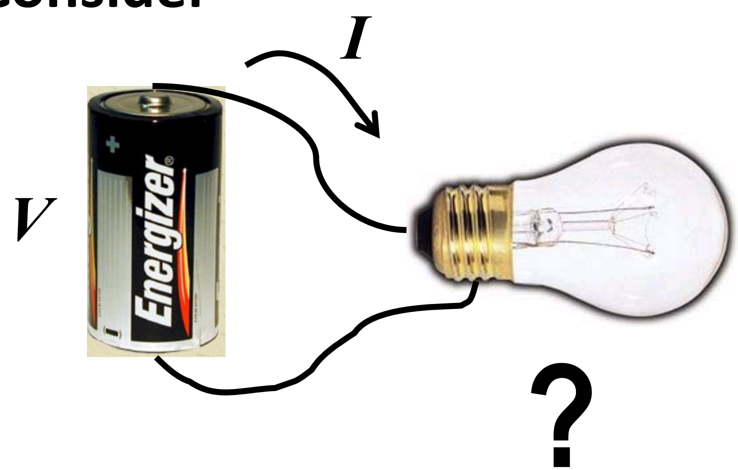
Abstraction

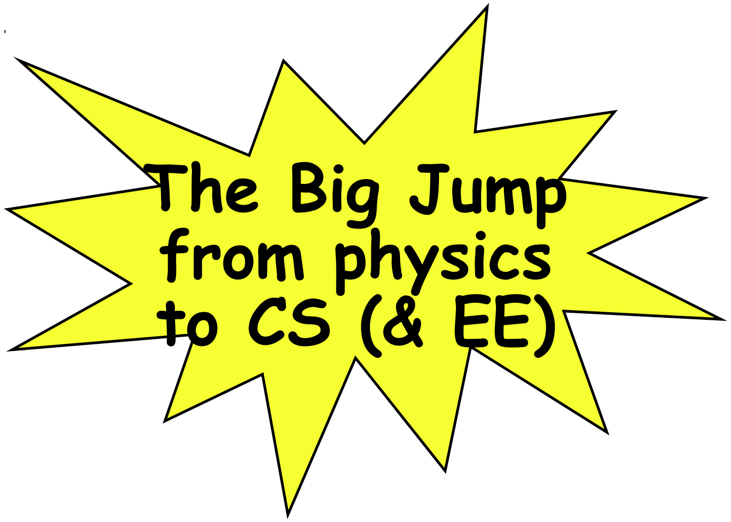
- Abstraction is what CS is all about!



Lumped Circuit Abstraction

Consider





- **Question: What is the current (I) through the light bulb?**

Lumped Circuit Abstraction

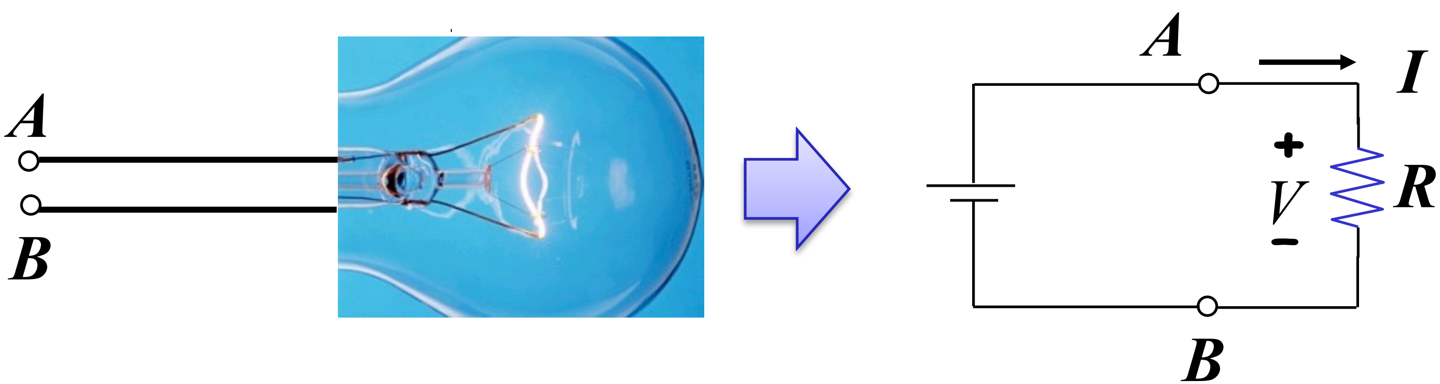
- **We could do it the Hard Way…**
  - Apply Maxwell's equations!

	Differential form	**Integral form**	
Faraday's	$\nabla \times E = -\dfrac{\partial B}{\partial t}$	$\oint E \cdot dl = -\dfrac{\partial \phi_B}{\partial t}$	**Voltage (V) (line integral of *E*)**
Continuity	$\nabla \cdot J = -\dfrac{\partial \rho}{\partial t}$	$\oint J \cdot dS = -\dfrac{\partial q}{\partial t}$	**Current (I) (flow of charges crossing S)**
Others	$\nabla \cdot E = \dfrac{\rho}{\varepsilon_0}$	$\oint E \cdot dS = \dfrac{q}{\varepsilon_0}$	
	⋮	⋮	

Lumped Circuit Abstraction

Easy Way!

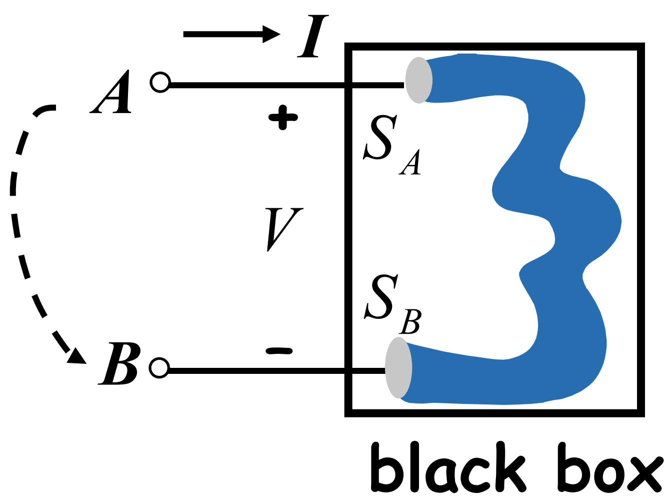
- Replace the bulb with a **discrete resistor** for the purpose of calculating the current.
- *R* is the "lumped circuit abstraction" of the bulb, representing the only property of interest.



and $I = \frac{V}{R}$

Lumped Circuit Abstraction

- **Assumption of LCA**
  - V and I must be defined for the element
  - Thus, element behavior is completely captured by its I-V relationship.

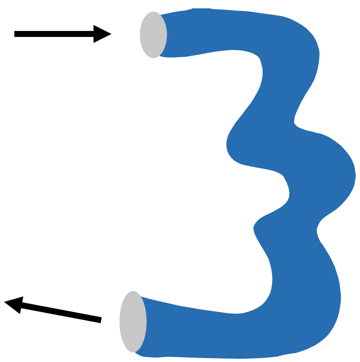


Lumped Circuit Abstraction

- I (Current) must be defined in LCA. It's true when

$$I \text{ into } S_A \quad = \quad I \text{ out of } S_B$$

$$\int_{S_A} J \cdot dS$$



$$\int_{S_B} J \cdot dS$$

from Maxwell

$$\underbrace{\int_{S_A} J \cdot dS}_{I_A} - \underbrace{\int_{S_B} J \cdot dS}_{I_B} = \frac{\partial q}{\partial t}$$

$$I_A = I_B \quad \textbf{only if } \frac{\partial q}{\partial t} = 0$$

So let's assume this

Lumped Circuit Abstraction

- V (Voltage) must also be defined.

see A & L

So let's assume this too

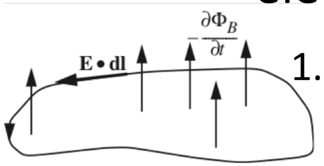
V_{AB} defined when $\frac{\partial \phi_B}{\partial t} = 0$

So $V_{AB} = \int_{AB} E \cdot dl$ outside elements

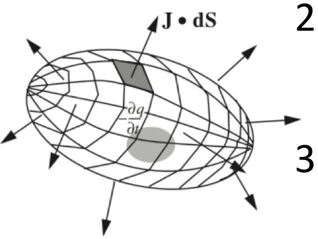
Lumped Matter Discipline (LMD)

Lumped Matter Discipline

- Certain constraints under which voltage, current, and resistance for an element are defined.
- Imposes three constraints on how we choose (lumped) circuit elements.



1. Rate of change of magnetic flux through any closed loop outside an element is zero all the time. $\boxed{\frac{\partial \phi_B}{\partial t} = 0}$

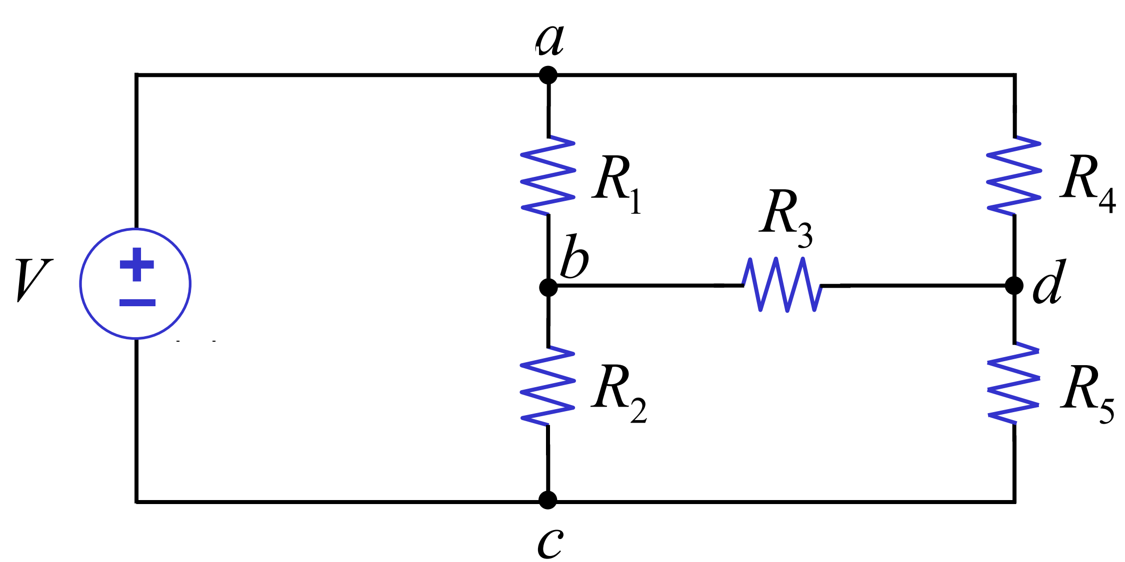


2. Total charge within an element is constant. (i.e., not time-varying) $\boxed{\frac{\partial q}{\partial t} = 0}$
3. Signal timescales are much larger than the propagation delay of electromagnetic waves across the lumped elements.

- Lumped circuit abstraction applies when elements adhere to the lumped matter discipline.

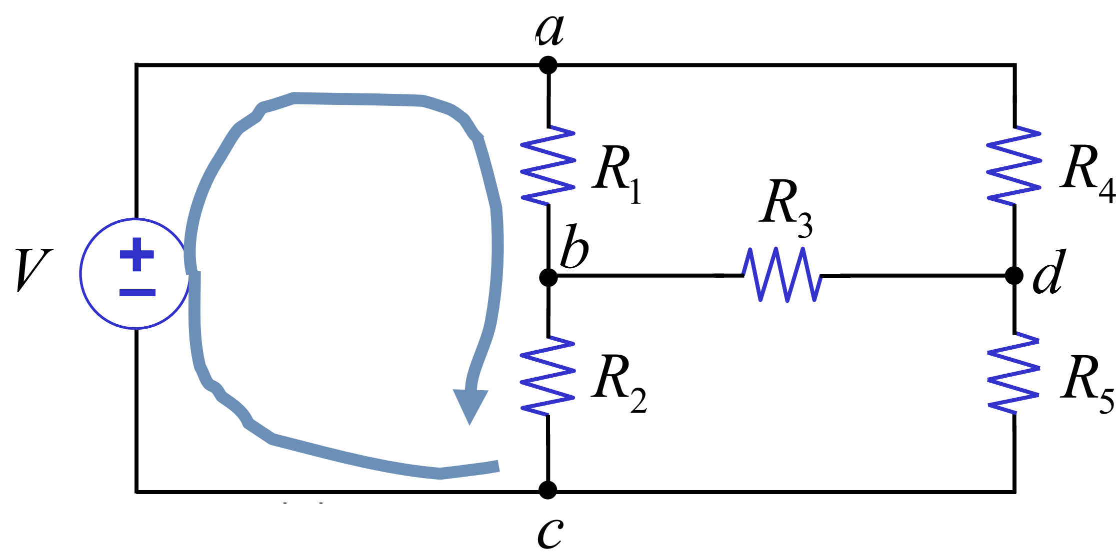
Example: Deriving Kirchhoff's Laws

- **So, what does LCA buy us?**
  - Replace the differential equations with simple algebra using lumped circuit abstraction (LCA).
  - For example - What can we say about voltages in a loop under the lumped matter discipline?



Example: Deriving Kirchhoff's Laws

- What can we say about voltages in a loop under LMD?



$$\oint E \cdot dl = -\cancel{\frac{\partial \phi_B}{\partial t}} \rightarrow 0$$

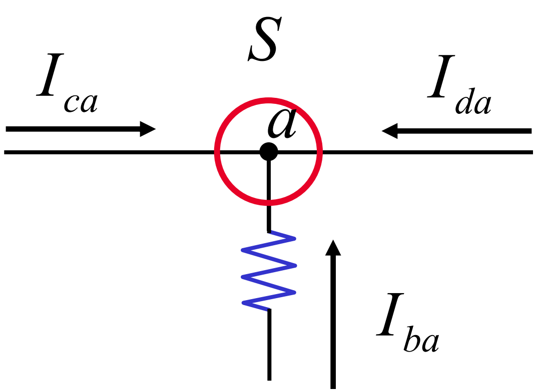
under DMD

$$\Rightarrow \int E \cdot dl + \int E \cdot dl + \int E \cdot dl = 0$$

$\Rightarrow$ **Kirchhoff's Voltage Law (KVL):**
The sum of the voltages in a loop is 0.

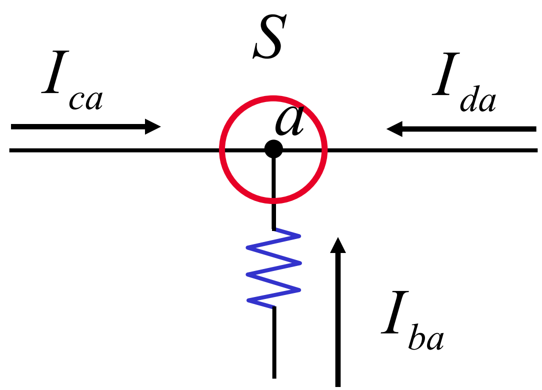
Example: Deriving Kirchhoff's Laws

- **What can we say about currents?**
  - Consider



Example: Deriving Kirchhoff's Laws

- **What can we say about currents?**



$$\oint_S J \cdot dS = -\frac{\partial q}{\partial t}$$

under LMD
0

$$\Longrightarrow I_{ca} + I_{da} + I_{ba} = 0$$

Kirchhoff's Current Law (KCL):

The sum of the currents into a node is 0.

Course Coverage and Schedule*

Schedule	Contents	Remarks [A&L]
Week 1	Course Outline & Introduction	Ch. 1
Weeks 2-3	Analysis of Resistive Networks	Ch. 2-3
Week 4	Analysis of Non-linear Circuits	Ch. 4 (9/25 – Chusok)
Weeks 5-6	Digital Abstraction and MOS Transistors	Ch. 5-6 (10/9 – Hangul)
Week 7	NMOS Amplifiers	Ch. 7
Week 8	Capacitors and Inductors	Ch. 9
Week 9	First-Order Transients	Ch. 10
Week 10	Energy and Power in Digital Circuits	Ch. 11
Week 11	Transients in Second-Order Circuits	Ch. 12
Weeks 12-13	Sinusoidal Steady State and Frequency Response	Ch. 13
Weeks 14-15	OP AMP and Diodes	Ch. 15-16

**** Schedule is tentative and subject to change.***

Grading System*

- Three exams: 30-30-30%
- Homework + Attendance/Class Participation: 10%

** Subject to change.*