EEE103 ELECTRICAL CIRCUITS

WEEK1- BASIC COMPONENTS AND ELECTRIC CIRCUITS

Ye Wu
ye.wu@xjtlu.edu.cn
Xi'an Jiaotong-Liverpool University
西交利物浦大学

Overview of Part 1

LO: Be familiar with the various laws and theorems in electrical circuit analysis.

- Week 1: Basic Components and Electric Circuits
- Week 2 : Voltage and Current Laws
- Week 3 : Basic Nodal and Mesh Analysis
- Week 4 : Handy Circuit Analysis Techniques

Homework Assignment 1 : Due Week 5

In Class Quiz 1: Week4 tutorial time. (Take in class).

CONTENT

- Units and Scale
- Charge, Current, Voltage, Power and Energy
- Voltage and Current Source
- Ohm’s Law

The SI System

The value of measurable quantity must have both a number and a unit.

- Base units:

Base Quantity	Name	Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

- Derived units:

Units for other quantities can be derived from these seven base units.

- ✓ work or energy: joule (J) (kg m^2 s^{-2} in SI base units)
- ✓ power (rate of doing work): watt (W)
- ✓ 1 W = 1 J/s

SI: Units and Prefixes

Any measurement can be expressed in terms of a unit, or a unit with a “prefix” modifier.

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

“Engineering Units”

- ✓ Number between 1-999
- ✓ Metric unit using a power divided by 3

Example: 0.048 W = 48 mW = 4.8 cW= 4.8*10^{-2}W

=48000 μW

Current and Charge

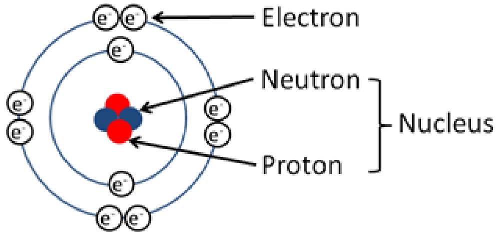
- Charge

Symbol: Q or *q;* units are coulomb (C).

The smallest charge, the *electronic charge*, is carried by

an electron $\left(-1.602\times10^{-19}\ \mathrm{C}\right)$

or a proton $\left(+1.602\times10^{-19}\ \mathrm{C}\right)$.



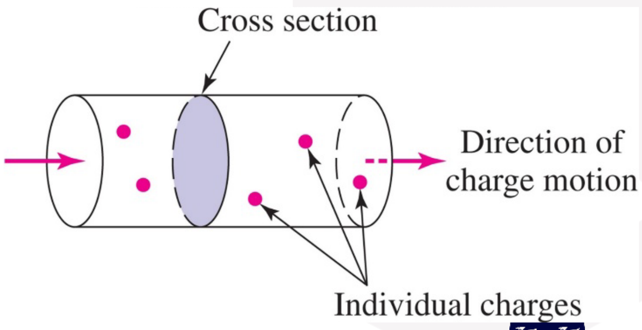
Charge is *conserved*: neither created nor destroyed.

- Current

Symbol: I or i; units are ampere (A)

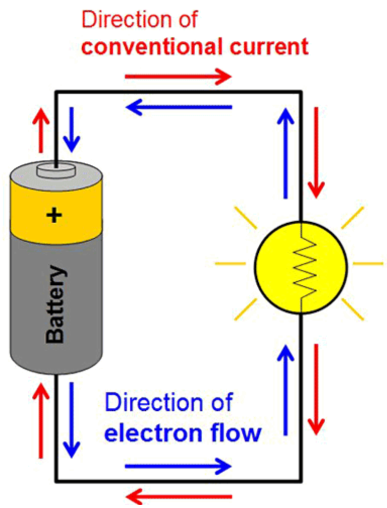
Current is the rate of charge flow:

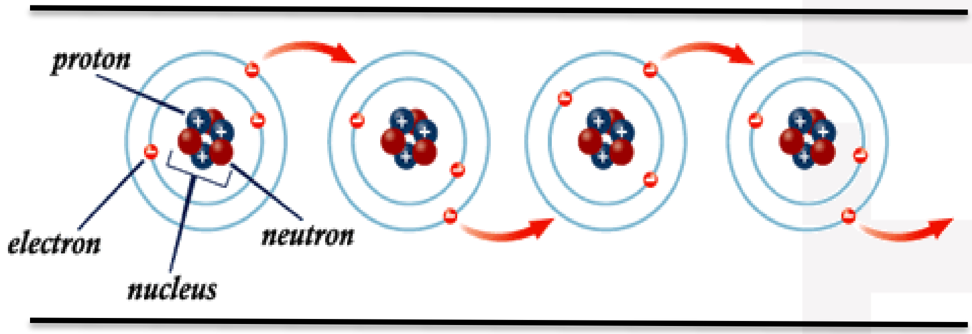
1 ampere = 1 coulomb/second (or 1 A = 1 C/s)



Current and Charge

- Conventional current and Electron current



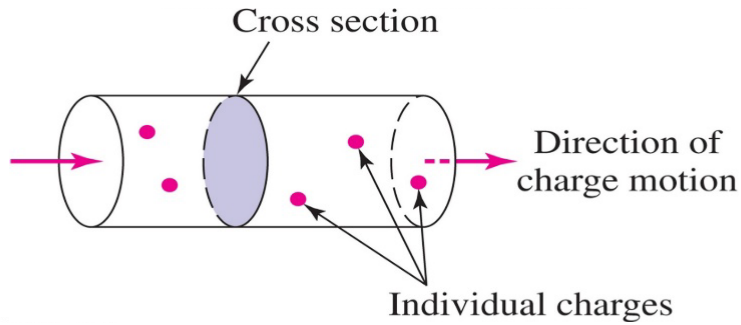


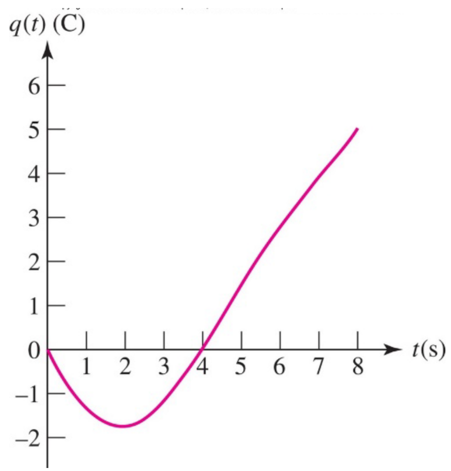
Electron flow model: Electrons flow from the negative terminal to the positive terminal of the source

Conventional current: Positive charges were thought to carry current

Current and Charge

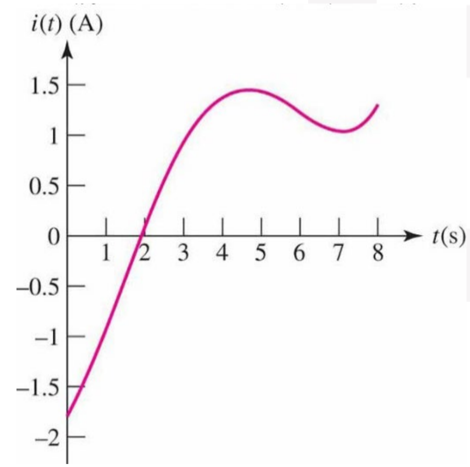
Current is the rate of charge flow: $i = \frac{dq}{dt}$





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

$$q(t) = \int_{t_0}^{t} i\,dt' + q(t_0)$$



(a)

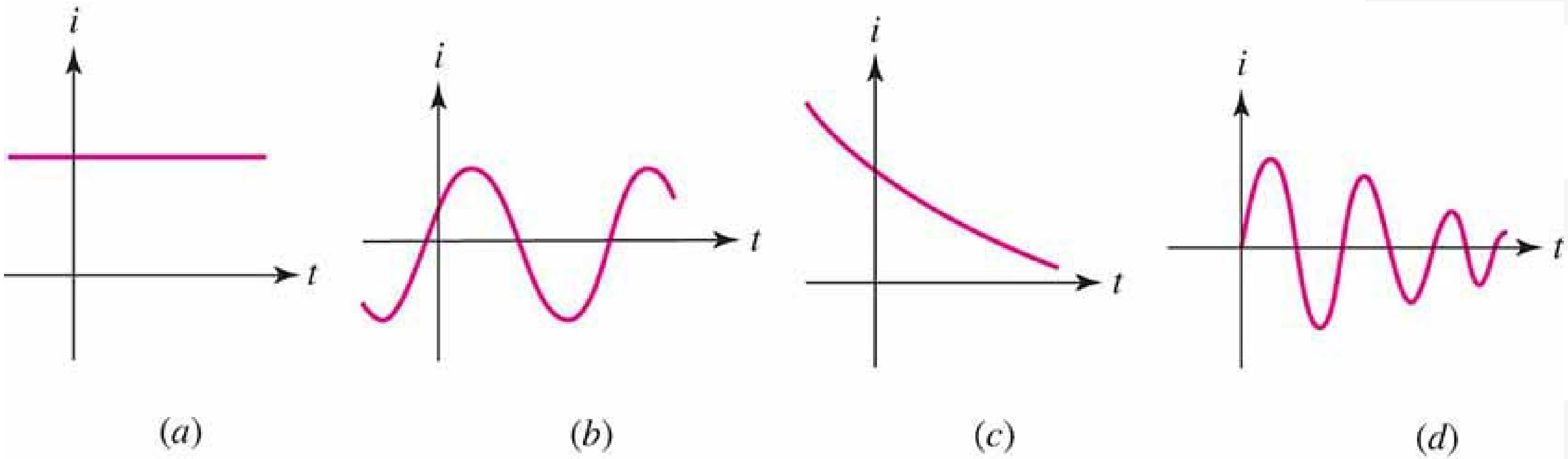
A graph of the instantaneous value of the total charge q(t) that has passed a given reference point since t = 0.

(b)

The instantaneous current i = dq/dt, where q is given in (a)

Current and Charge

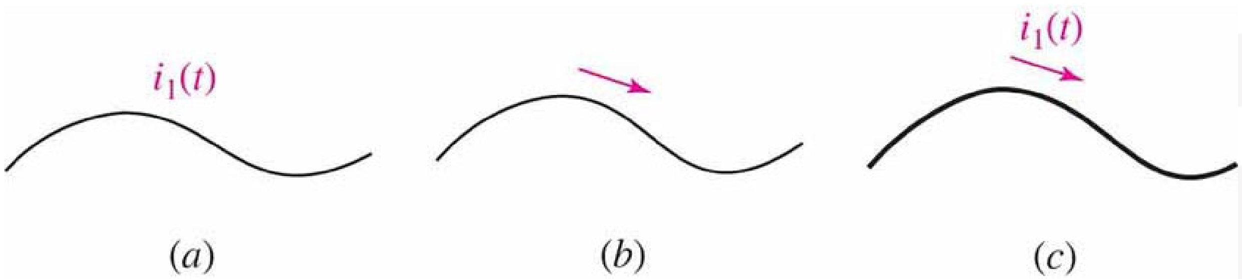
Several types of current:



(a) Direct current (dc). (b) Sinusoidal current (ac). (c) Exponential current. (d) Damped sinusoidal current.

Current and Charge

Current must be designated with both a direction and a magnitude

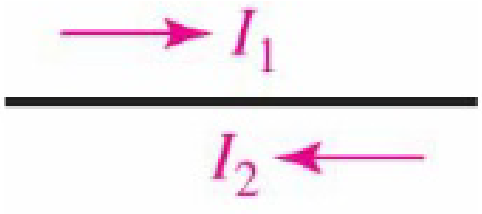


(a, b) Incomplete, improper, and incorrect definitions of a current. (c) The correct definition of i_1 (t).

Two methods of representation for the exact same current.

Example: Current and Charge

Electrons are moving *left to right* to create a current of 1 mA. Determine I_1 and I_2.



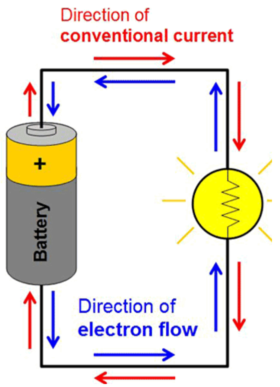
- The direction of electron movement is opposite to the current direction
- Current direction is form right to left.
- I_1 = -1 mA, I_2= +1 mA

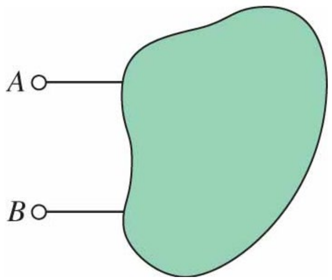
Voltage

- Circuit Elements

A circuit element usually has two terminals (sometimes three or more).

The relationship between the voltage v across the terminals and the current i through the device defines the circuit element model.



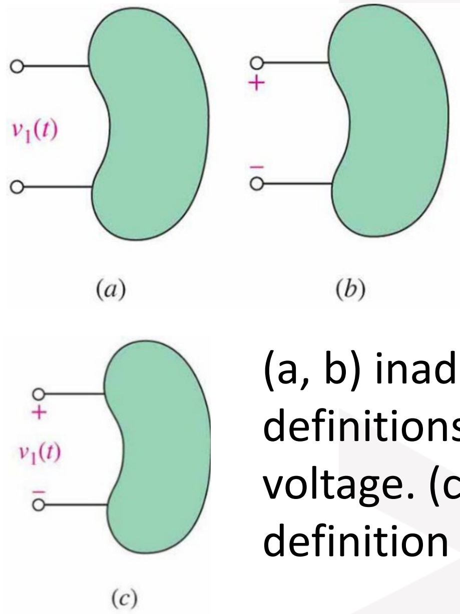


- Voltage

Symbol: V or v*;* units are volt (V)

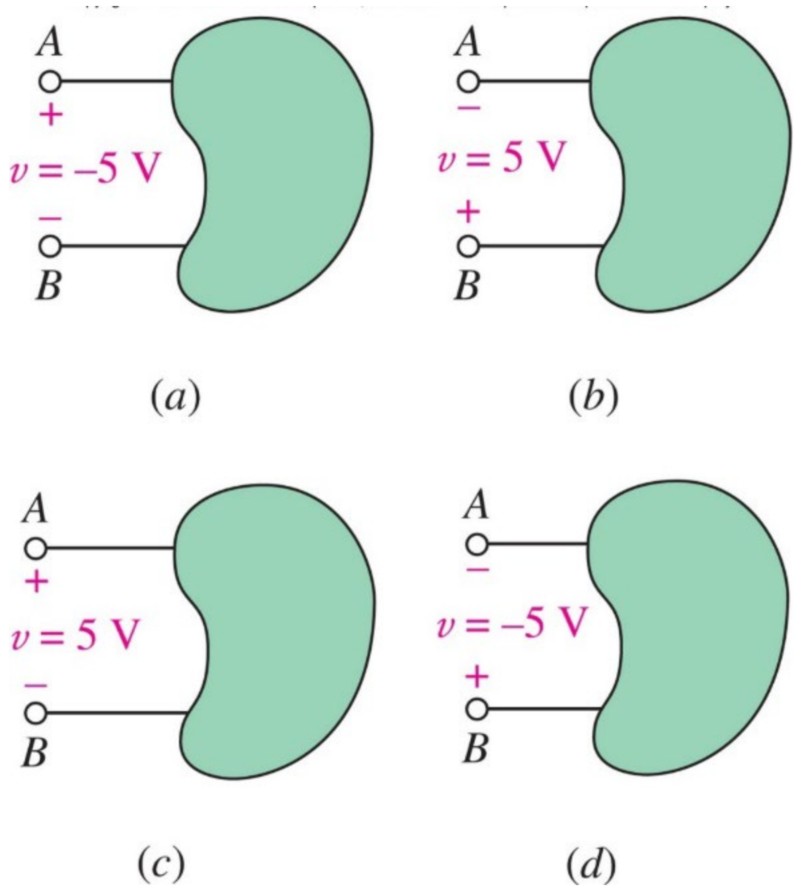
When 1 J of work is required to move 1 C of charge from A to B, there is a voltage of 1 volt between A and B.

Voltage (V or *v*) across an element requires both a magnitude and a polarity.



(a, b) inadequate definitions of a voltage. (c) A correct definition

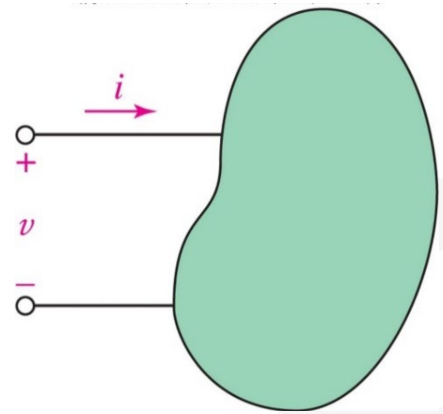
Example: Voltage



(a)=(b), (c)=(d)

Power: *p = vi*

Symbol: P or p*;* units are watt (W)



The power required to push a

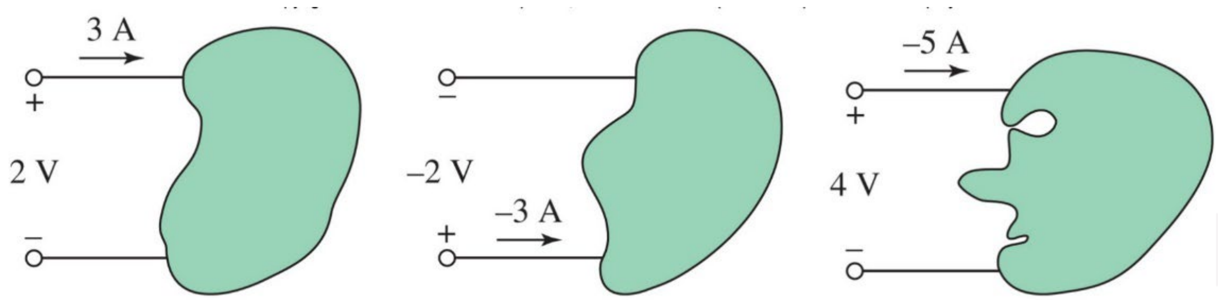
current *i* (C/s) into a voltage *v* (J/C) :

$p = vi$ (J/s = W)

Passive sign convention: the current arrow is directed into the element at the plus marked terminal.

When power is positive, the element is *absorbing* energy.When power is negative, the element is *supplying* energy.

Example: Power Absorbed



(a) (b) (c)

How much power is absorbed by the three elements above?

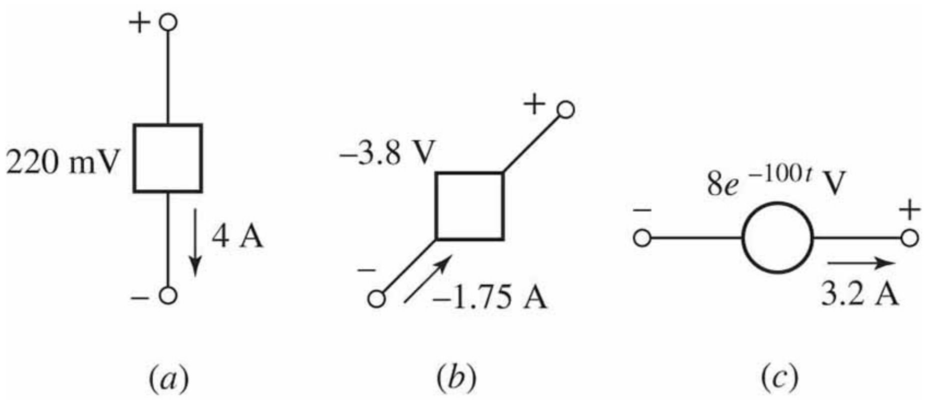
(a) P=2V*3A=6 W

(b) P=-2V*(-3)A =6 W

(c) P=4V*(-5)A =-20 W

*(Note: (c) is actually supplying power)

Example: Power Absorbed



How much power is absorbed by the three elements above?

Energy (w)

Symbol: W or w; units are joule (J)

Energy is integral of power (Power is rate of work/energy)

$$w(t) = \int_{t_0}^{t} p\ dt = \int_{t_0}^{t} vi\ dt$$

(1 joule = 1 watt × 1 second)

Energy determines total electricity need or how long your battery will last.

Other convenient energy unit:

- ✓ watt hours(Wh): 1 Wh = 3600 J
- ✓ kilowatt hours(kWh): 1 kWh = 3.6×10^6 J

Energy Example: Battery

Battery Energy in units of joules (J) or watt-hours (Wh)

Battery capacity often given in amp-hours (Ah)

$$w = \int vi\, dt = V \int i\, dt = VQ$$

w = (battery voltage) × (capacity in Ah)

A 1.5 V battery with capacity of 2 Ah:

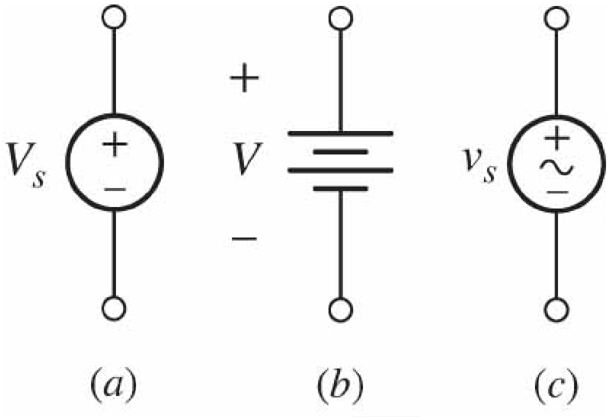
- Has total energy of 3 Wh = 10.8 kJ
- Can supply a circuit drawing 200 mA for 10 h

Independent Voltage Sources

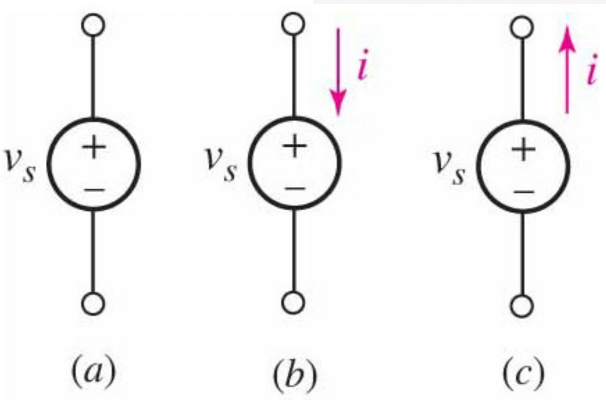
- An ideal voltage source is a circuit element that will maintain the specified voltage v_s across its terminals.

- The current will be determined by other circuit elements.

- An ideal voltage source has no current limit.



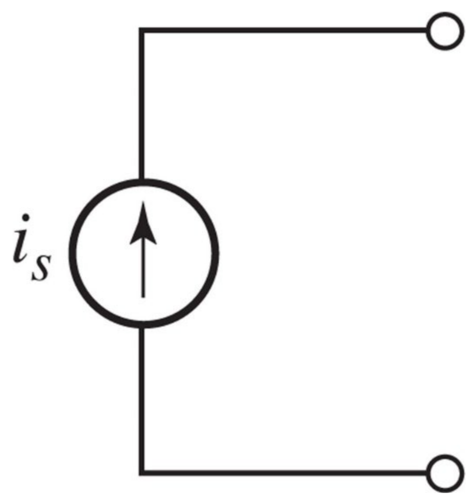
(a) DC voltage source symbol; (b) battery symbol; (c) ac voltage source symbol



Independent Current Sources

An ideal current source is a circuit element that maintains the specified current flow i_s through its terminals.

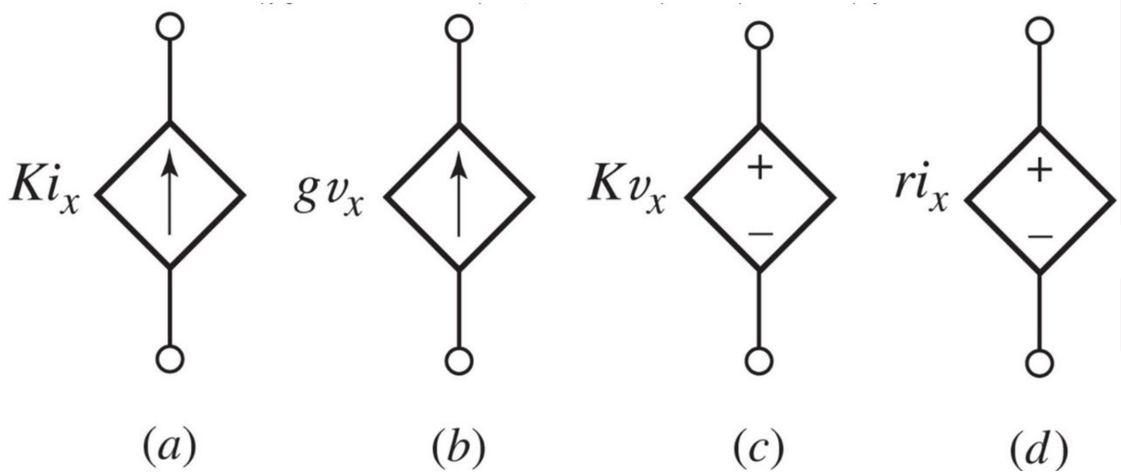
The voltage is determined by other circuit elements ($V \neq 0$).



Dependent Sources

Dependent current sources (a) and (b) maintain a *current* specified by another circuit variable.

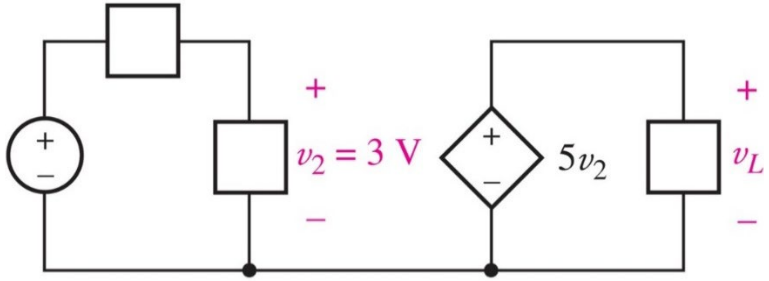
Dependent voltage sources (c) and (d) maintain a *voltage* specified by another circuit variable.



K:dimensionless scaling constant
g: scaling factor with units of A/V
r: scaling factor with units of V/A

Example: Dependent Sources

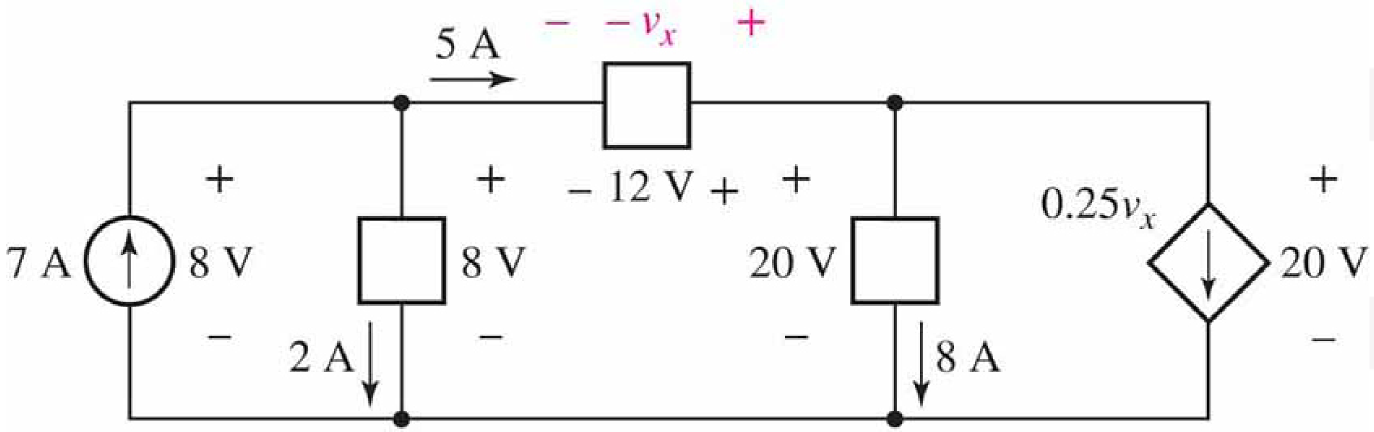
If v_2 is known to be 3V, find the voltage v_L in the circuit below.



$$v_L = 5v_2 = 5 * 3V = 15V$$

Practice

Find the power absorbed by each element in the circuit

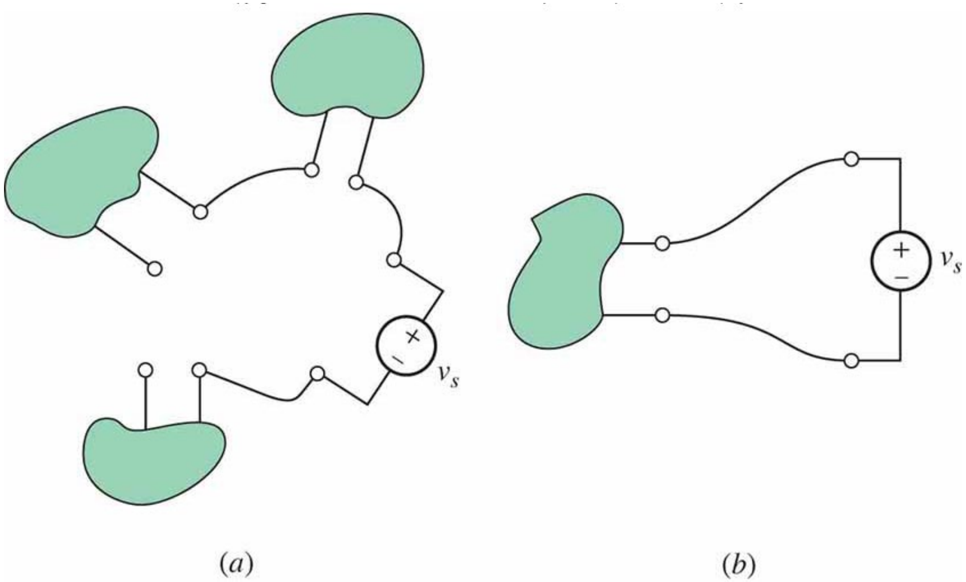


Networks and Circuits

Network: The interconnection of two or more simple *circuit elements* forms an electrical network.

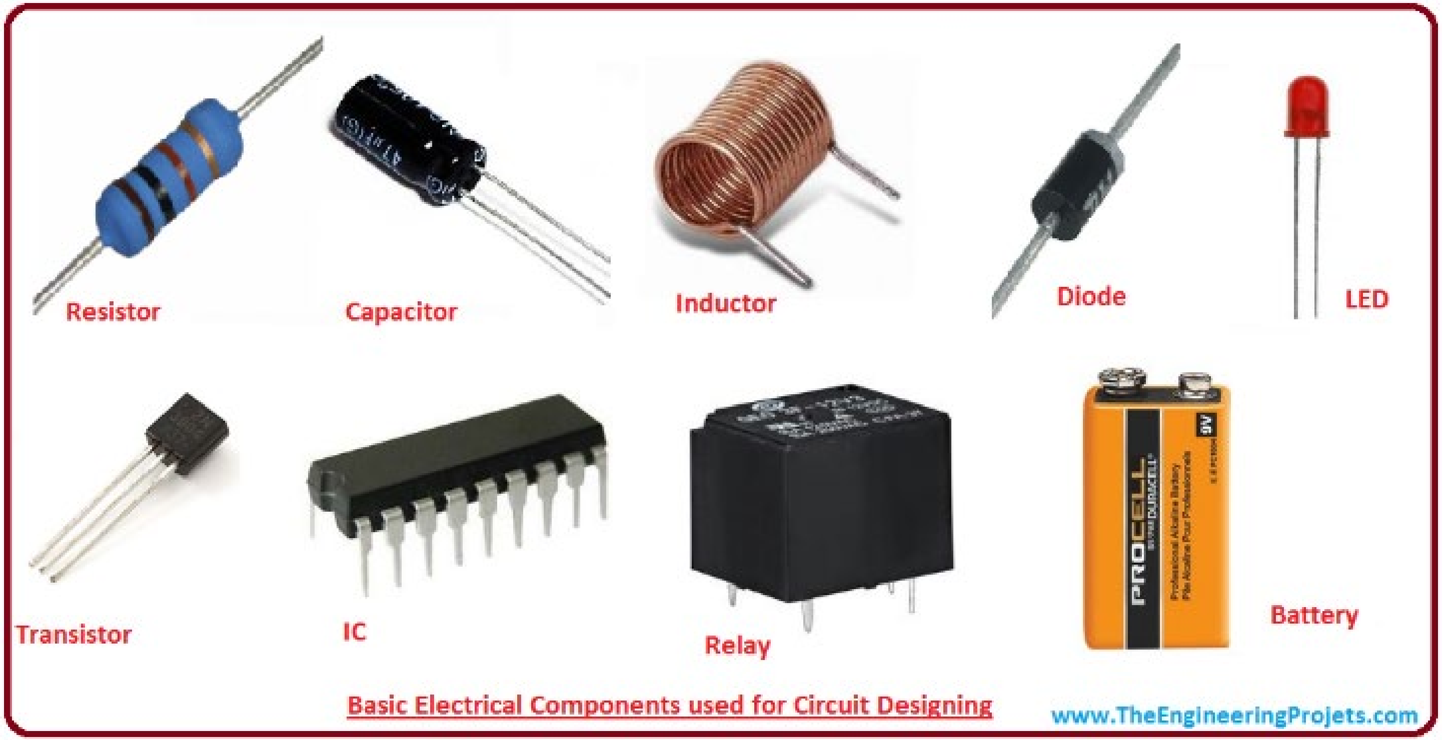
Circuit: If the network contains at least one closed path, it is also an electric circuit.

(Note: Every circuit is a network, but not all networks are circuits)



(a) A network that is not a circuit.
(b) A network that is a circuit.

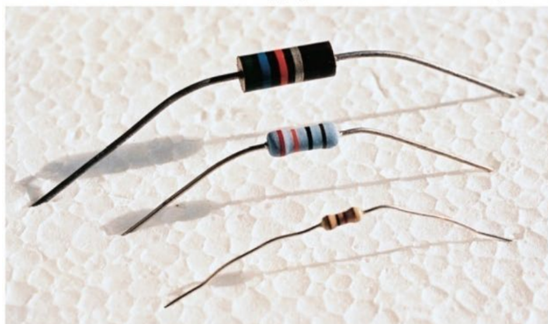
Basic Components



Resistors

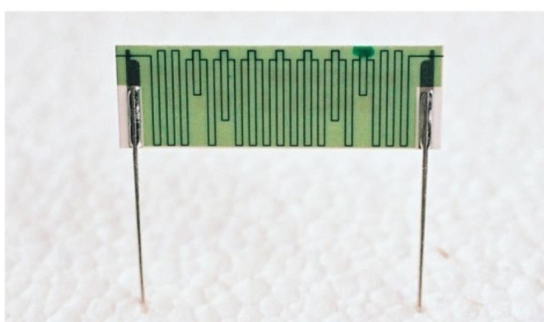
(a) typical resistors (b) power resistor

(c) a 10 TΩ resistor (d) circuit symbol



(a)

(b)



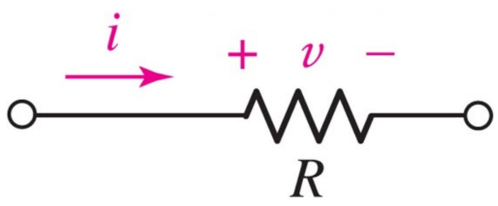
(c)

(d)

Ohm's Law: Resistance

A (linear) resistor is an element for which

$$v = iR$$

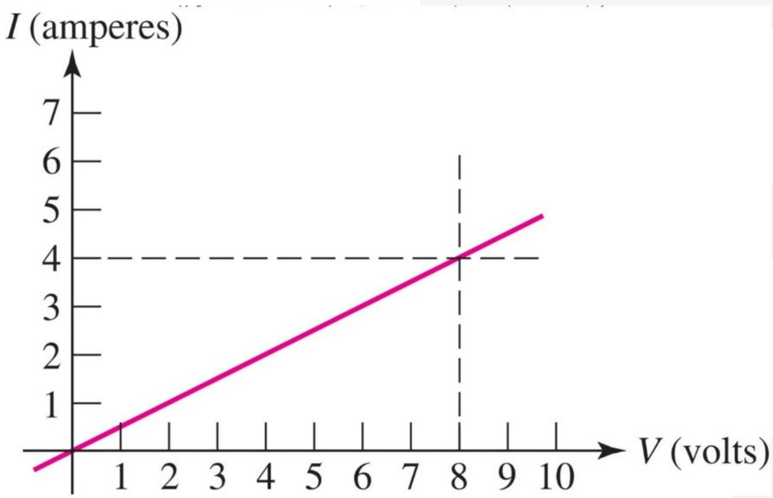


where the constant R is a resistance.

The equation is known as "Ohm's Law."

The unit of resistance is **ohm (Ω)**.

$$1\ \Omega = 1\ \text{V/A}$$



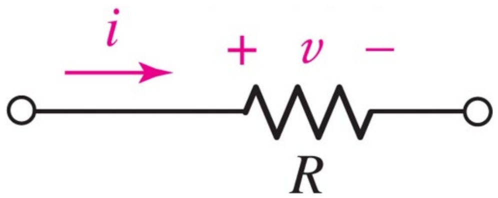
In this example, the slope is 4A/8V or 0.5 Ω^{-1}.

This is the graph for a 2 ohm resistor

Power Absorption

Resistors absorb power: since *v* = *iR*

(v and i are selected to satisfy the passive sign convention)



$$p = vi = v^2/R = i^2 R$$

Positive power means the device is absorbing energy.

Power is always positive for a resistor! (or a resistor is always obsorbing energy)

Example: Resistor Power

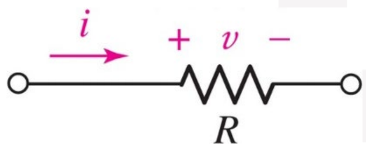
A 560 Ω resistor is connected to a circuit which causes a current of 42.4 mA to flow through it.

Calculate the voltage across the resistor and the power it is dissipating.

$$v = iR = (0.0424)(560) = 23.7 \text{ V}$$

$$p = vi = (23.7V)(42.4mA) = 1.005\text{W}$$

Alternatively:



$$p = i^2 R = (0.0424)^2 (560) = 1.007 \text{ W}$$

Or:

$$p = v^2/R = (23.7)^2/560 = 1.003W$$

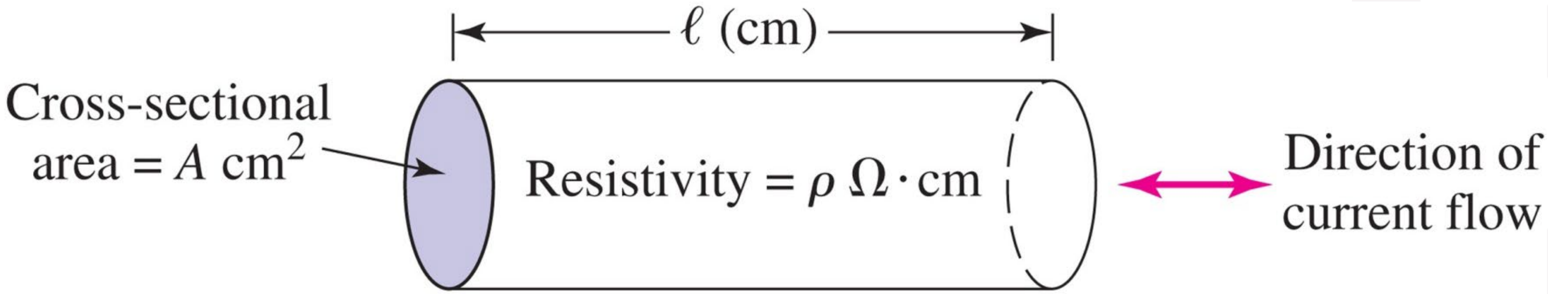
Ohms Law Formulas

Ohms Law Formulas				
Known Values	Resistance (R)	Current (I)	Voltage (V)	Power (P)
Current & Resistance	---	---	$V = I \times R$	$P = I^2 \times R$
Voltage & Current	$R = \frac{V}{I}$	---	---	$P = V \times I$
Power & Current	$R = \frac{P}{I^2}$	---	$V = \frac{P}{I}$	---
Voltage & Resistance	---	$I = \frac{V}{R}$	---	$P = \frac{V^2}{R}$
Power & Resistance	---	$I = \sqrt{\frac{P}{R}}$	$V = \sqrt{P \times R}$	---
Voltage & Power	$R = \frac{V^2}{P}$	$I = \frac{P}{V}$	---	---

Wire Gauge and Resistivity

The resistance of a wire is determined by the resistivity of the conductor as well as the geometry:

$$R = \rho l / A$$



[In most cases, the resistance of wires can be assumed to be 0 ohms.]

Common Electrical Wire Materials and Resistivities

ASTM Specification**	Temper and Shape	Resistivity at 20°C ($\mu\Omega \cdot cm$)
B33	Copper, tinned soft, round	1.7654
B75	Copper, tube, soft, OF copper	1.7241
B188	Copper, hard bus tube, rectangular or square	1.7521
B189	Copper, lead-coated soft, round	1.7654
B230	Aluminum, hard, round	2.8625
B227	Copper-clad steel, hard, round, grade 40 HS	4.3971
B355	Copper, nickel-coated soft, round Class 10	1.9592
B415	Aluminum-clad steel, hard, round	8.4805

* C. B. Rawlins, "Conductor materials," *Standard Handbook for Electrical Engineering,* 13th ed., D. G. Fink and H. W. Beaty, eds. New York: McGraw-Hill, 1993, pp. 4-4 to 4-8.

** American Society of Testing and Materials.

Conductance

We sometimes prefer to work with *the reciprocal of resistance* (1/*R*), which is called conductance (symbol *G*, unit siemens (S)).

A resistor *R* has conductance $G = 1/R$.

Ohm's law (*i*-*v* equation) can be written as

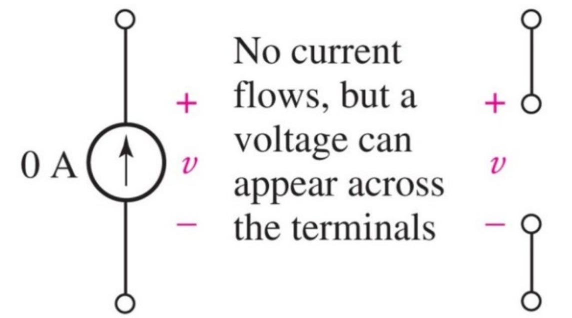
$$i = Gv$$

Open and Short Circuits

An open circuit between A and B means $I = 0$.

Voltage across an open circuit: any value.

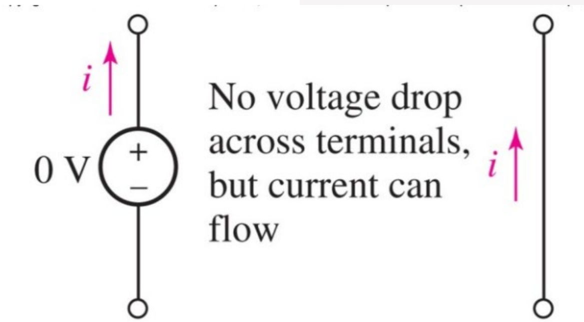
An open circuit is equivalent to R = ∞ Ω.

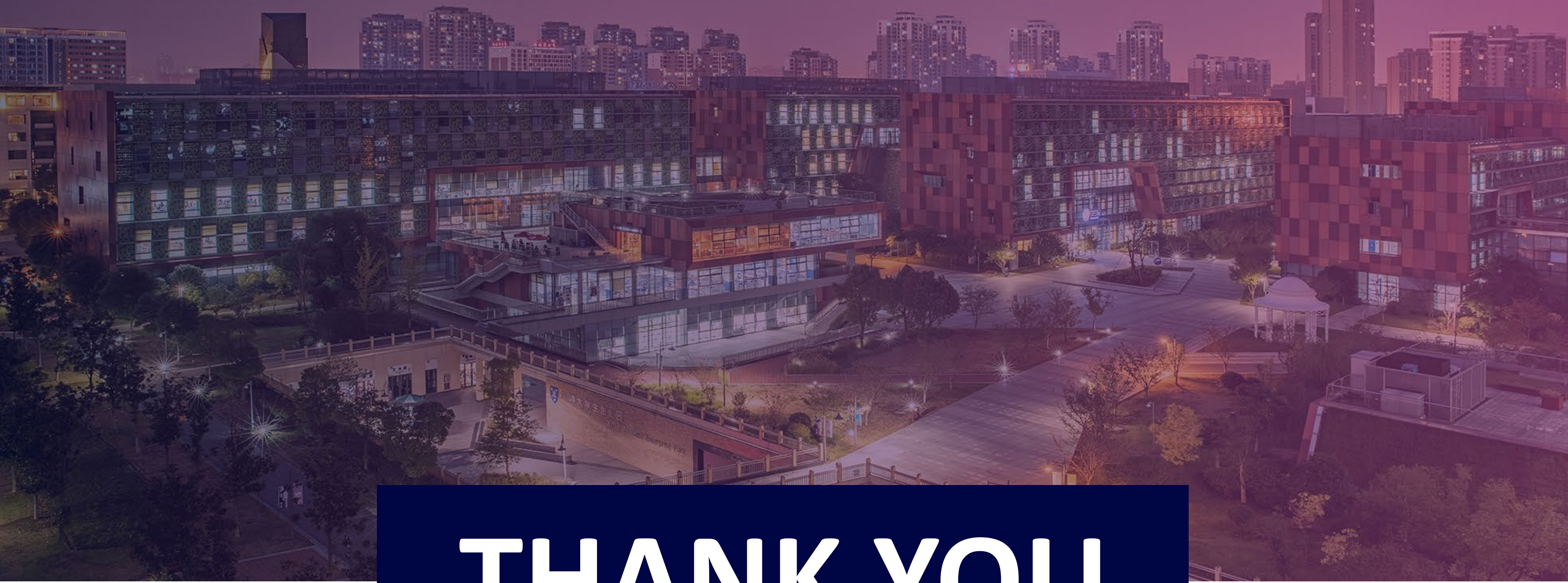


A short circuit between A and B means $v = 0$.

Current through a short circuit: any value.

A short circuit is equivalent to R = 0 Ω.





THANK YOU