UNSW SYDNEY Australia's Global University

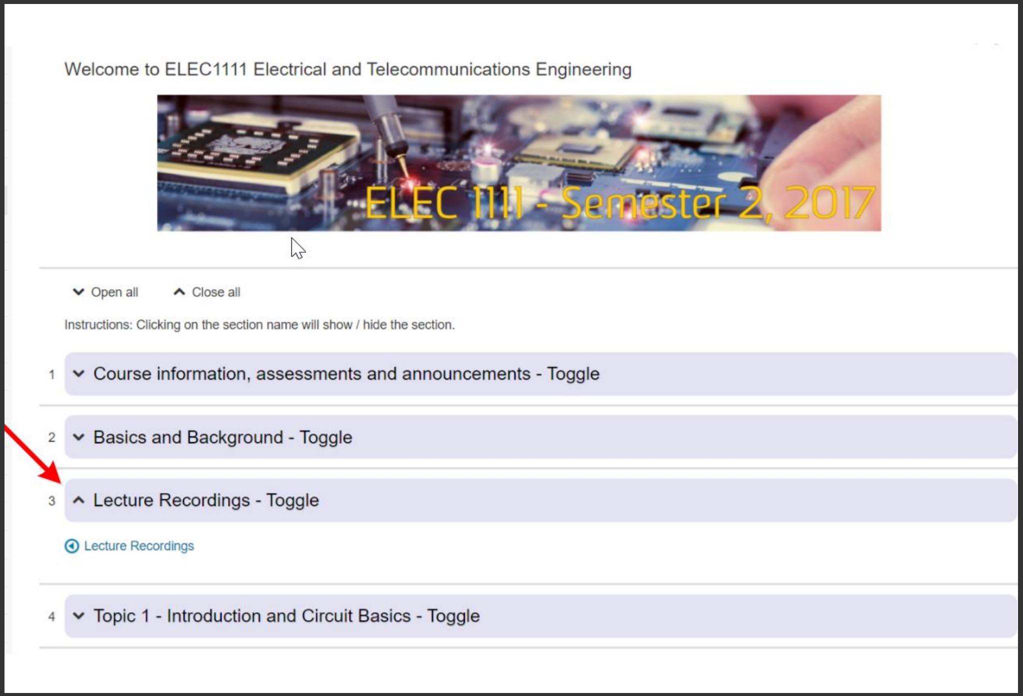
Faculty of Engineering

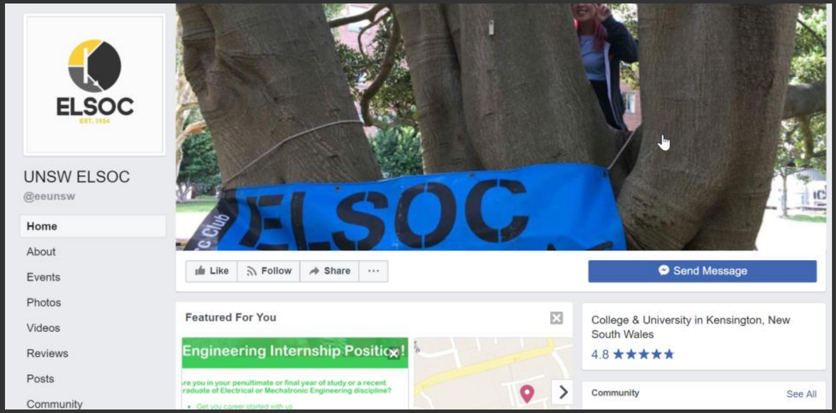
School of Electrical Engineering and Telecommunications

ELEC 1111 – Topic 1 – Circuit Basics

Announcement

- Lecture videos are now accessible via a different link (Section 3 on Moodle page, Lecture Recordings)
- Discord Channel is now managed by Dr. Konstantinou g.konstantinou@unsw.edu.au
- Check out ELSOC Website and Facebook page for all the support from your fellow students and workshop, free BBQ and drink news http://www.elsoc.net/ https://www.facebook.com/eeunsw/





Topic/Week 1 Content

This lecture covers:

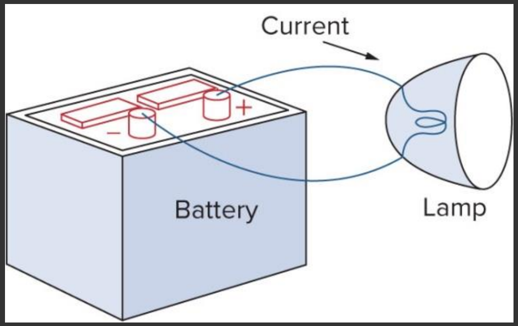
- Concept of a Circuit
- Systems of Units
- Charge, Current and Voltage
- Power and Energy
- Passive and Active
- Voltage & Current Sources
- Independent and Dependent Sources
- (Brach, Node, and Mesh/Loop will be covered in Topic2)

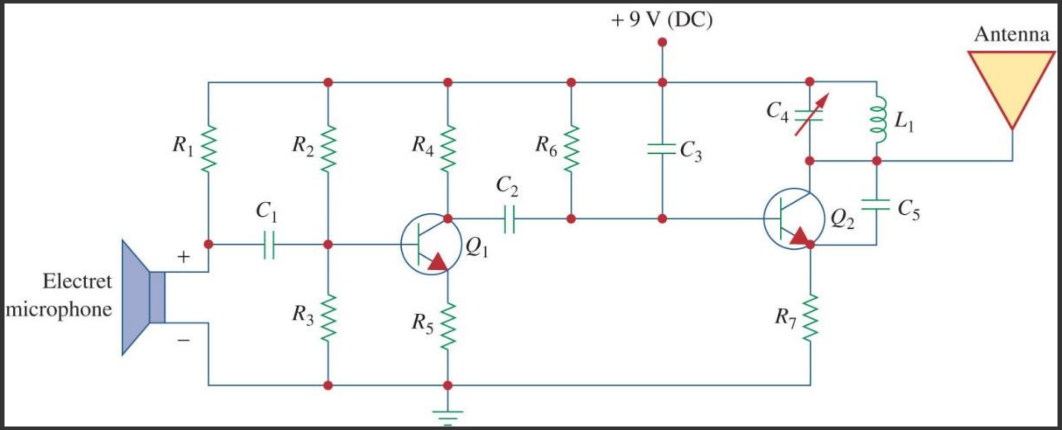
Corresponds to Chapter 1 of your textbook

What is a circuit?

An electric circuit is an interconnection of electrical elements

It may consist of only two elements or many more





System of Units

Basic SI units

- International System of Units (SI Units) is founded on seven/7 base units for seven base quantities assumed to be mutually independent
- To quantify measured values, we must use units

Quantity	Basic unit	Symbol
Length	metre (meter)	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Electric current	ampere	A
Amount of substance	mole	mol
Luminous intensity	candela	Cd

System of Units

Derived SI units

- Derived quantities are defined in terms of the seven base quantities via a system of quantity equations
- SI derived units are obtained from these equations and the seven SI base units

For: Further reading:
http://physics.nist.gov/cuu/Units/units.html

Historical Context of the units:
http://physics.nist.gov/cuu/Units/current.html

Derived Quantity	Derived unit	Symbol	Expression
Plane angle	radian	rad	-
Frequency	hertz	Hz	s^{-1}
Force	newton	N	$Kg.m/s^2$
Energy (work)	joule	J	N.m
Power	watt	W	J/s
Electric charge	coulomb	C	s.A
Electric potential difference/ electromotive force (emf)	volt	V	J/C or W/A
Resistance	ohm	Ω	V/A
Conductance	siemens	S	A/V
Capacitance	farad	F	C/V
Magnetic flux	weber	Wb	V.s
Inductance	henry	H	Wb/A

System of Units

SI prefixes and multipliers

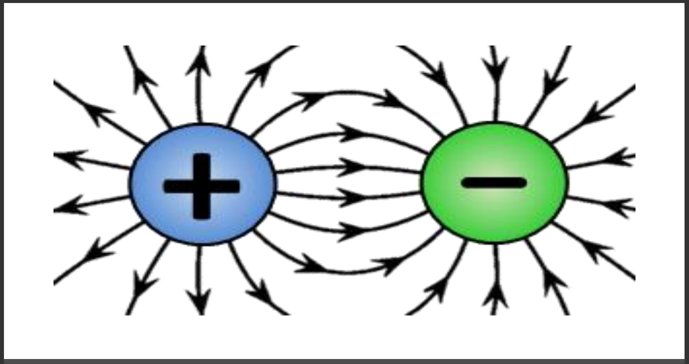
Multiplier	Prefix	Symbol
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	F
10^{-18}	atto	a

Multiplier	Prefix	Symbol
10^{1}	deca	da
10^{2}	hecta	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E

600,000,000 mm = 600,000 m = 600 km

Electric charge

- An electrical property of the atomic particles inside a matter
- Measured in **coulomb** (C)
- Electron carries Negative charge (1.602×10^{-19} C)
- Proton carries Positive charge of the same magnitude
- One coulomb of charge is $1/(1.602 \times 10^{-19}) = 6.24 \times 10^{18}$ electrons
- Charge is always multiple of electronic charge in nature
  - Electronic charge: $e = -1.602 \times 10^{-19}$ C
- Charge cannot be created or destroyed, only transferred (*Law of Conservation of Charge*)

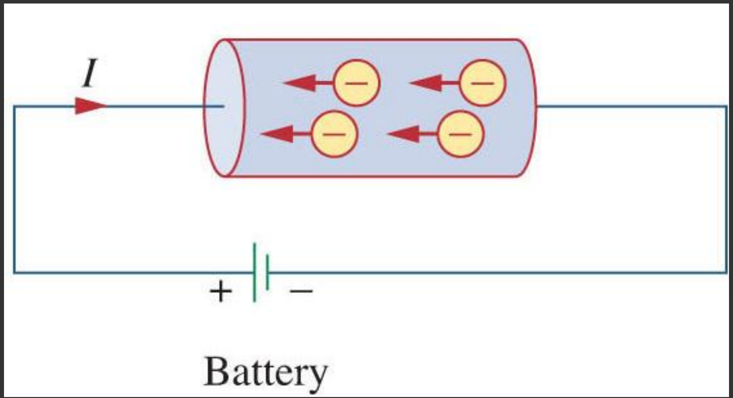


Notation

- Q: Constant charge
- $q(t)$ or q: Instantaneous or time-varying charge

Current

- The movement of electronic charge is called **current**
- Historically the moving charges were thought to be positive
- Practically both negative and positive charges are moving when compelled by an electromotive force
- In metallic conductors, current is created by negatively-charged electrons
- By <u>convention</u>, the direction of current is the net flow of positive charge



Convention

- Standard way of describing something so that others in the profession understand what we mean
- IEEE conventions will be used, e.g, for notations like *Q* as constant charge.

Current

- The rate of change of charge (*q*) per unit of time through an element

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

- The charge transferred over a period of time

$$Q = \int_{t_0}^{t_1} i\,dt \qquad t_0 \le t \le t_1$$

Current is measured in amperes (A) through the element

1 ampere = 1 coulomb/second
1 A = 1 C/s

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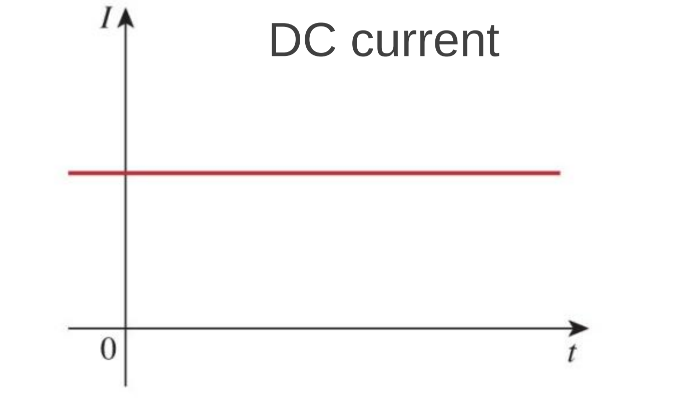
DC vs AC current

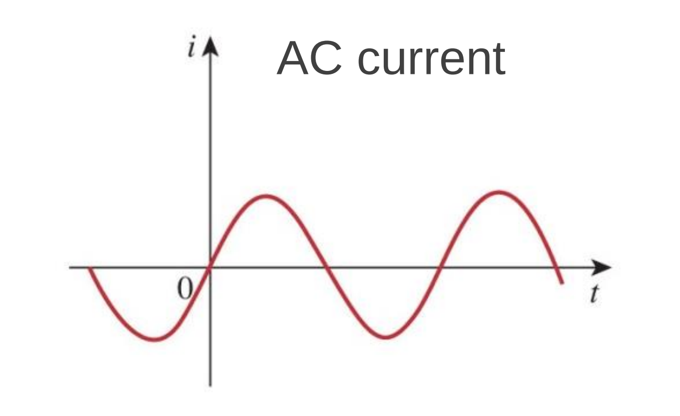
- Direct current (DC) is defined as a current that flows only in ***one direction***
  - It can be constant or time varying
  - Battery is an example of DC current
- Alternating current (AC) is defined as a current that changes ***changes direction*** over time
  - Main power at homes is an example of AC current

Notation

- I: Constant current (DC)
- $i(t)$ or i: Instantaneous or time-varying current (cab be AC or DC)
- j is used to describe unit imaginary number instead of i, e.g., $a+jb$



(a)

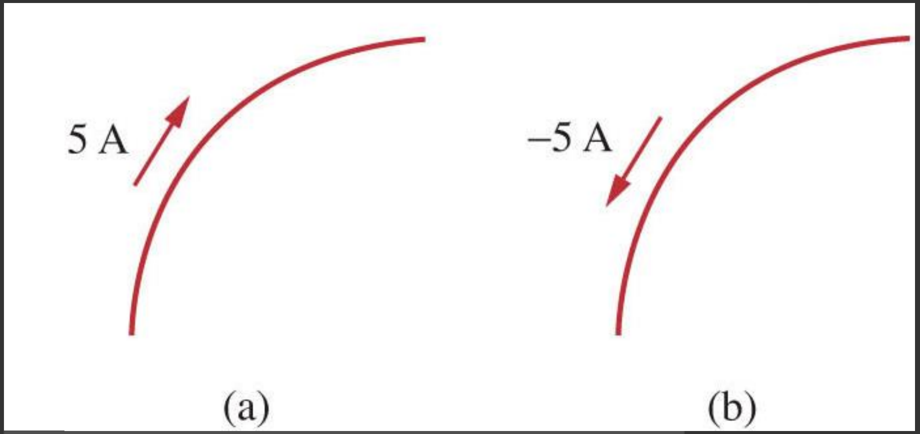


(b)

Current value and direction

- Current is described by its ***value*** and ***direction***
- By convention, the direction can be chosen arbitrary in circuits
- The algebraic sign of the current and the relevant circuit laws will ultimately determine the actual direction in which the charge is moving

A **positive current** through an element is equivalent to a **negative current** flowing in the **opposite direction**



Example

The current flowing through an element is given as follows,

$$i = \begin{cases} 4 \text{ A} & 0 < t \leq 1 \\ 4t^2 \text{ A} & t > 1 \end{cases}$$

Calculate the charge entering the element from $t = 0$ to $t = 2$ s.

(Solution via document camera)

Voltage

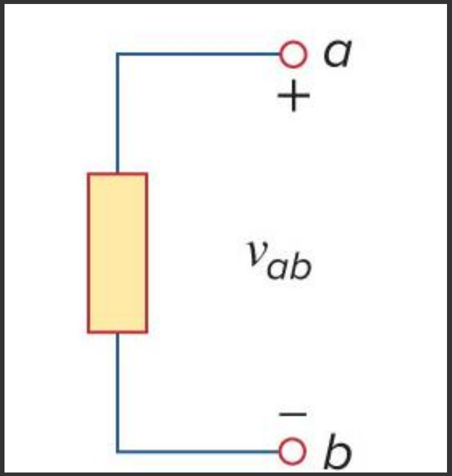
- Electrons move when there is a difference in charge between two locations
- This difference is expressed as the ***potential difference***, or voltage
- It is always expressed with reference to two locations
- Voltage is defined as the energy (*w*) required to move a unit of charge (*q*) from a reference point to another point through an element by and external electromotive force

$$v_a - v_b = v_{ab} = \frac{dw}{dq}$$

v_{ab} is potential at point *a* with respect to point *b*
v_a is potential at point *a*
v_b is potential at point *b*

Voltage is measured in volts (V) across the element

1 volt = 1 joule/coulomb
= 1 newton-meter/coulomb



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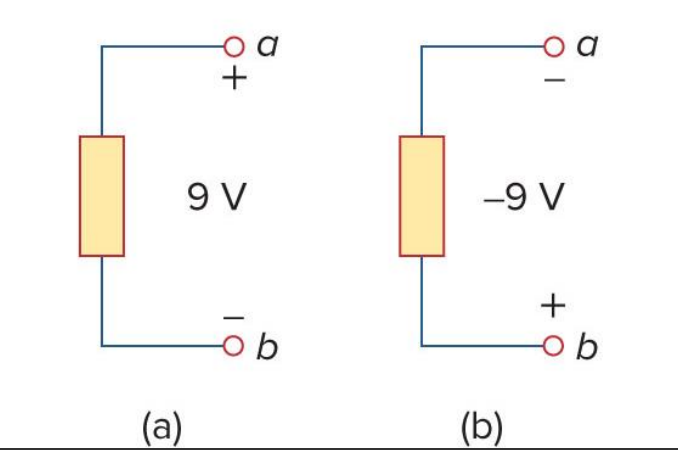
Voltage value and polarity

- Voltage is described by its ***value*** and ***polarity***, (+) and (−) signs
- By convention, the polarity can be chosen arbitrary in circuits
- The algebraic sign of the voltage and the relevant circuit laws will ultimately determine the actual polarity

A **positive voltage** across a component is equivalent to a **negative voltage** with **reverse polarity**



$$v_{ab} = -v_{ba}$$

DC vs AC voltage

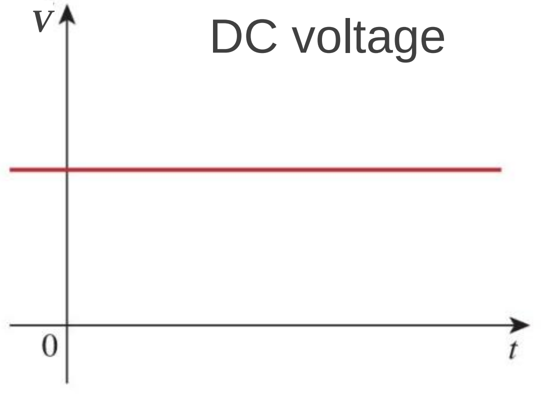
- DC voltage is defined as a voltage with **fixed polarity**
  - It can be constant or time varying
  - Battery is an example of DC voltage

- AC voltage is defined as a voltage with alternating polarity over time
  - Main power at homes is an example of AC voltage

Notation

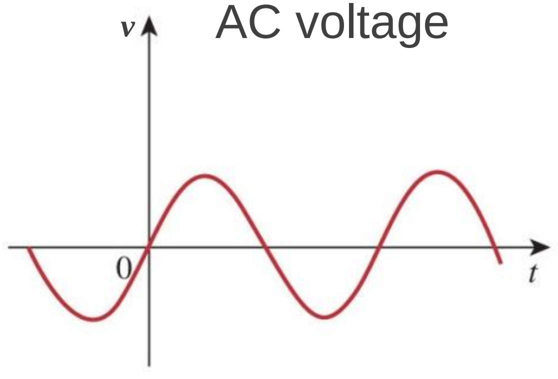
- *V*: Constant voltage (DC)
- *v*(*t*) or *v*: Instantaneous or time-varying voltage (cab be AC or DC)

DC voltage



(a)

AC voltage



(b)

Power

- Current and voltage alone are not sufficient to describe the amount of energy consumed by an electric element
- Power is defined as the rate of expending or absorbing energy (*w*) per unit of time

$$p = \frac{dw}{dt}$$

- Using the definitions for voltage ($v_{ab} = \frac{dw}{dq}$) and current ($i = \frac{dq}{dt}$), we have the power as the product of voltage across the element and current through it

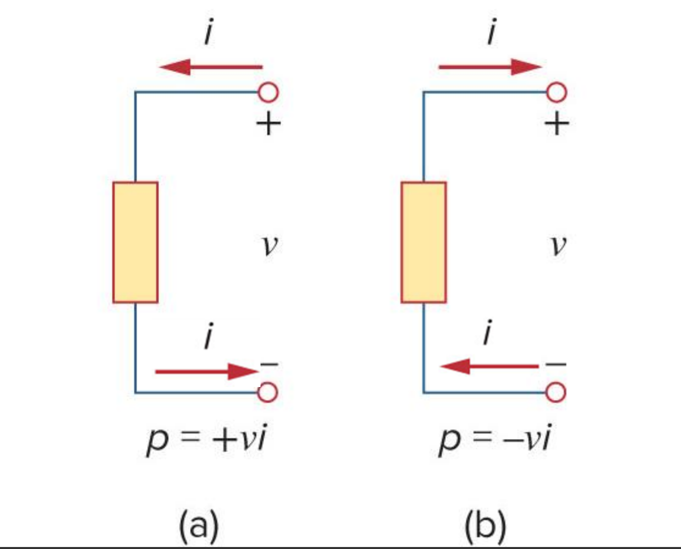
$$p = vi$$

Power is measured in watts (W)

1 watt = 1 joule/second
= 1 volt-ampere

Power - passive sign convention

- The direction of current flowing through an element and the polarity of voltage across that element defines the algebraic sign of the power
- Power is ***positive*** when the ***current enters*** through the ***positive terminal*** of an element ($p = +vi$, Fig. (a)), and it is ***negative*** when the ***current enters*** through the ***negative terminal*** of the element ($p = -vi$, Fig. (b))



Positive power is **absorbed** or **consumed** by an element (Fig. (a))

Negative power is **supplied** or **generate** by an element (Fig. (b))

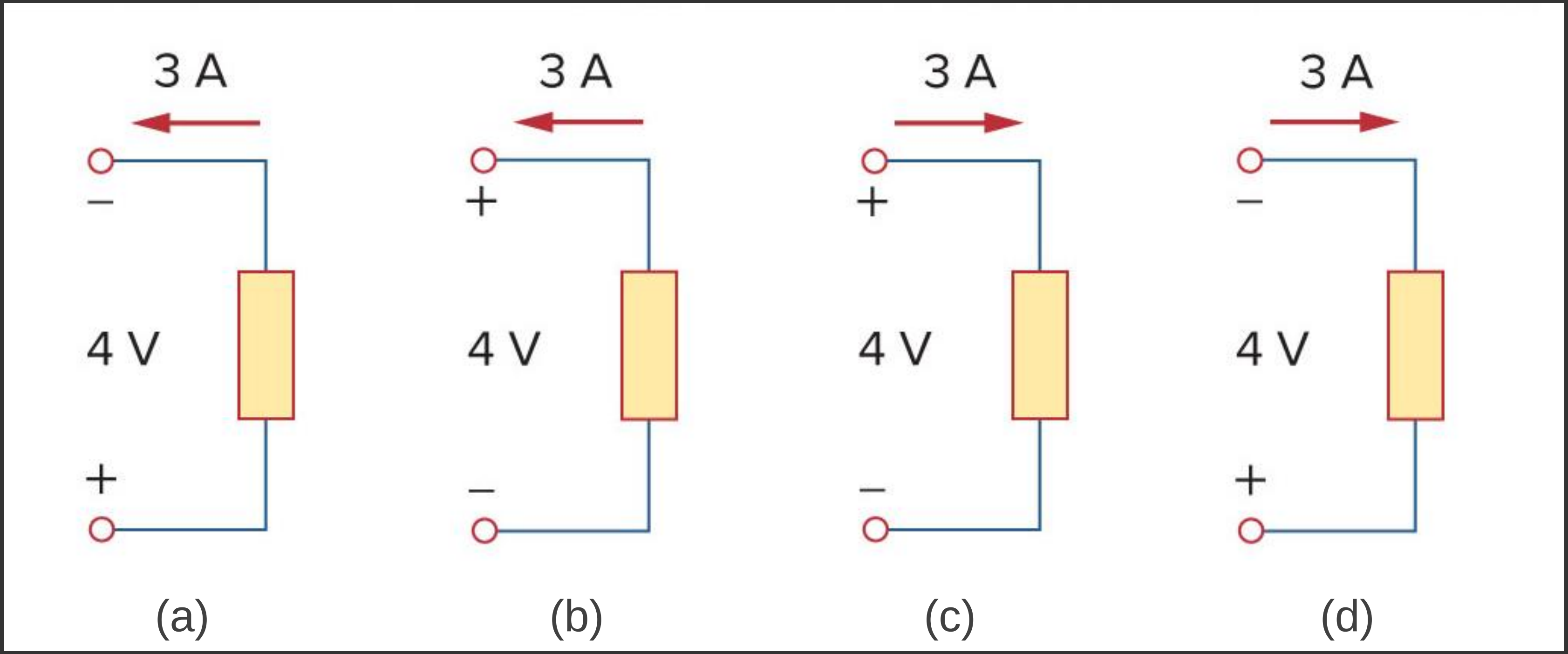
+Power absorbed = −Power supplied

Notation

- *P*: Constant power (DC)
- *p*(*t*) or *p*: Instantaneous or time-varying power (cab be AC or DC)

Power - passive sign convention

Let’s play: Absorbed or Supplied?!?



A S A S

Power – conservation of energy

- In a circuit, energy cannot be created or destroyed
- Power also must be conserved
- The sum of all power supplied must be absorbed by the other elements

Total power supplied = Total power absorbed

$$\sum p_s = \sum p_a$$

$$\sum p = 0$$

Energy

- The capacity to do work (considering passive sign convention

$$w = \int_{t_0}^{t} p\, dt = \int_{t_0}^{t} vi\, dt \qquad t_0 \le t \le t_1$$

Energy is measured in joules (J)

1 joule = 1 watt-second

Electric power utility companies measure energy in watt-hours (Wh) and kilowatt-hours (kWh)

1 Wh = 3600 J and 1 kWh = 3,600,000 J

Notation

- *W*: Constant energy (DC)
- *w*(*t*) or *w*: Instantaneous or time-varying energy (cab be AC or DC)

Circuit elements

- Building blocks of electric circuits
- Electric circuit is an interconnection of the elements
- There are two types of circuit elements

Active elements

- Generate or supply power
  - Generators
  - Batteries
  - Operational Amplifiers

Passive elements

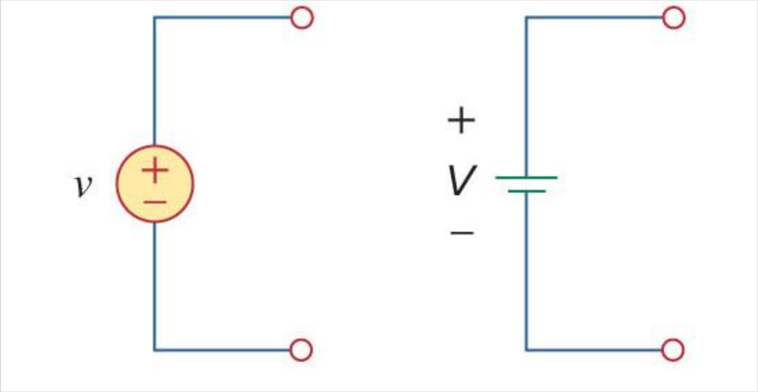
- Absorb or consume power
  - Resistors
  - Capacitors
  - Inductors

- Noted that only resistor dissipates/consumes energy ideally
- Inductor and capacitor do not!

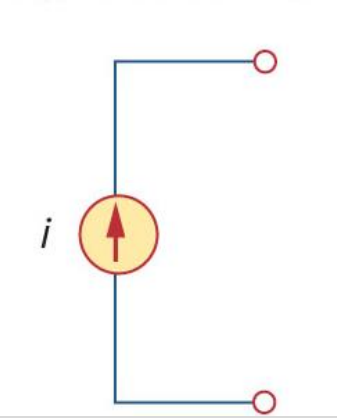
Active elements

Independent sources

An **ideal independent source** is an **active element** that provides a specified voltage and current, and that is **completely independent** of any other voltage or current in the circuit



independent **voltage source**



independent **current source**

Active elements

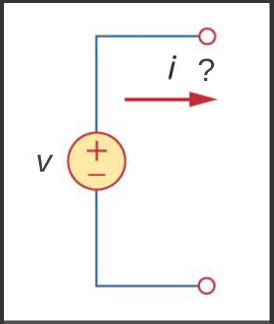
Independent sources

Ideal voltage source

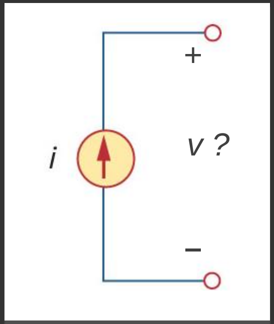
- Has **no internal resistance** (series)
- Capable of **producing any amount of current** needed to establish the desired voltage at the terminal
- The **voltage is known** at the terminals, but the current is not

Ideal current source

- Has **infinite resistance** (parallel)
- Capable of **producing any amount of voltage** needed to establish the desired current through the terminal
- The **current is known** through the terminal, but the voltage is not



Independent **voltage source**



Independent **current source**

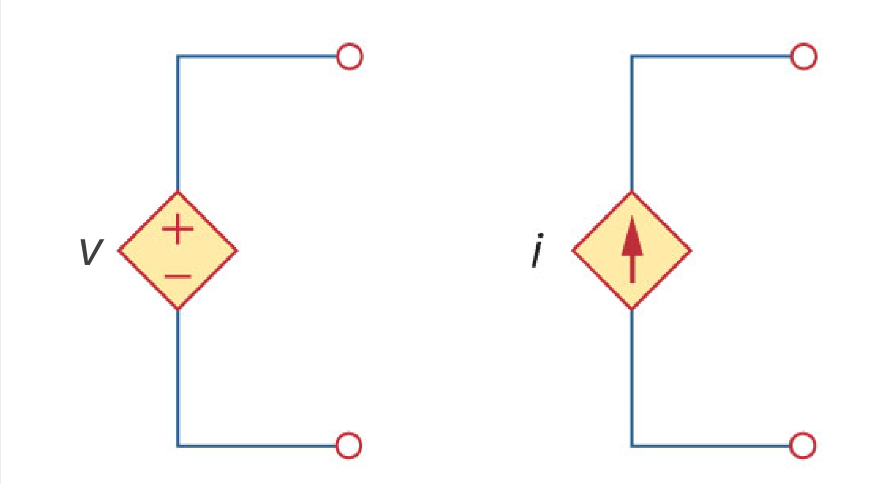
Active elements

Dependent sources

An **ideal dependent (controlled) source** is an active element whose **output value is controlled** by another voltage or current in a circuit

Four types

- voltage-controlled voltage source (VCVS)
- current-controlled voltage source (CCVS)
- voltage-controlled current source (VCCS)
- current-controlled current source (CCCS)



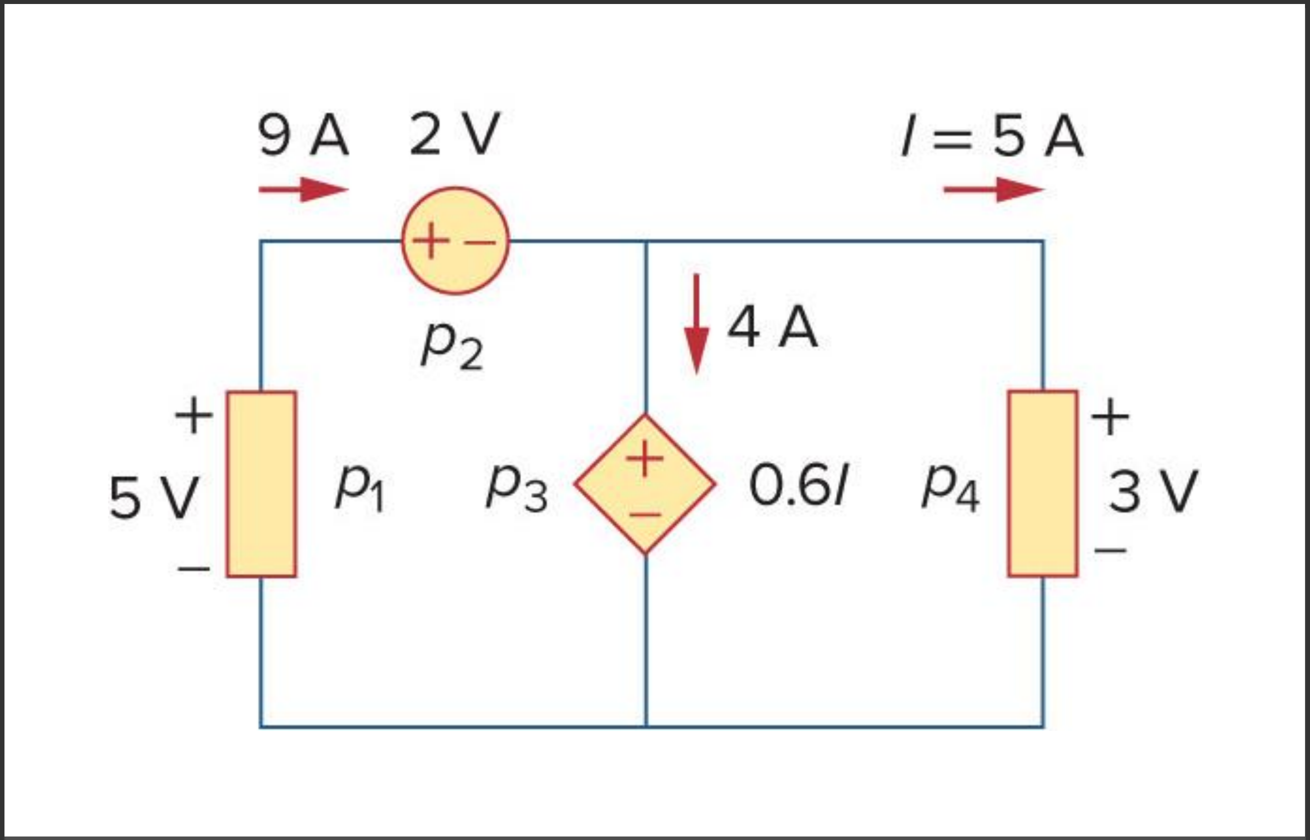
Dependent **voltage source**

Dependent **current source**

Symbolically represented as a diamond

Example

Calculate the power supplied or absorbed by each element. (solution via document camera)



Active elements

More on sources (independent or dependent)

Ideal voltage and current sources can **generate infinite power**

Actual voltage sources have an upper **current limit** (**limited output power**)

Ideal voltage and current sources can **absorb infinite power** from the circuit

Actual current sources have an upper **voltage limit** (**limited output power**)

Questions