Alexander-Sadiku
Fundamentals of Electric Circuits

Chapter 1
Basic Concepts

Basic Concepts - Chapter 1

1.1 Systems of Units.
1.2 Electric Charge.
1.3 Current.
1.4 Voltage.
1.5 Power and Energy.
1.6 Circuit Elements.

What is an Electric Circuit?

- In electrical engineering, we are usually interested in transferring energy or communicating signals from one point to another.

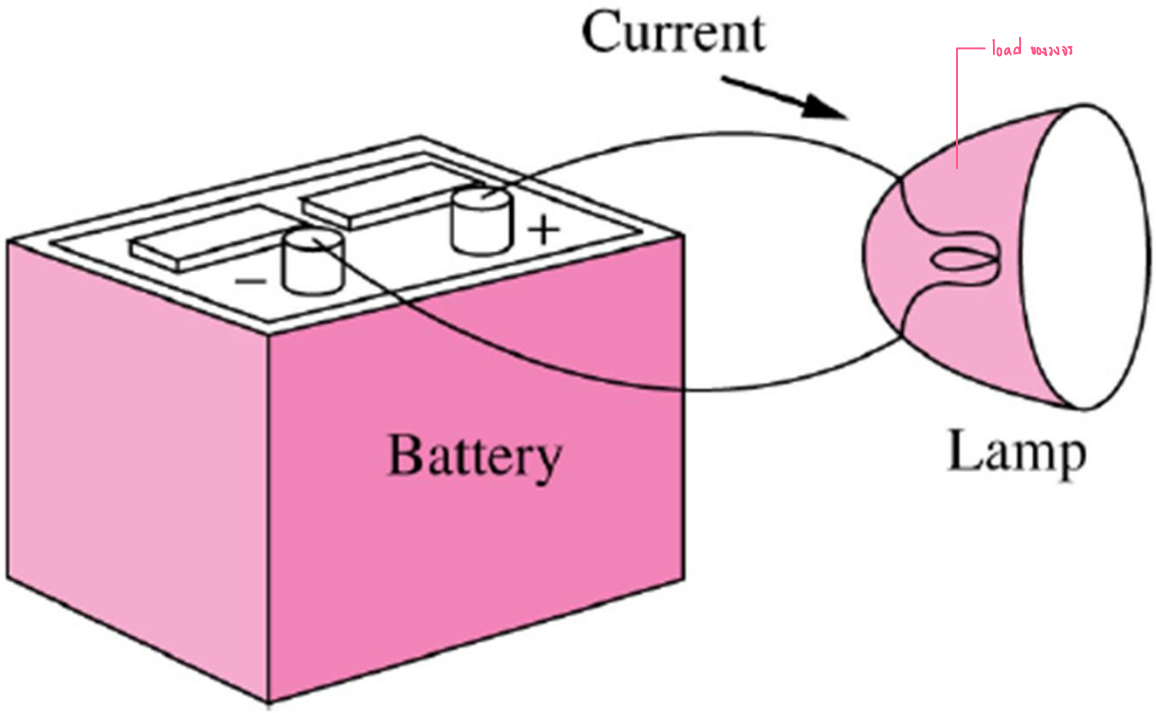
  To do this, we often require an interconnection of electrical components.

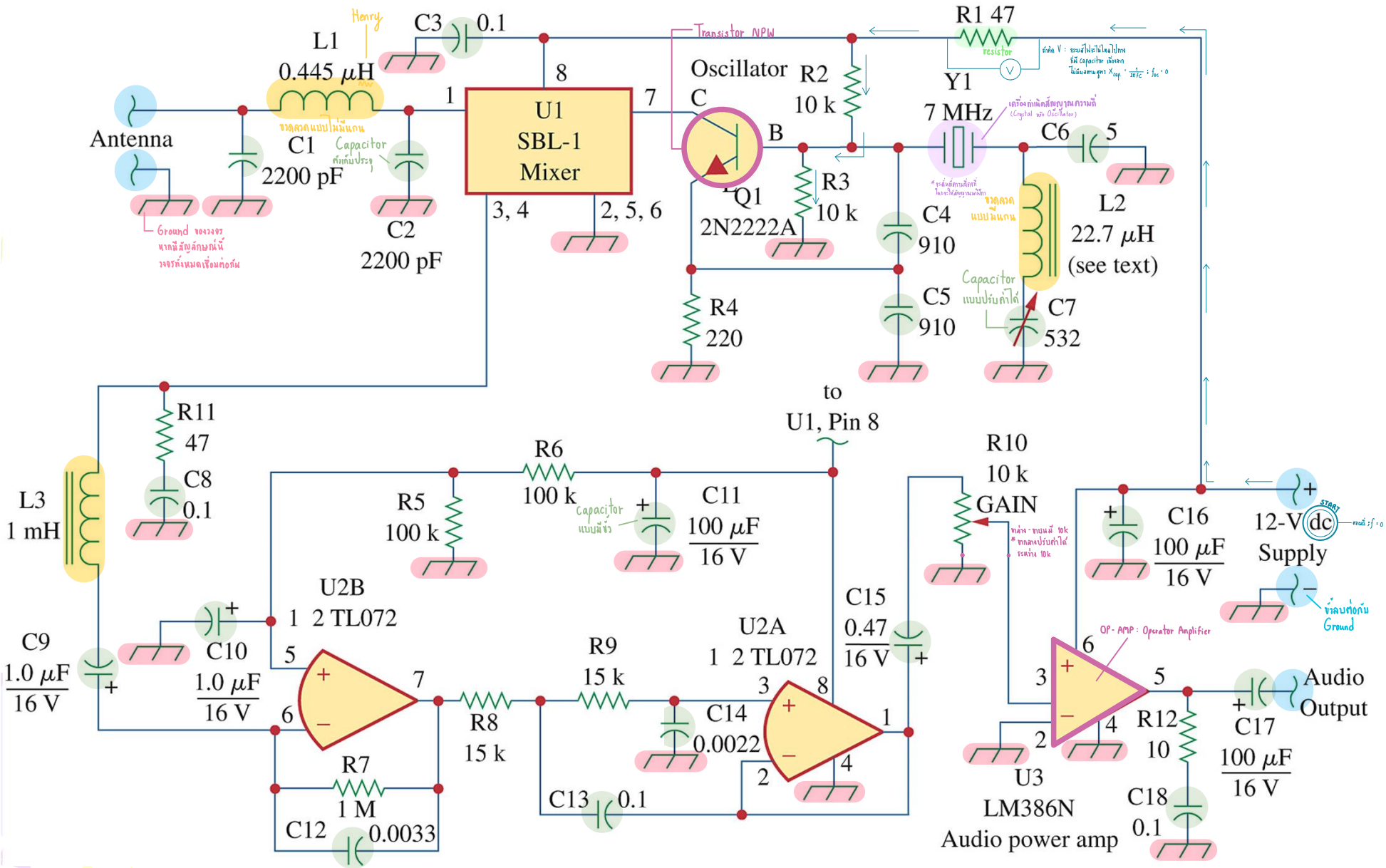
  "An electric circuit is an interconnection of electrical components."

- Typical circuit or electrical components that we will see in this year:

  batteries or voltage sources, current sources, resistors, switches, capacitors, inductors, diodes, transistors, operational amplifiers, ...

A Simple Circuit





1.1 System of Units (1)

Six basic units

Quantity	Basic unit	Symbol
Length (ความยาว)	meter	m
Mass (มวล)	kilogram	Kg
Time (เวลา)	second	s
Electric current (กระแสไฟฟ้า)	ampere	A
Thermodynamic temperature (อุณหภูมิ)	kelvin	K
Luminous intensity (ความเข้มแสง)	candela	cd

1.1 System of Units (2)

สร้างหน่วยใหม่จากหน่วยพื้นฐาน

The derived units commonly used in electric circuit theory

Quantity	Unit	Symbol
electric charge	coulomb	C
electric potential	volt	V
resistance	ohm	Ω
conductance	siemens	S
inductance	henry	H
capacitance	farad	F
frequency	hertz	Hz
force	newton	N
energy, work	joule	J
power	watt	W
magnetic flux (เส้นแรง)	weber	Wb
magnetic fiux density	tesla	T

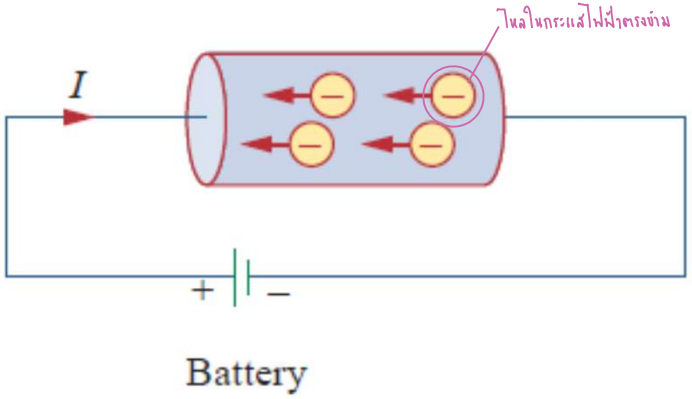
Factor	Prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Decimal multiples and submultiples of SI units

1.2 Electric Charges

- Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).
- The charge e on one electron is negative and equal in magnitude to 1.602×10^{-19} C which is called as electronic charge. The charges that occur in nature are integral multiples of the electronic charge.

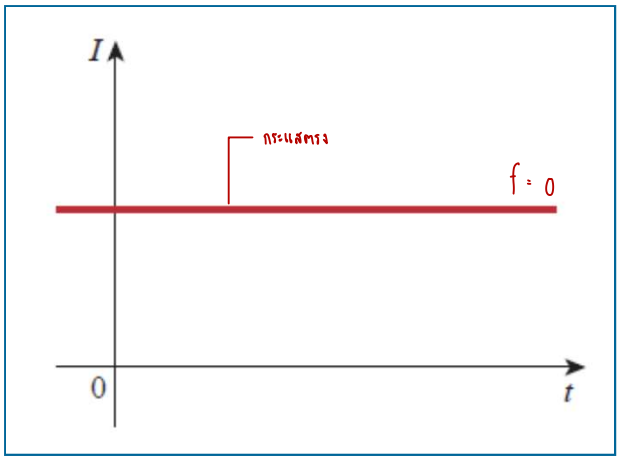
1.3 Current



- Electric current i = dq/dt.
- The unit of ampere can be derived as

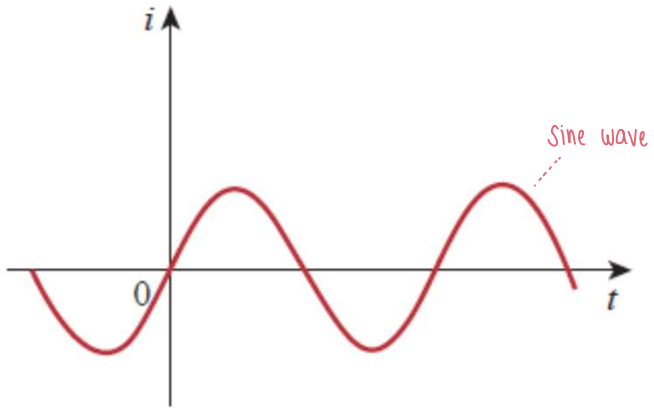
  1 Ampere = 1 Coulomb/second.

1.3 Direct Current



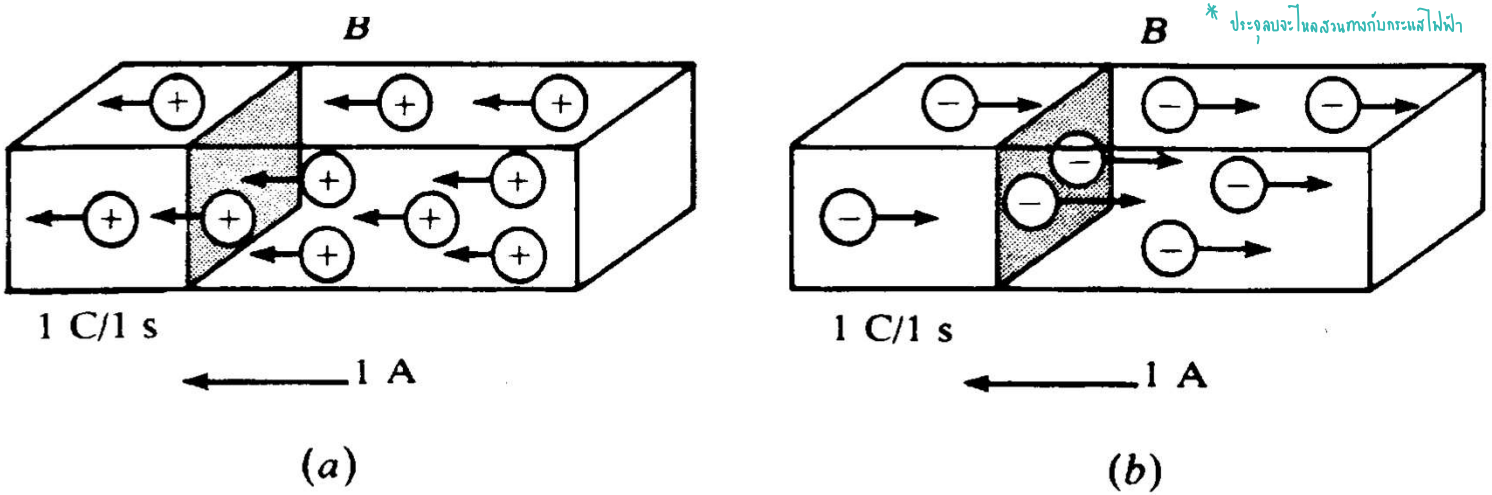
- A direct current (dc) is a current that remains constant with time.

1.3 Alternating Current



- An alternating current (ac) is a current that varies sinusoidally with time. (reverse direction)

1.3 Current Flow

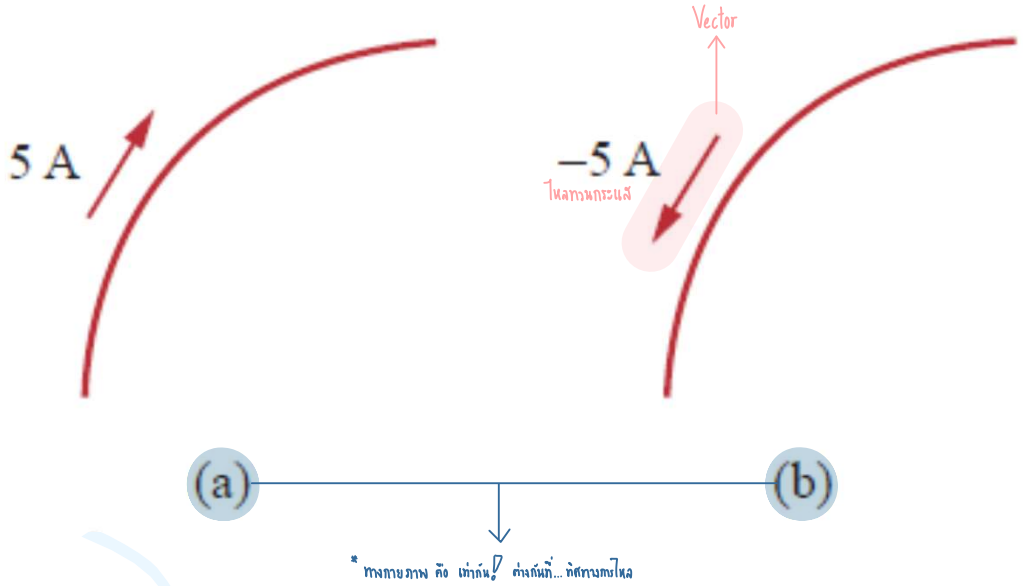


* ประจุลบจะไหลสวนทางกับกระแสไฟฟ้า

Positive ions

Negative ions

1.3 Current Flow



1.3 Current

Example 1

How much charge represented by 4,600 electrons? ; $e^- = 1.602 \times 10^{-19}$

จะได้ $4600 \text{ electrons} \times 1.602 \times 10^{-19} \text{ C/electrons}$

$= 7.369 \times 10^{-16}$

1.3 Current

Example 2

4×10^{6}

Calculate the amount of charge represented by four million protons.

$$= +1.602 \times 10^{-16} \times 4 \times 10^{6}$$

$$= 6.408 \times 10^{-33}$$

1.3 Current

Example 3

The total charge entering a terminal is given by $q = 5t \sin 4\pi t \text{ mC}.$

Calculate the current at t=0.5 s.

ใช้ Diff ผลคูณ

$$i = \frac{dq}{dt} = \frac{d}{dt}(5t \sin 4\pi t) \text{ mC/s} = (5 \sin 4\pi t + 20\pi t \cos 4\pi t) \text{ mA}$$

At $t = 0.5$,

$$i = 5 \sin 2\pi + 10\pi \cos 2\pi = 0 + 10\pi = 31.42 \text{ mA}$$

(0, 1, 3.142...)

C.4 Derivatives

If $U = U(x)$, $V = V(x)$, and a = constant,

$$\frac{d}{dx}(aU) = a\frac{dU}{dx}$$

$$\frac{d}{dx}(UV) = U\frac{dV}{dx} + V\frac{dU}{dx}$$

1.3 Current

$$\frac{d}{dx}\left(\frac{U}{V}\right) = \frac{V\frac{dU}{dx} - U\frac{dV}{dx}}{V^2}$$

$$\frac{d}{dx}(aU^n) = naU^{n-1}$$

$$\frac{d}{dx}(a^U) = a^U \ln a \frac{dU}{dx}$$

$$\frac{d}{dx}(e^U) = e^U \frac{dU}{dx}$$

$$\frac{d}{dx}(\sin U) = \cos U \frac{dU}{dx}$$

$$\frac{d}{dx}(\cos U) = -\sin U \frac{dU}{dx}$$

Example 4

The total charge entering a terminal is given by

$$q = (10 - 10e^{-2t})\ \text{mC}$$

Calculate the current at t=0.5 s.

$$\frac{dq}{dt} = (10 - 10e^{-2t})$$

$$= 20e^{-2t}$$

$$= 20e^{-2(0.5)}$$

$$= \frac{20}{2.7}$$

$$= 7.36\ \text{mA}$$

1.3 Current

Example 5

Determine the total charge entering a terminal between t=1 s and t = 2 s if the current passing the terminal is $i = (3t^2 - t)$ A.

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

$$Q = \int i\,dt$$

$$= \int_1^2 (3t^2 - t)\,dt$$

$$= \left(t^3 - \frac{t}{2}\right)\Big|_1^2$$

$$= \left[(2)^3 - \frac{2}{2}\right] - \left[(1)^3 - \frac{1}{2}\right]$$

$$= 6 - \frac{1}{2}$$

$$= 5.5\ C$$

1.3 Current

Example 6

* 1 A = 1 C/sec
= 60 C/min

A conductor has a constant current of 5 A. How many electrons pass a fixed point on the conductor in one minute?

จะได้ $\frac{300\ C/min}{1.602 \times 10^{-19}\ C/electronic} = 1.87 \times 10^{21}\ electronic/min$

1.3 Current

Example 6

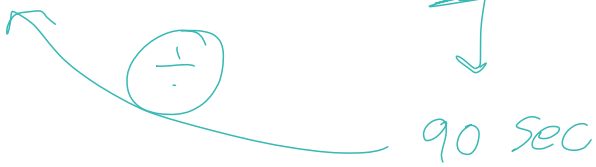
A conductor has a constant current of 5 A. How many electrons pass a fixed point on the conductor in one minute?

$$\frac{300\ \text{C/min}}{1.602x10^{-19}\ \text{C/electron}} = 1.87x10^{21}\ \text{electrons/min}$$

1.3 Current

Example 7

ถ้าประจุไฟฟ้าเคลื่อนที่ผ่านตัวนำ 900 Coulombs ในเวลา 1.5 นาที จะมีกระแสไฟฟ้าไหลผ่าน กี่แอมแปร์



10 A

1.3 Current

Example 8

อิเลกตรอนอิสระเคลื่อนที่ในโลหะตัวนำ โดยใน 2 วินาทีจะเคลื่อนผ่านพื้นที่หน้าตัดแห่งหนึ่ง 4×10^{10} ตัว จงหากระแสไฟฟ้าที่ผ่านตัวนำนี้

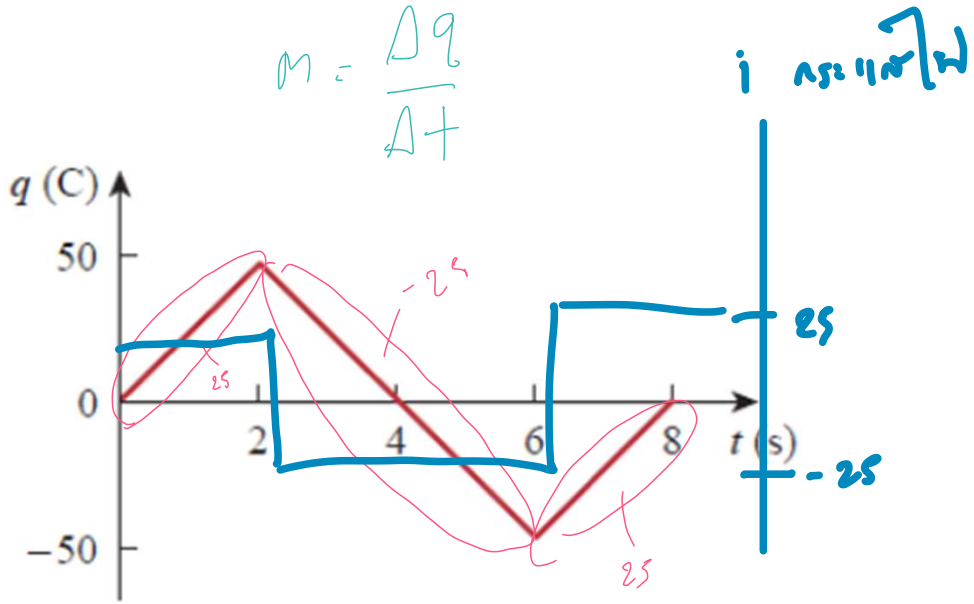
$$\frac{4 \times 10^{10} \times 1.602 \times 10^{-19}}{2}$$

$$= 3.204 \times 10^{-9} \text{ A}$$

1.3 Current

Example 9

จงเขียนกราฟ ของกระแสและเวลา



1.4 Voltage

- Voltage (or potential difference) is the energy required to move a unit charge through an element, measured in volts (V).

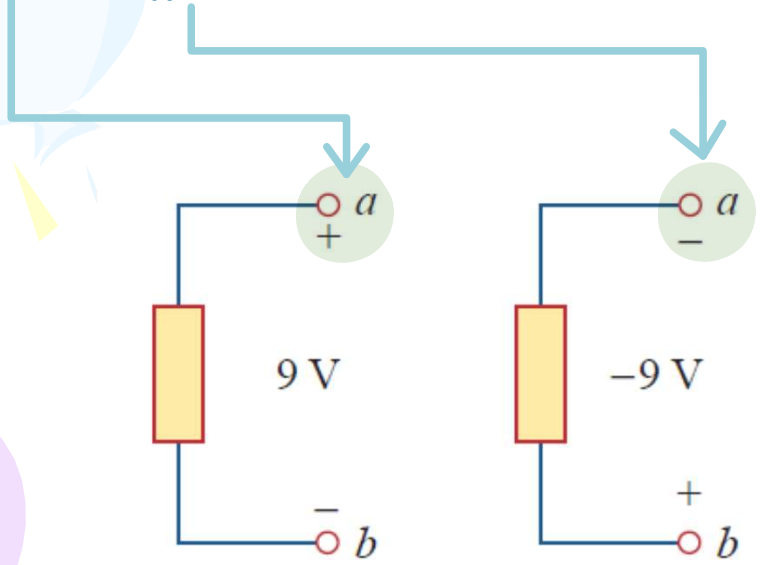
$$v_{ab} \triangleq \frac{dw}{dq}$$

  - W is energy in joules (J) and Q is charge in coulomb (C).

$$1 \text{ volt} = 1 \text{ joule/coulomb} = 1 \text{ newton-meter/coulomb}$$

1.4 Voltage

- Electric voltage, $v_{ab,}$ is always across the circuit element or between two points in a circuit.
  - $v_{ab} > 0$ means the potential of a is higher than potential of b.
  - $v_{ab} < 0$ means the potential of a is lower than potential of b.



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

1.4 Voltage

Example 1

ถ้าความต่างศักย์ระหว่าง 2 จุดมีค่าเท่ากับ 42 V จงหาค่าของงานที่ต้องการในการนำประจุขนาด 6 C จากจุดหนึ่งไปยังอีกจุดหนึ่ง

$$V_{ab} = \frac{\Delta W}{\Delta C}$$

$$42\ V = \frac{W}{6\ C.}$$

$$= 252\ J.$$

1.4 Voltage

Example 2

แรงดันของแบตเตอรี่ควรจะมีค่าเท่าใดโดยที่แบตเตอรี่ซึ่งใช้พลังงาน 800 J ในการเคลื่อนย้ายประจุจำนวน 40 C ผ่านความต้านทาน

$$V = \frac{\Delta W}{\Delta C}$$

$$= \frac{800\ J}{40\ C}$$

$$= 20\ V$$

1.5 Power and Energy

- Power is the time rate of expending or absorbing energy, measured in watts (W).

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

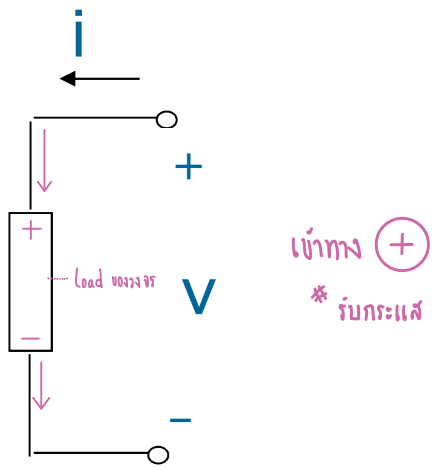
-

- Mathematical expression:

$$p = \frac{dw}{dt} = \frac{dw}{\cancel{dq}} \cdot \frac{\cancel{dq}}{dt} = vi$$

$$p = vi$$

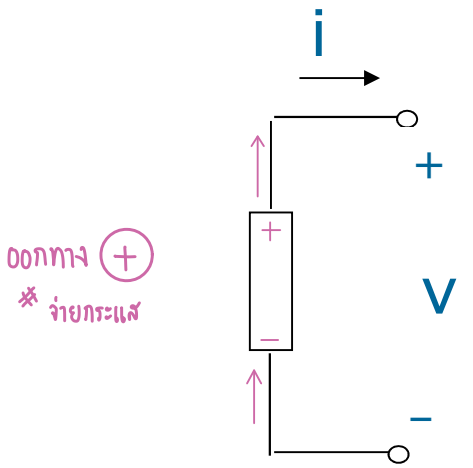
1.5 Power and Energy



P = +vi

absorbing power

*รับพลังงาน



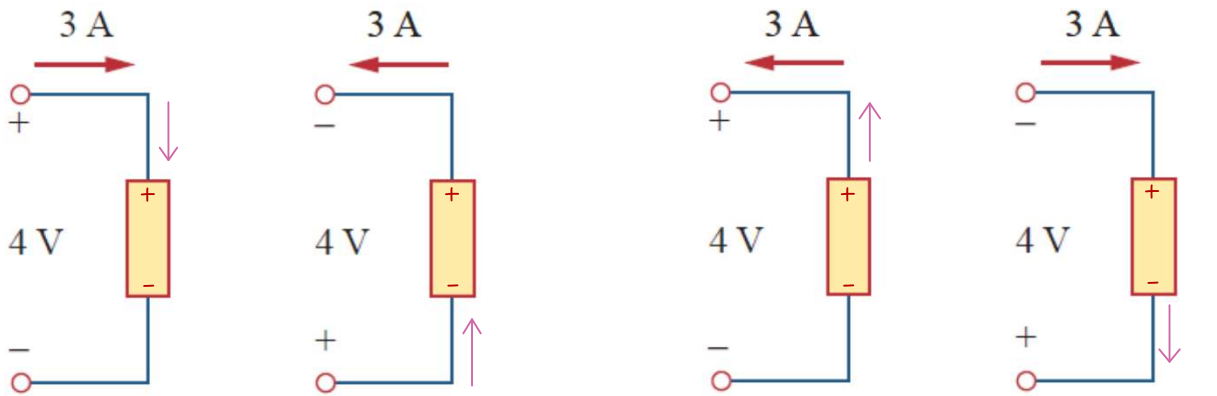
P = –vi

supplying power

*จ่ายพลังงาน

1.5 Power and Energy

$P = VI$



A - +12 A

B - +12 A

C - −12 A

D - −12 A

1.5 Power and Energy (2)

- The law of conservation of energy

กฎอนุรักษ์พลังงาน

$$\sum p = 0$$

* ไม่สูญหายแต่เปลี่ยนรูป

- Energy is the capacity to do work, measured in joules (J).
- Mathematical expression $w = \int_{t_0}^{t} pdt = \int_{t_0}^{t} vidt$

1.5 Power and Energy

$i = 2\ A$, $t = 10\ Sec$, $W = 2.3\ kJ$, $V = 2V$

Example 1

An energy source forces a constant current of 2 A for 10 s to flow through a lightbulb. If 2.3 kJ is given off in the form of light and heat energy, calculate the voltage drop across the bulb.

$$W = \int Vi\ dt$$

$$V = \frac{1}{i} \cdot \frac{dW}{dt} = \frac{1}{2\ A} \cdot \frac{2.3 \times 10^3\ J}{10\ sec.}$$

$$= 115\ V$$

1.5 Power and Energy

Example 2

To move charge q from point a to point b requires -30 J. Find the voltage drop v_{ab} if: (a) $q = 2$ C, (b) $q = -6$ C.

W พลังงาน

$$\Delta V_{ab} = \frac{\Delta W}{\Delta C}$$

(a) ; $\frac{-30\ \text{J}}{2\ \text{C}} = -15$ V

(b) ; $\frac{-30\ \text{J}}{-6\ \text{C}} = +5$ V

1.5 Power and Energy

Example 3

Find the power delivered to an element at $t = 3$ ms if the current entering its positive terminal is

$$i = 5\cos 60\pi t \text{ A}$$

and the voltage is: (a) $v = 3i$, (b) $v = 3\, di/dt$.

$\rightarrow 3\left(\frac{di}{dt} 5\cos 60\pi(3)\right)$

$= 3\left(\frac{15}{2}\pi t^{2}\right)^{3}$

1.5 Power and Energy

Example 4

Find the power delivered to the element in Example 3 at $t = 5$ ms if the current remains the same but the voltage is: (a) $v = 2i$ V,

1.5 Power and Energy

Example 5

How much energy does a 100-W electric bulb consume in two hours?

1.5 Power and Energy

Example 6

A stove element draws 15 A when connected to a 240-V line. How long does it take to consume 60 kJ?

$P = \frac{W}{t} = VI$

$= I^2R = \frac{V^2}{R}$

$t = \frac{Q}{I}$

$V = \frac{W}{Q}$

$VI = 3600$

$\frac{W}{t} = VI$

$\frac{60 \times 10^3}{t} = 3600$

$t = \frac{60 \times 10^3}{3600}$

$= 6$

$I = 15A$

$V = 240V$

want $W = 60\ kJ$

1.5 Power and Energy

Example 7

จงหาพลังงานที่ใช้ เมื่อหลอดไฟ 60 W ใช้ไปในเวลา 2 ชั่วโมง

1.5 Power and Energy

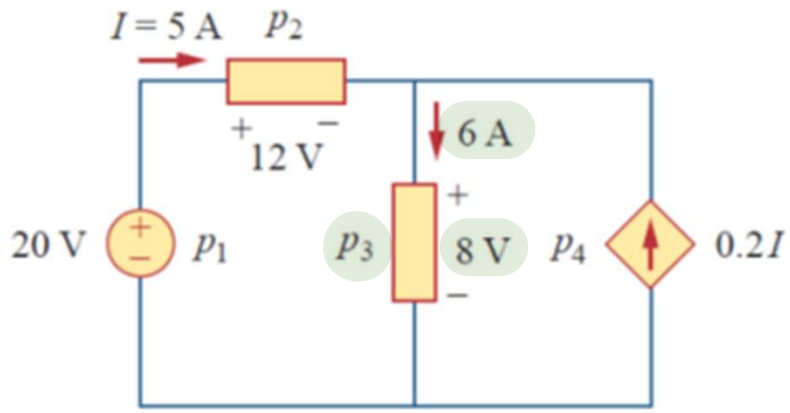
Example 8

จงหาจำนวนของอิเล็กตรอนต่อวินาทีที่ไหลผ่านหลอดไฟเมื่อหลอดไฟนั้นต่ออยู่กับแหล่งจ่ายแรงดันขนาด 120 V โดยที่หลอดไฟดังกล่าวมีขนาด 75 W

1.5 Power and Energy

Example 9

กำลังงานดูดกลืน (absorbed power) ที่ต้องการโดย อุปกรณ์ P3 คือเท่าใด



$P_3 = VI$

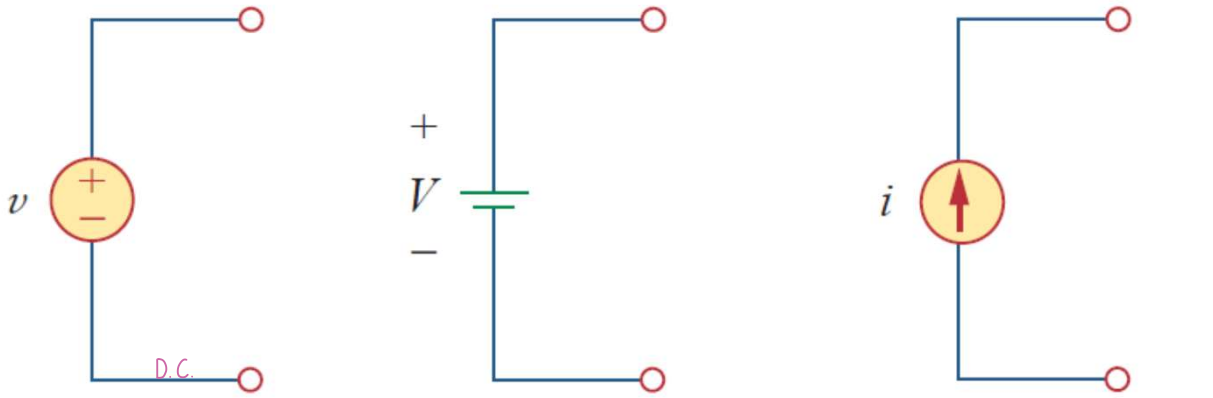
$= 8\ V \times 6\ A$

$= 48\ V$

1.6 Circuit Elements

แหล่งกำเนิดอิสระ ซึ่งไม่ขึ้นกับอะไร

An ideal independent source is an active element that provides a specified voltage or current that is completely independent of other circuit elements.



แหล่งกำเนิด, แหล่งจ่ายพลังงาน

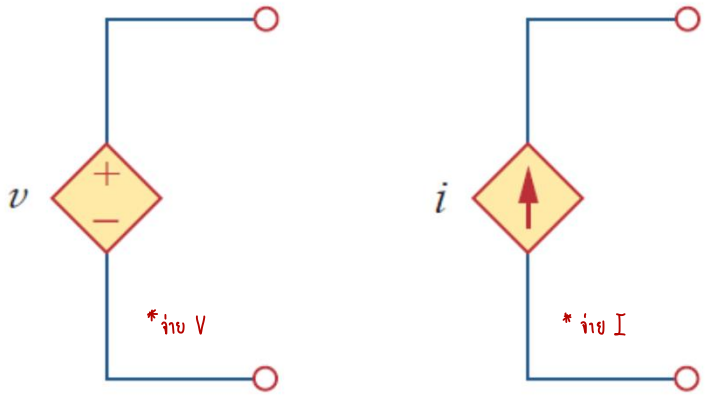
voltage source

current source

1.6 Circuit Elements

แหล่งกำเนิดซึ่งขึ้นกับตัวอื่น

An ideal dependent (or controlled) source is an active element in which the source quantity is controlled by another voltage or current.



Control Source

คุมค่า...

V คงที่
1. A voltage-controlled voltage source (VCVS).
2. A current-controlled voltage source (CCVS).

I คงที่
3. A voltage-controlled current source (VCCS).
4. A current-controlled current source (CCCS).

I : กระแสไฟฟ้า

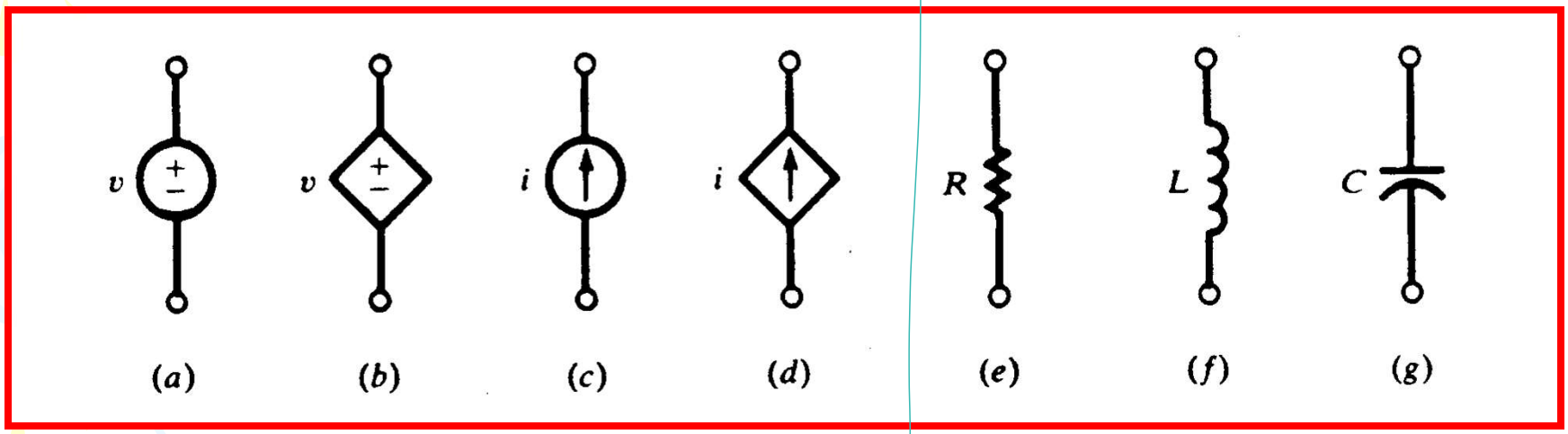
1.6 Circuit Elements

จ่ายพลังงาน

Active Elements

รับพลังงาน

Passive Elements



Independent sources

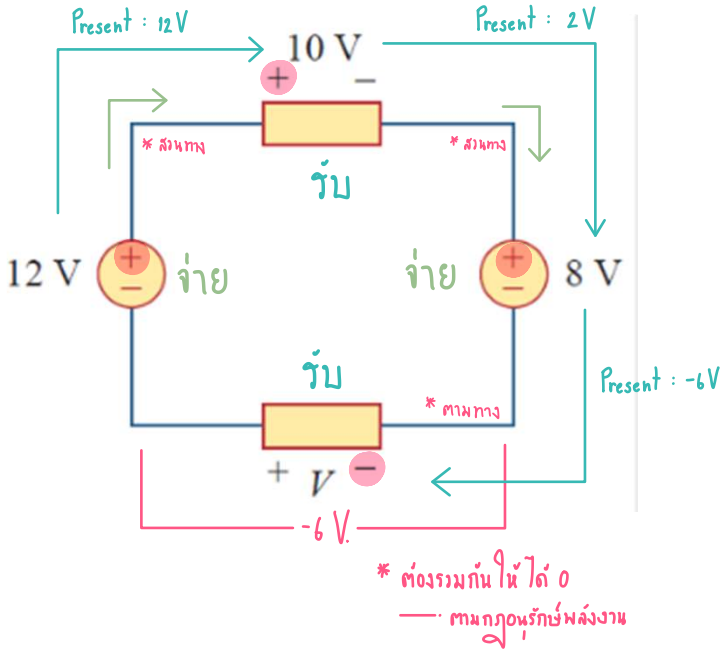
Dependant sources

- **A dependent source is an active element in which the source quantity is controlled by another voltage or current.**
- **They have four different types: VCVS, CCVS, VCCS, CCCS. Keep in minds the signs of dependent sources.**

1.6 Circuit Elements

Example 1

จากรูป V มีค่าเท่าใด



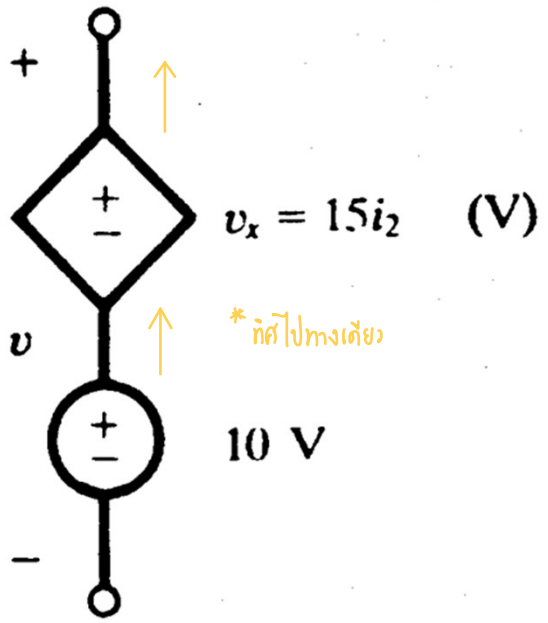
1.6 Circuit Elements

Example 2

$i_2 = 1A$

V มีค่าเท่าใด

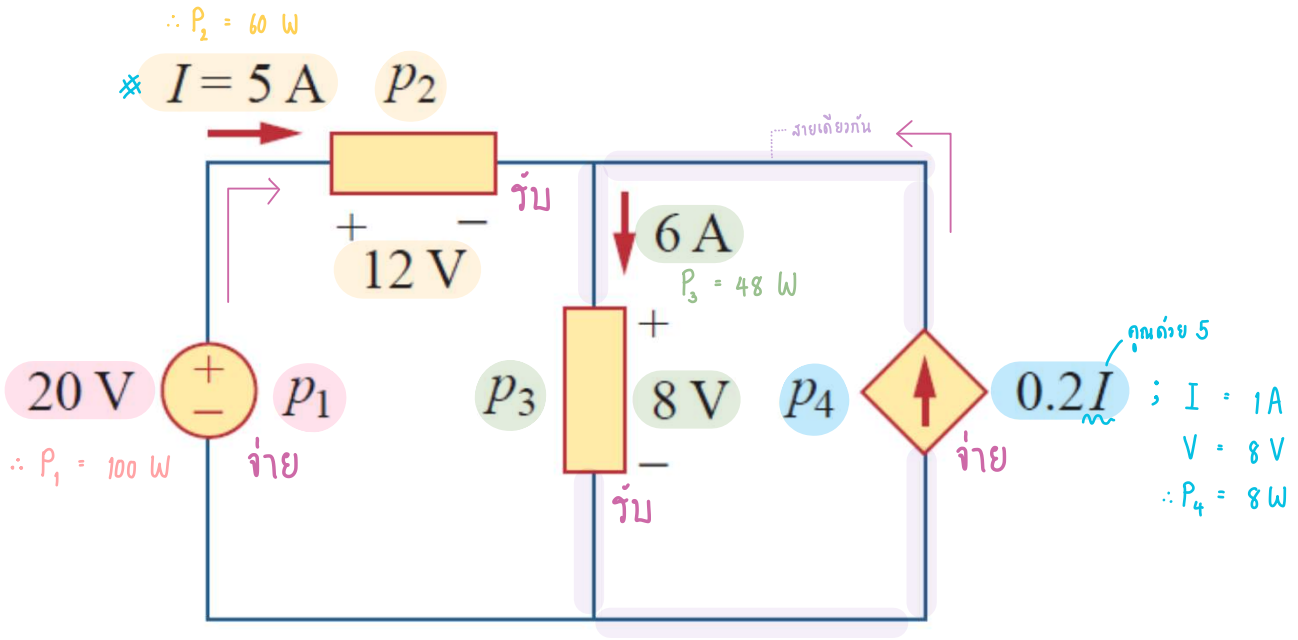
└ รวม V_{All} ได้ 25 V.



P = VI

1.6 Circuit Elements

Example 3

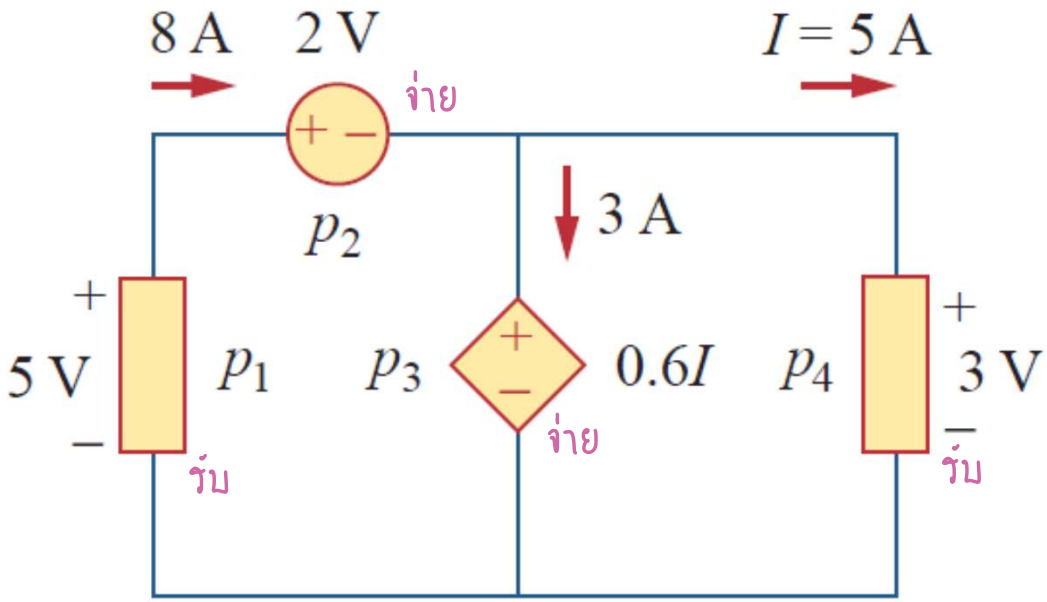


Calculate the power supplied or absorbed by each element

1.6 Circuit Elements

Example 4

* ± : อยู่ข้างนอก เป็น "รับ"
อยู่ข้างใน เป็น "จ่าย"



Compute the power absorbed or supplied by each component