Electric Circuits

Lecture 0 – Course Introduction

Dr. Xinbo ZOU

Office: SIST #3-324
Email: zouxb@shanghaitech.edu.cn

Welcome!

- Lectures
  - Tuesday, Thursday 8:15AM – 9:55AM, SIST 1D-108

- Office hours
  - Choose one from the following:

1.Monday: 4:00pm - 5:00pm

2.Tuesday: 7:00pm - 8:00 pm

3.Thursday: 4:00pm -5:00pm

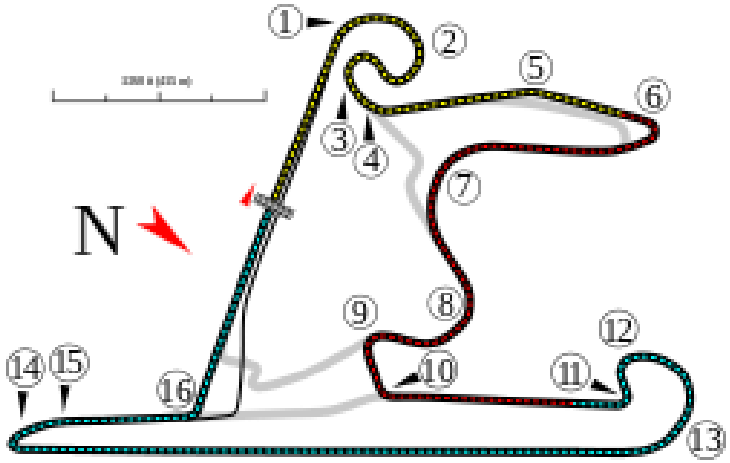
  - Or by appointment

  - TAs:

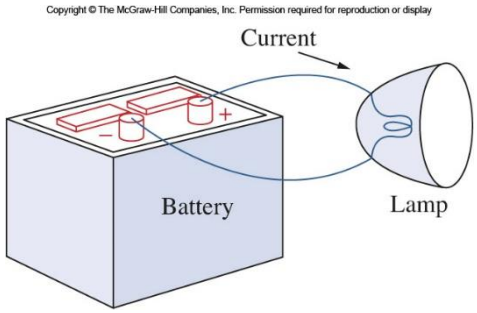
施天远 <shity@shanghaitech.edu.cn>;
黄梓怡 <huangzy1@shanghaitech.edu.cn>

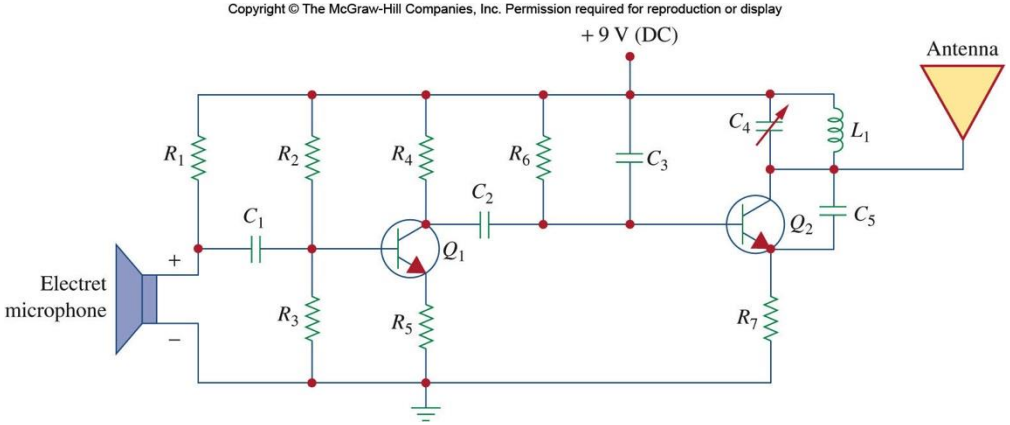
Circuit:

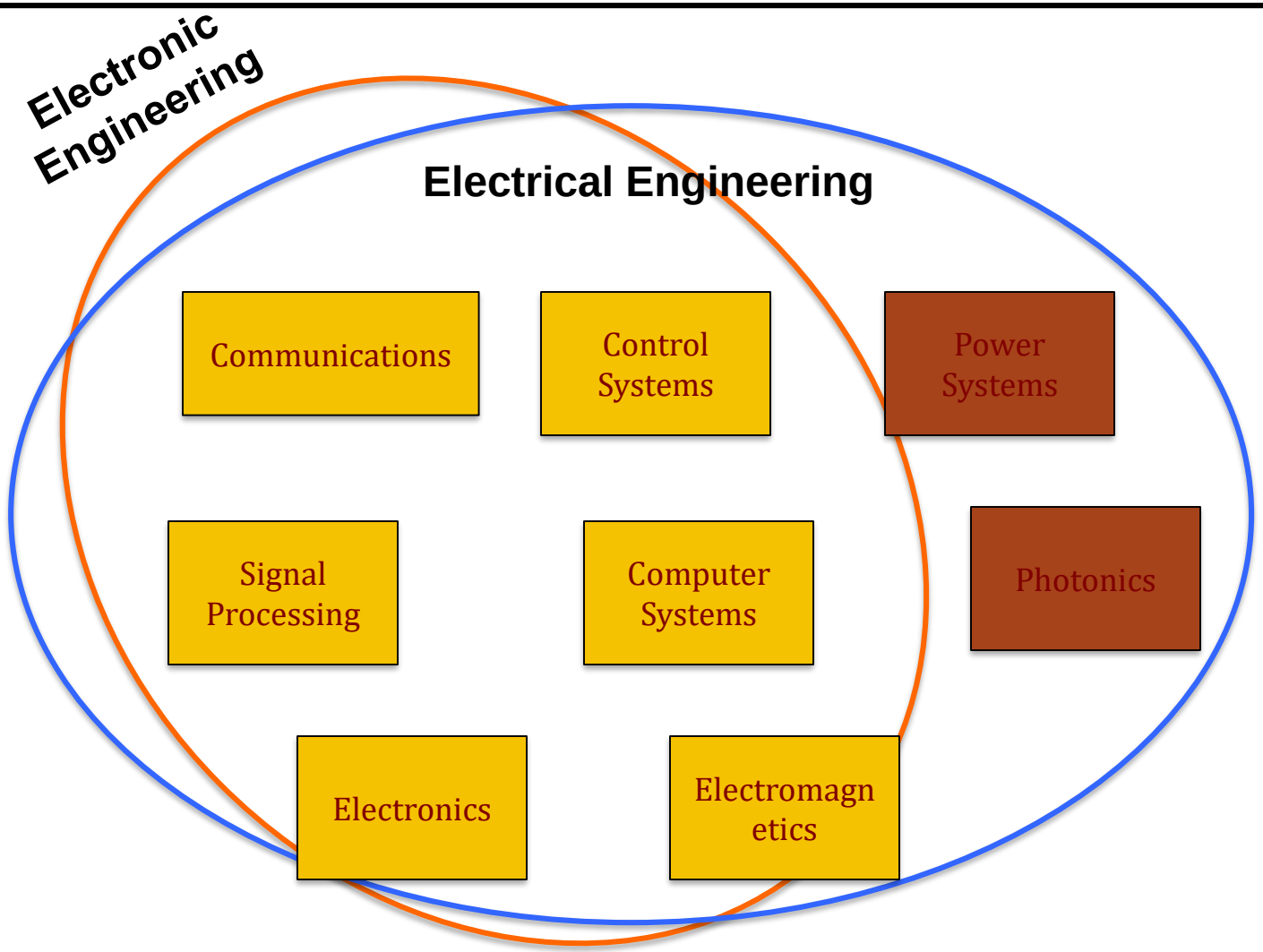
a roughly circular line, route, or movement that starts and finishes at the same place.



- An *electric circuit* is an interconnection of electrical elements.







Circuits are designed for the following two objectives:

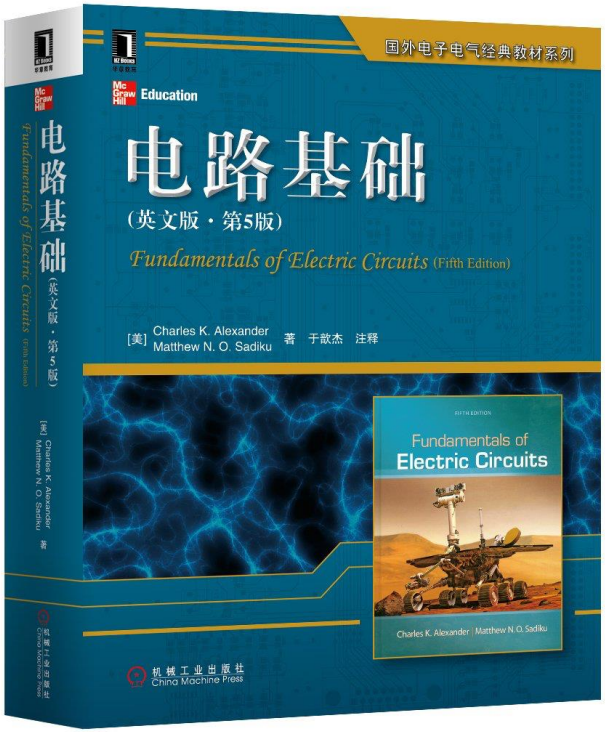
1. To gather, store, process, transport, and present *information*.
2. To distribute, store, and convert ***energy*** between various forms."

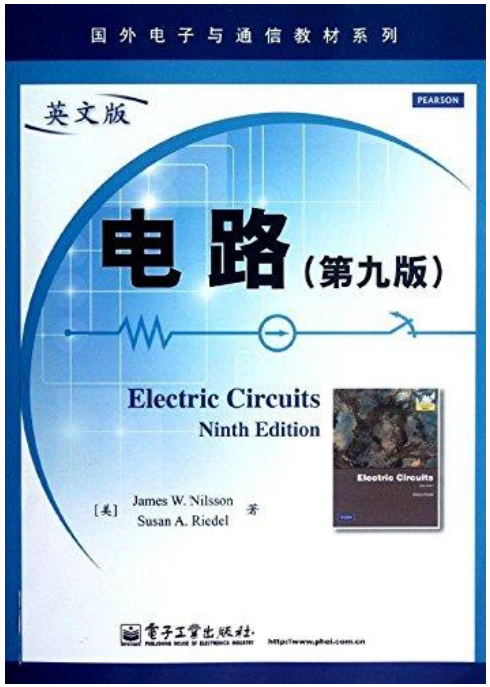
In EE111-Electric Circuits

- You will learn various analysis methods in lectures to analyze the ***behaviors of electric circuits***.
- The methods combine the *physicist's models of natural phenomena* with the *mathematician's tools.*
- ***Behavior analysis often refers to quantitative calculation of electrical element properties: current, voltage, power and so on…***

References

- Charles K. Alexander and Matthew N. O. Sadiku, *Fundamentals of Electric Circuits*, 5th edition, McGraw Hill, 2012.
- James W. Nilsson and Susan Riedel, *Electric Circuits*, 9th edition, Prentice Hall, 2010.





Topics to be Covered in This Course

- Basics: circuit elements; currents, voltages; power/energy;
- Purely resistive circuits:
  - Basic circuit laws (Ohm, Kirchhoff, Wye-Delta etc.)
  - Circuit analysis: nodal analysis and mesh analysis
  - Circuit theorems: Thevenin, Norton, Superposition
  - Operational amplifiers: ideal, inverting/non-inverting, summing and difference)
- Time domain analysis of circuits
  - Capacitor, inductor
  - First-order and second-order circuits
- AC circuits
  - Sinusoidal steady-state analysis and power calculations
  - Three-phase circuits; magnetically coupled circuits
  - Frequency response: transfer function; filters
- Laplace transform

Workload/Grading Policy

- 8 homework assignments: 24%

- 1 Midterm exam (30%) + 1 Final exam (40%)
  - Midterm exam: Week 9 (tentative)
  - Final exam: Week 17-18
  - NO make-up exams!

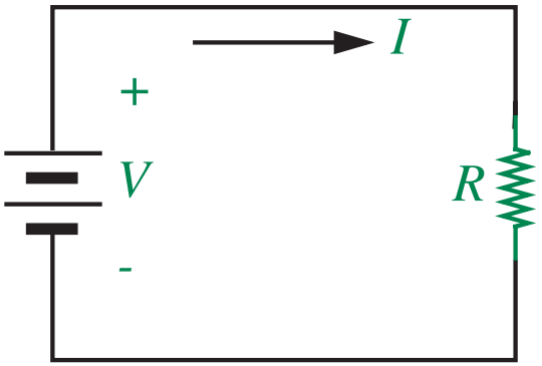
- Quizzes and Attendance Check (6%)
  - Quizzes are held in classes and will not be announced in advance.
  - Again no make-up quizzes.

请务必遵守学术道德规范！

- 单次作业抄袭
  - 抄袭与被抄袭者该次作业均计零分，课程总成绩打九折。
- 累计两次作业抄袭
  - 抄袭与被抄袭者相应作业计零，课程总成绩均打七折。
- 累计三次作业抄袭者，或者考试作弊者
  - 课程总成绩计零，同时上报信息学院学术委员会处理。

Lecture 1
Circuit Terminology

The Ideal Basic Circuit Element

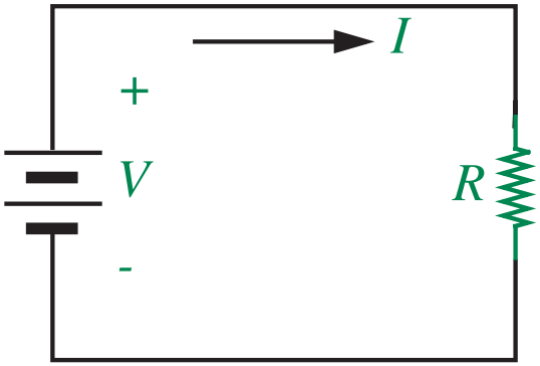


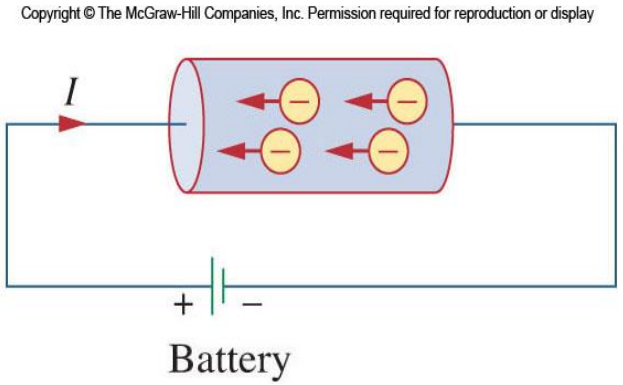
Attributes:

- Two terminals (points of connection)
- Mathematically described in terms of current and/or voltage
- Cannot be subdivided into other elements

Electric Current

- Charges in motion leads to electric flow (current)





- The current flowing through a surface can be defined as

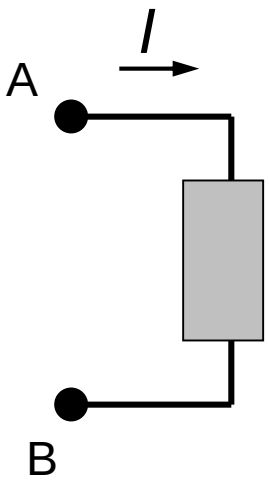
$$I = \frac{dq}{dt}$$

Unit: A

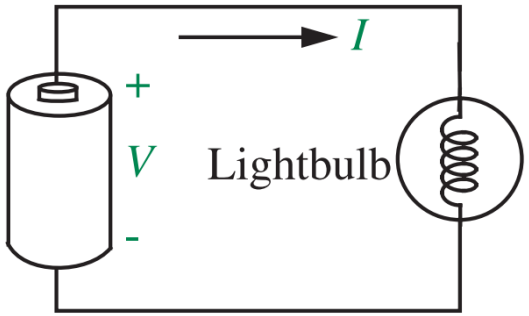
- Conventional to take the current flow as the movement of positive charges

Reference directions for current

- In order to perform circuit analysis to determine the currents in an electric circuit, you need to specify reference directions.



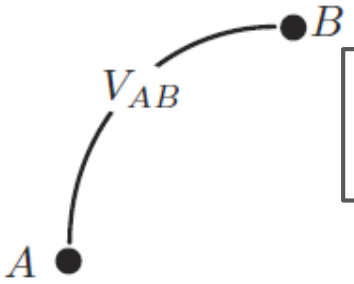
- Reference direction for the current is indicated by an arrow.



In electrical circuits, the path of motion is well defined by wires/circuit elements.

Voltage difference

- The voltage difference V_{AB} between *A* and *B* is the amount of potential energy difference, when moving a unit of charge from A to B.

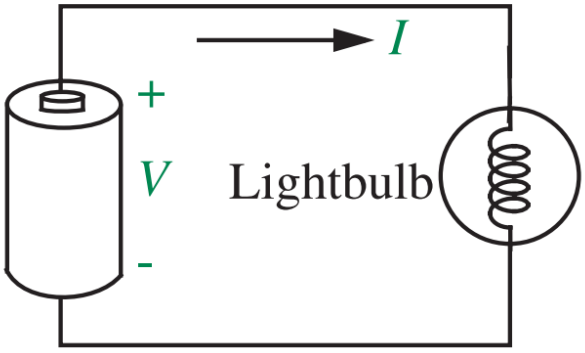


$$V_{AB} = \frac{d\mathrm{E}}{dq}$$

Unit: V

  - If a total charge of Δq is moved from $A \rightarrow B$, the energy **difference** is

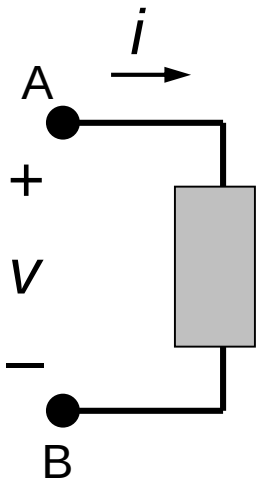
$$E_A - E_B = \Delta E = \Delta q \cdot V_{AB}$$



Voltage is a relative quantity and usually is implicitly referenced to a known point in the circuit (ground) or in some cases a point at infinity.

Reference directions for voltage

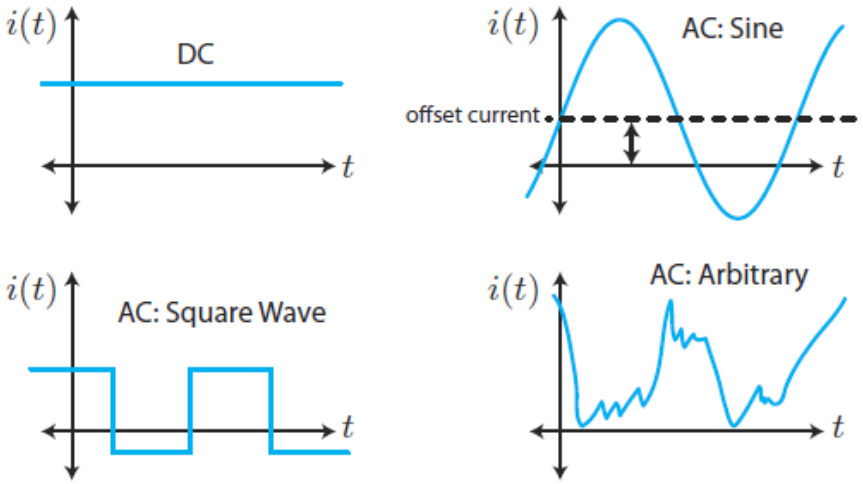
- In circuit analysis, in order to determine the voltages in an electric circuit, one needs to specify reference directions.



- Polarity reference for voltage can be indicated by plus and minus signs.

$$V_{AB} \equiv V_A - V_B$$

DC versus (v.s.) AC



- A constant current is called a “Direct Current" (DC). Otherwise it’s AC (alternating current).
  - Some AC typical waveforms are shown above. Any time-varying current is known as an AC.
  - Note that the sign of the current does not necessarily have to change (the current does not have to alter direction).

Circuit Elements

- 5 ideal basic circuit elements:
  - voltage source
  - current source

  } ***active elements***, capable of generating electric energy

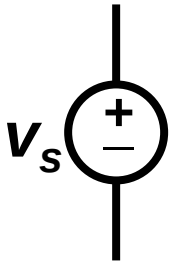
  - resistor
  - inductor
  - capacitor

  } ***passive elements***, incapable of generating electric energy

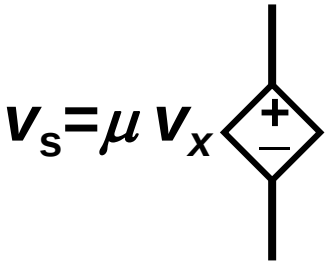
Ideal Voltage Source

- Circuit element that maintains a prescribed voltage across its terminals, **regardless of the current flowing in those terminals**.
- Voltage is known, but current is determined by the circuit to which the source is connected.
- The voltage can be either **independent** or **dependent** on a voltage or current elsewhere in the circuit.

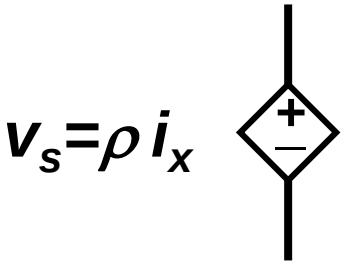
Device symbols:



independent



voltage-controlled

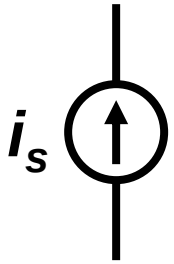


current-controlled

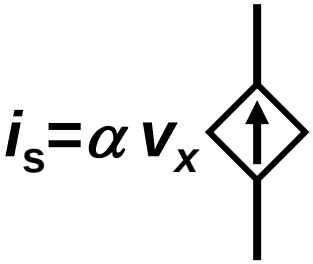
Ideal Current Source

- Circuit element that maintains a prescribed current through its terminals, **regardless of the voltage across those terminals**.
- Current is known, but voltage is determined by the circuit to which the source is connected.
- The current can be either **independent or dependent** on a voltage or current elsewhere in the circuit.

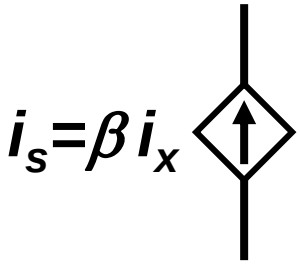
Device symbols:



independent



voltage-controlled



current-controlled

Resistor/Resistance/Conductance

Circuit symbol: 

Unit: **Ohm (*Ω*)**

- The current flowing in the resistor is proportional to the voltage across the resistor:

$$V = I\,R$$ (Ohm's Law)

- **Conductance** is the reciprocal of resistance

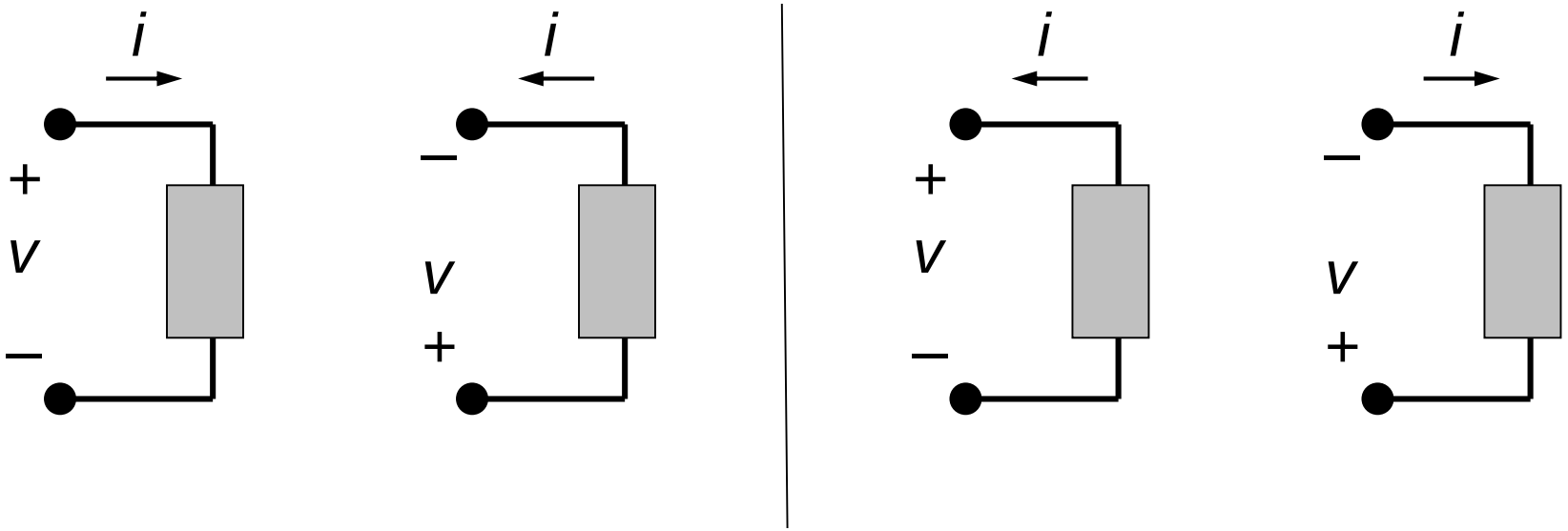
$$G = \frac{1}{R} = \frac{\mathrm{I}}{V}$$

Unit: Siemens (S)

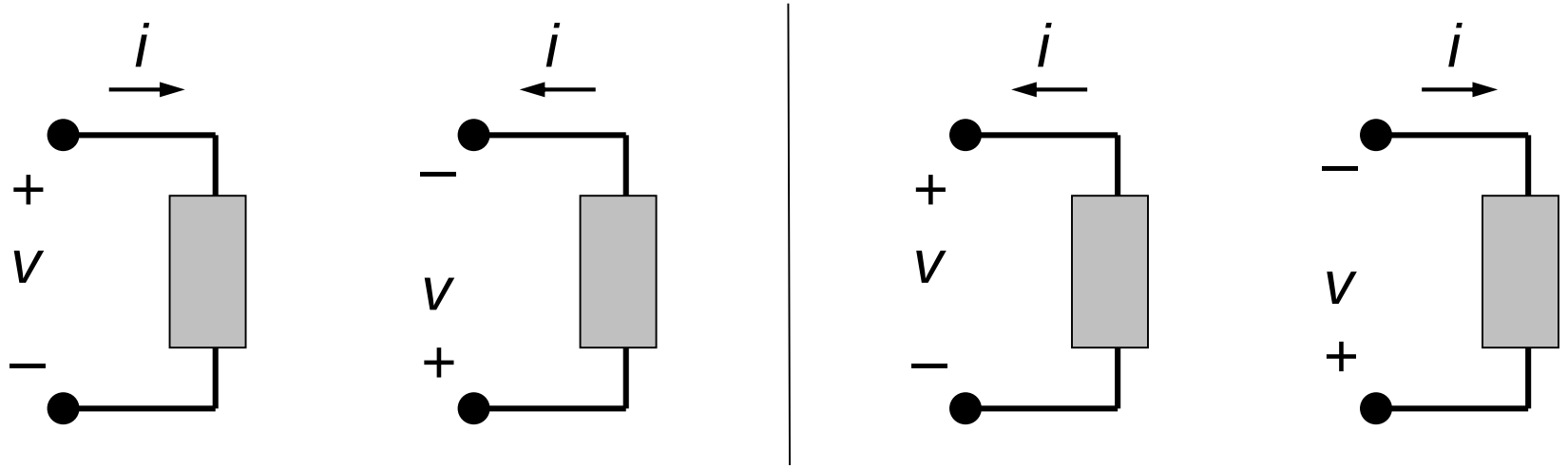
Werner von Siemens
1816-1892

Passive Sign Convention

- Whenever the reference direction for the current in an element is in the direction of the reference voltage drop across the element, use positive sign in any expression that relates the voltage to the current. Otherwise, use a negative sign.



Passive Sign Convention

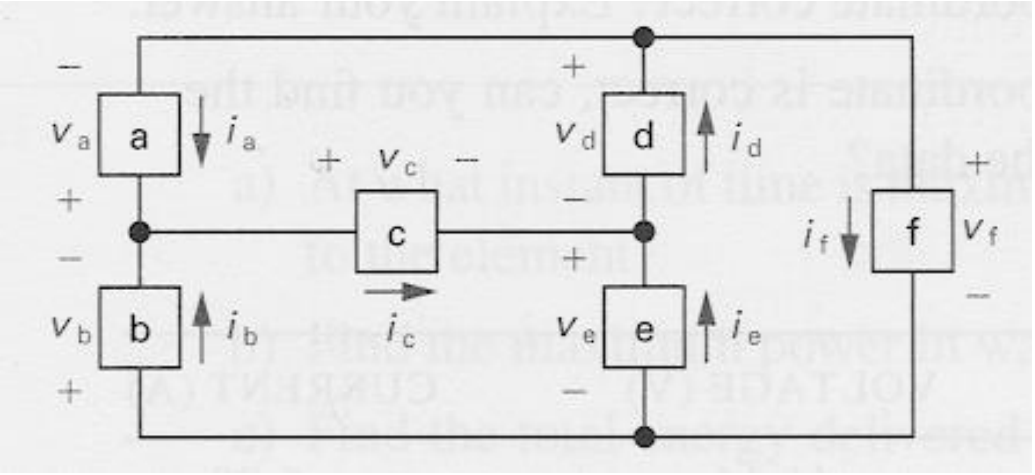


$p = vi$ $p = -vi$

- If $p > 0$, power is absorbed by the element.
  - electrical energy into heat (resistors in toasters), light (light bulbs), or acoustic energy (speakers); by storing energy (charging a battery).
- If $p < 0$, power is extracted from the element.

Power Calculation Exercise

Find the power absorbed by each element:

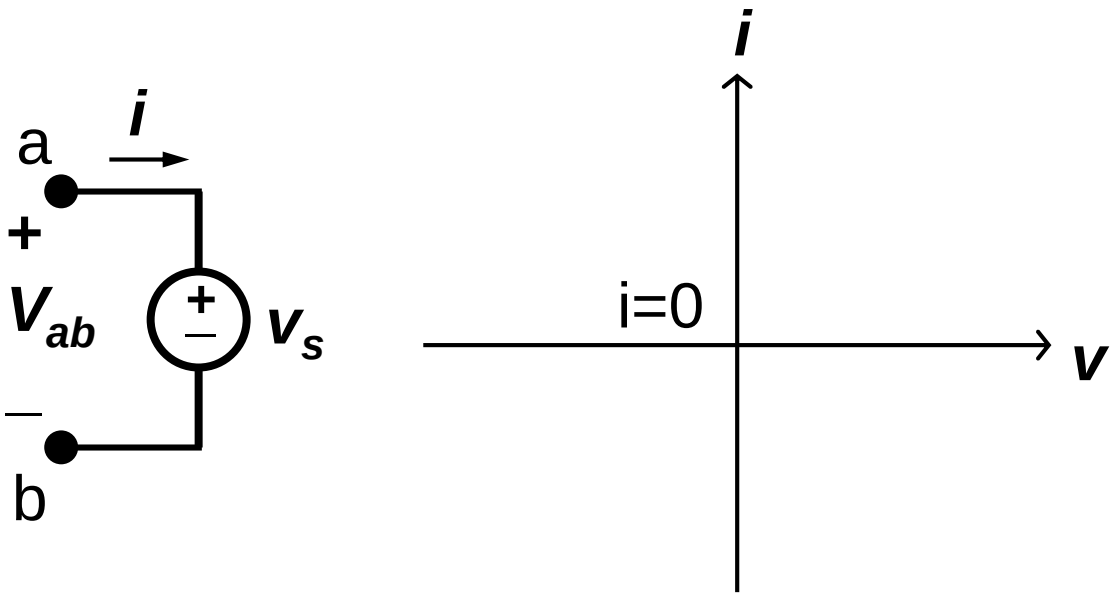


ELEMENT	VOLTAGE (V)	CURRENT (A)
a	−18	−51
b	−18	45
c	2	−6
d	20	−20
e	16	−14
f	36	31

Conservation of energy:
Does total power delivered equal total power absorbed?

[Source: Berkeley]

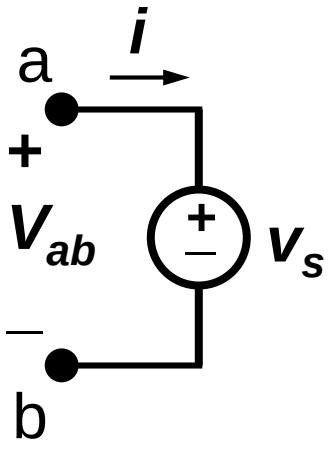
I-V Characteristic of Ideal Voltage Source

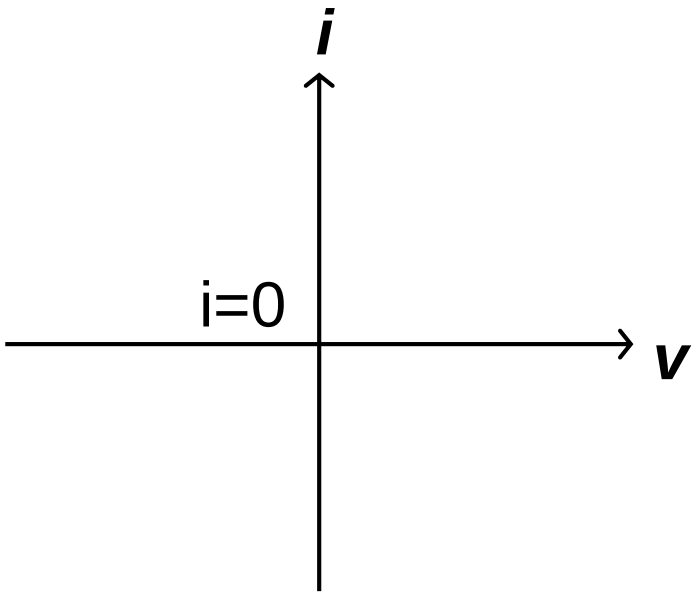


Plot the *I-V* characteristic for $v_s > 0$. For what values of *i* does the source absorb power? For what values of *i* does the source release power?

[Source: Berkeley]

I-V Characteristic of Ideal Voltage Source

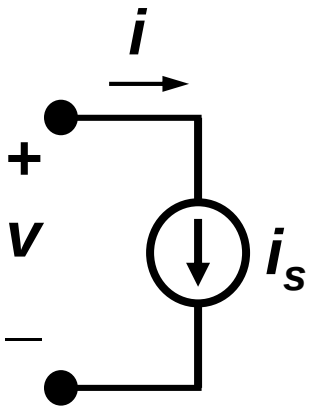


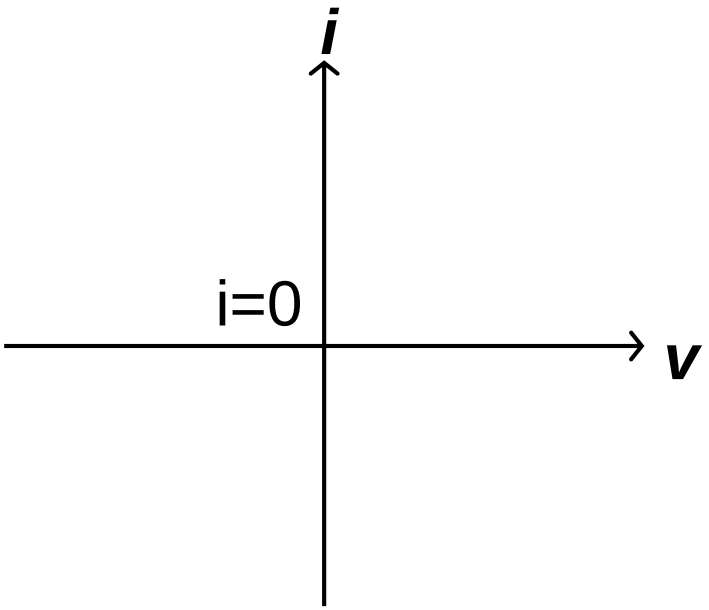


Plot the *I-V* characteristic for $v_s < 0$. For what values of *I* does the source absorb power? For what values of *i* does the source release power?

[Source: Berkeley]

I-V Characteristic of Ideal Current Source

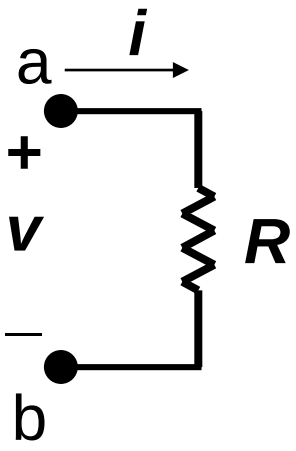


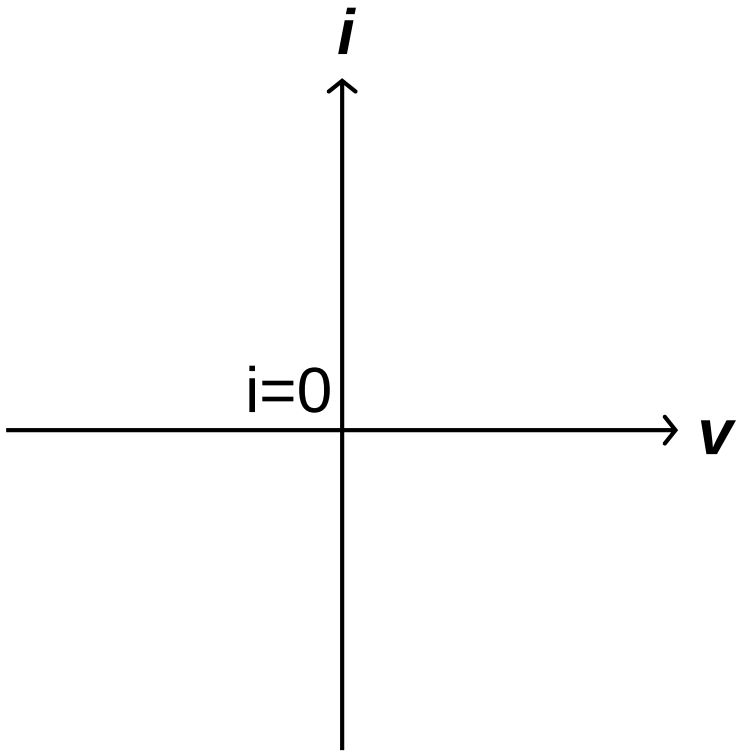


Plot the *I-V* characteristic for $i_s > 0$. For what values of *v* does the source absorb power? For what values of *v* does the source release power?

[Source: Berkeley]

I-V Characteristic of Ideal Resistor





Plot the *I-V* characteristic for $R = 1$ k ohm.

What is the slope?

[Source: Berkeley]

SI Unit prefixes

Prefix	Symbol	10^n	Prefix	Symbol	10^n
yotta	Y	10^{24}	deci	d	10^{-1}
zetta	Z	10^{21}	centi	c	10^{-2}
exa	E	10^{18}	milli	m	10^{-3}
peta	P	10^{15}	micro	μ	10^{-6}
tera	T	10^{12}	nano	n	10^{-9}
giga	G	10^{9}	pico	p	10^{-12}
mega	M	10^{6}	femto	f	10^{-15}
kilo	k	10^{3}	atto	a	10^{-18}
hecto	h	10^{2}	zepto	z	10^{-21}
deca	da	10^{1}	yocto	y	10^{-24}

Exercise

- Calculate the power supplied or absorbed by each element in the following figure.