Electirc Circuit ㄉㄉ學

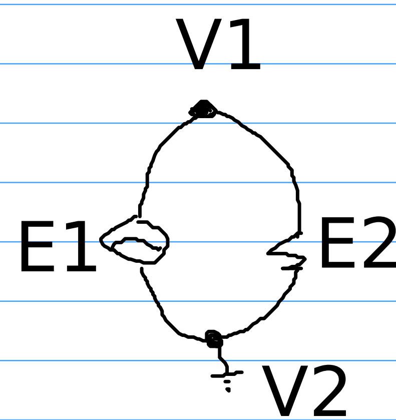
9/18

blahblahblah:
- cloud computing
- multicore (parallel programming)
- embeded software
- cosummer application mobel apps

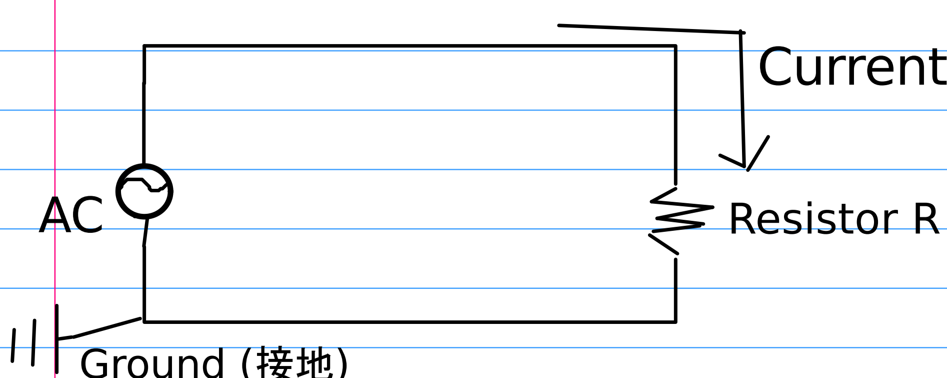
in our course:
- electric circuits
- 電子元件
- basic eletric cirtuit
- 60% are concepts

Grading:
- 3-4 homeworks
- midterm
- final

Textbook: Microelectronic Circuits 6/e



electric circuits
- components / devices   # 元件
- graph
    - vetrices (distinct electirc potential) # compare to ground V=0
    - edges (components)
- to represents the connections between electric components
- must be a components (or more) between vertices
- Edge 必對稱於 component
- voltage
    - the difference between two virtices



9/20

basic electrical circuit theory

basic concept:
- circuit
- votage / current / power
- signal
  - AC/DC
  - RMS

Definition of electric circuits:
- a graph, connections of vertices and edges, whereby every edge contains exact one electric component (Active | Passive*).
  And every vertex has a specific electric potent, where one of them is defined as 0 volt , i.e. ground

* active (gereating power), passive (consumming power)

measurment:
- electirc potential # for vertex
- current # for edge
- electric power
- V.I.P. !

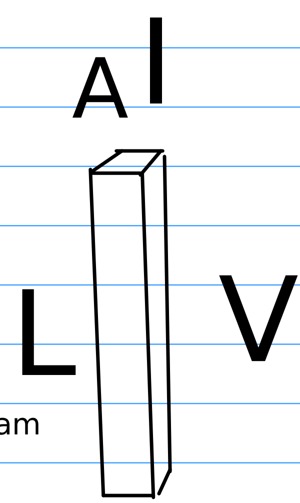
$\varepsilon = 1/2\ mv^2$
$\rho = mv$

能量守恆 Hamiltonian
動量守恆 Newtonian

Ohm's Law:
- $V = I R$
- R's definitoin => V / I

$R = \rho L / A = V / I$

$E = V / L = \rho I/A$ # 電場, electirc feild stream
$J = I/A$ # current density
$E = \rho J$



考慮長度為 L
截面積為 A
兩端電壓差為 V
通過電流 I
之導體

9/25

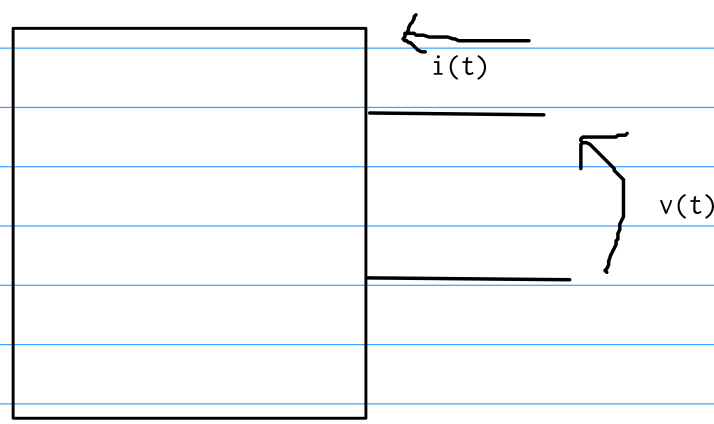
Basic electric circuits

- basic circuits concept
    - signal
    - devices
        - passive : RHL
- KVL / KCL Kirchhoff's Voltage & Current Law
    - theoretical formulation
    - progmatic solution
- Equivalent Curcuits (等效線路)
    - Thevenin Equiv. (voltage based)
    - Norton's Equiv. (current based)

    [duality]
- independent concepts

    generalized concepts of resistance

two port circuits



Z = V / I

一般化的電路：

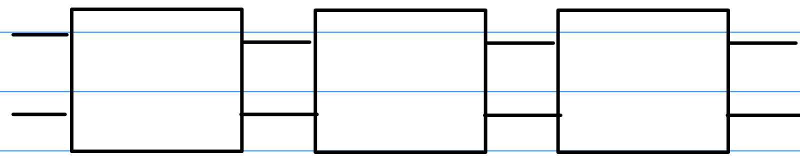
input impedance => transfer function => output impedeance # 線性代數（？）

LTI system, Linear time-invariant system

=> observation window 要先定好

circuit cascade (串聯)

- to find the best matching (coupling, 藕合)



time domain analysis
- signal as waveform (波形)

Frequency domain analysis
- signal as a spectra (譜)
- system freqency response
  => Laplace & Fourier transforms

voltage source => signal source

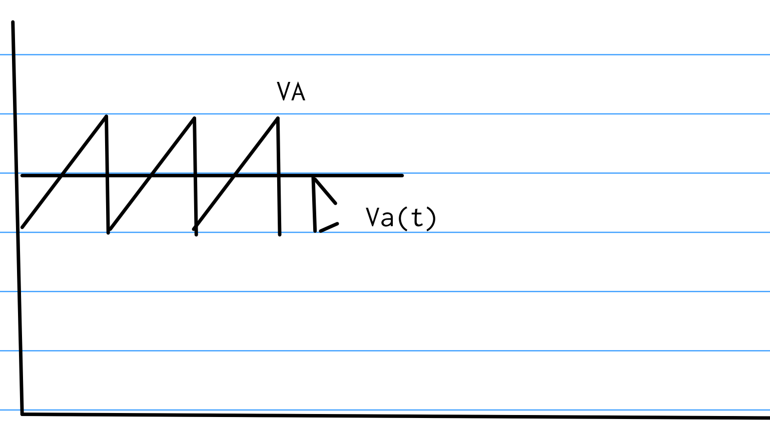
Ohm's Law
邵：這個大家都知道，一點都不好玩 QQ

i(t) = v(t) / R

notation:
- when v, i in lower case => time varying
  AC value (X)

VA => reference to ground
Va => VA average
DC value

Vs(t) = VA(t)
VA(t0) => VA(t) at t0
Va(t) = VA(t) - VA => AC value (O)



Graph in Electric Circuits
- Every vertex has a distinct voltage
- Every edge has a distinct current

iR(t) => Edge, component   actual value = compare to zero current

IR => Average of iR DC value constant
ir(t) => AC value = iR(t) - IR

RMS # Richard Matthew Stallman (X)

Rooted Mean Squared

$$V_a = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} v_\tau^2(\tau)d\tau} \quad <=> \sqrt{\frac{1}{3}(a^2+b^2+c^2)}$$

P = IV

Electric power = current * Voltage

$$P_\tau(t) = \frac{1}{T}\int_{t_0}^{t_0+T} i(\tau)v(\tau)d\tau$$

$$Apply\ Ohm's\ Law : i_R(t) = \frac{V_A(t)}{R}$$

$$P_\tau(t) = \frac{1}{T}\int_{t_0}^{t_0+T} \frac{v_A^2(t)}{R}d\tau$$

$$\propto \frac{1}{T}\int_{t_0}^{t_0+T} v_A^2(t)d\tau$$

$$\propto (v_A^{rms})^2$$

$$P_\tau(t) = \frac{(v_A^{rms})^2}{R}$$

9/27

Basic electric conponent

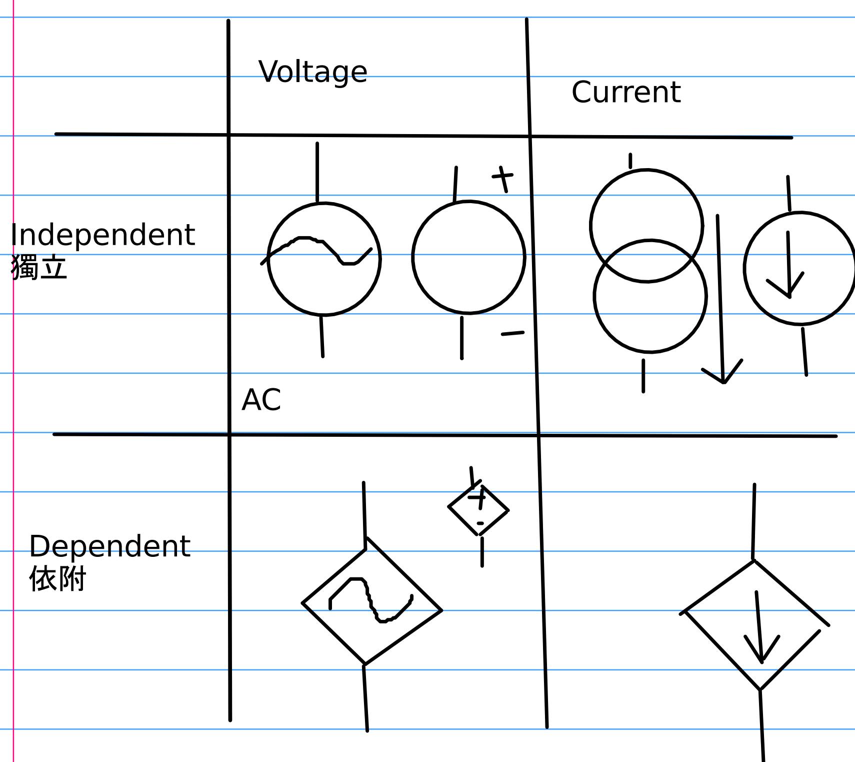
- Active
    - voltage / current sources
    - independent / dependent
- Passive
    - resisters
    - capacitors (電容)
    - Inductors (電感)
- Linearly and time invariance
- abstract models, maybe not real
- only to show some charactristics of components

Active components

- productor / generator of 'signal' power
- energe transfer => AC -> DC -> waveform
- waveform generator

VI(t) : voltage input

$$P_I(t) = \frac{1}{RT}\int_{t_0}^{t_0+T} v_I^2(\tau)\, d\tau$$



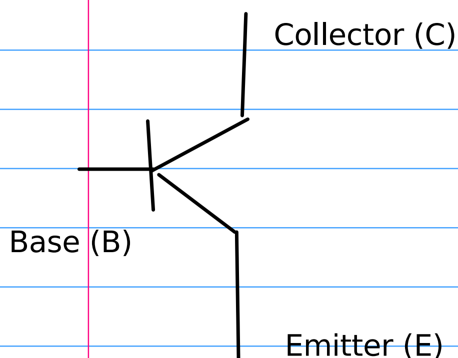
independent:

- Signal characteristics / amplitude / freqency / phase not dependent on other electric measuments in the circuits

dependent:

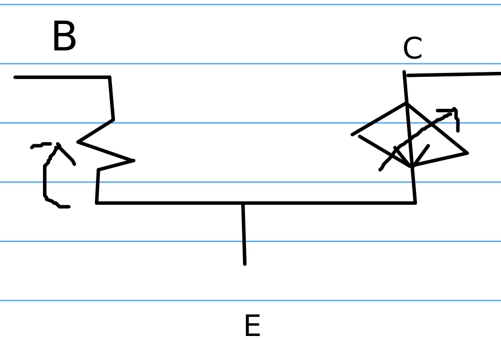
- Signal characteristics / amplitude / freqency / phase dependent on other electric measuments in the circuits

Bipole Junction Transistor(BJT)



VBE 改變 => 放大於 iCE

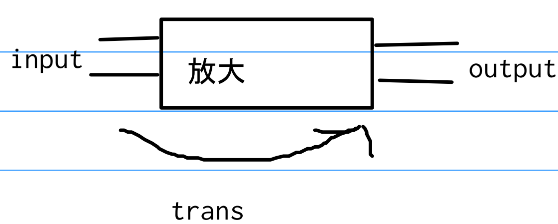
=> Amplifier



$$i_{CD} = g_m V_{BE}$$

$$g_m = \frac{i_{CE}}{V_{BE}}$$

$$= \frac{i_{input}}{V_{input}}$$



trans-conductance 電導量

gain (增益)

Passiva components
- consume signal power
- resister / capacitor / inductor
=> linear components

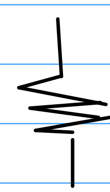
linear system
a systerm 滿足 law of superposition (疊加)

$$ax_1(t) + bx_2(t) \Rightarrow ay_1(t) + by_2(t)$$

$$S(ax_1 + bx_2) \Rightarrow aS(x_1) + bS(x_2)$$

time invarience
邵：我現在嚇你一跳，五秒鐘後我再嚇你一跳，你就不怕了嘛~

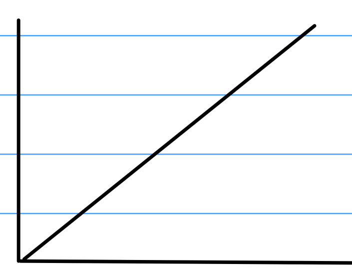
10/2
Basic concepts
- electric components
  - passive components (idealized)
    Resistor (R)
    Compacitor (C)
    Inductor (I)



Resistor
碳模電阻 => 紋理愈細 =>L 愈大 R 愈大

v-i characteristic (電器特別)
Ohm's Law
V = IR

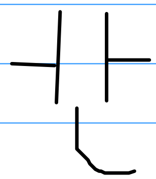
v-i char diagram



Line 理想上是直線
斜率是電阻
理想是常數

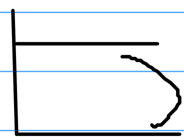
Thermal effect (熱效應)
- produce heat when operating
- 溫度上升 電阻率係數 電阻下降
- 對於良好的導體而言，電子運動近似於 ideal gas
- Thermal run away => 愈來愈熱 => 功率上升 => 燒掉囉 ^q^

Capacitor



insulator (絕緣體) medium　或是 Air medium

原理: electric inducstance
　　　　charging => discharging



C: Capacitance 電容量
charge amount 電荷量

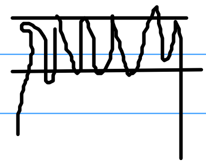
$$Q_c = \int_0^{\tau} i_c(t)\,d\tau \quad // C\ for\ charge\ amount$$

$$V_c(t) = \frac{1}{c}\int_0^{\tau} i_c(t)\,d\tau$$

$$i_c(t) = c\frac{dV_c(\tau)}{d\tau}$$

$$C = \gamma AW$$

Inductor 電感線圈
- inductance



$$V(t) = L\frac{di(t)}{dt}$$

$$i(t) = \frac{1}{L}\int_0^{\tau} v(\tau)\ d\tau$$

L = 電感值

原理：electromagnetic inductance 電磁感應

電容跟電感連在一起 => 電磁學上的鐘擺模型

init: 電容充好電 （獲得電位能）

電容放電
電感產生抵制的感應電流
電容充電

力學能守恆的機械模型在電磁學上的等價

Capacitor 儲存電能
Inductor 調節能量
Resistor 損耗

How to solve an Electirc Circuit

- Find all the voltage and current values in that circuit
- All solution
  - voltage @ each vertex
  - current @ each edge (find loop currents) # for all loop in circuits

- Partial solution
  - input => |circuit| => output

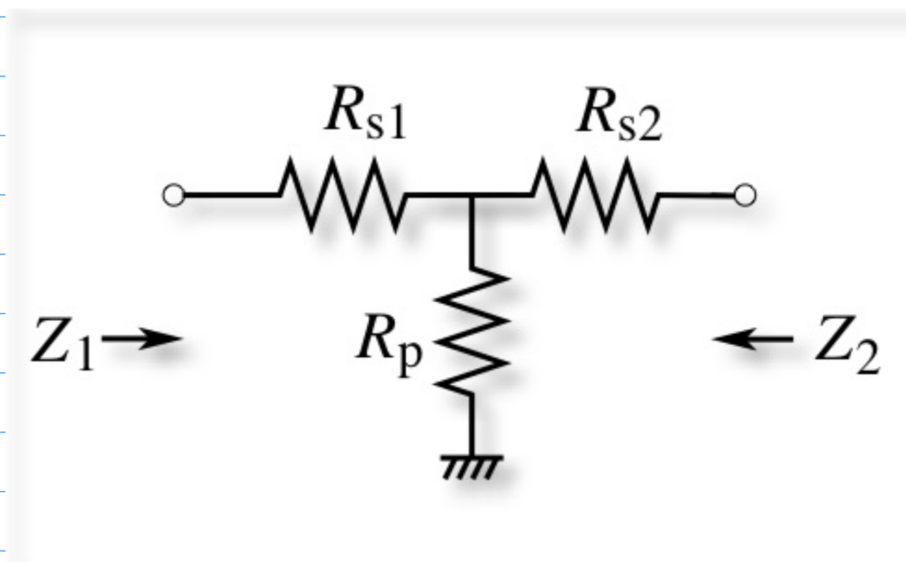
- using Kirchhoff's Voltage & Current Laws

正負很重要！！！

KVL

- 其實就是能量守恆 (the conservation of potential energy)

T-circuit



loop: 走完一圈的 edge
一定要新的 loop 找新的 vertex 多走，沒有走過的 edge

KVL:

sum of all Vl in loop for all Loop is 0

$$\sum_{l \in Loop} V_l = 0$$

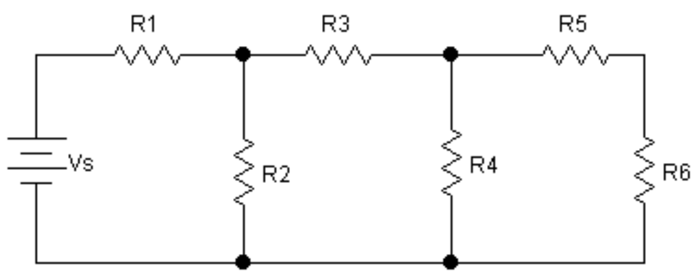
10/4

大助教：呂家哲ㄉㄉ

Kirchhiff's Voltage and Current Laws (KCL & KVL)
- Basic Principles
- Basic Rules
- Sinplification

Ex.

Ladder circuit (梯形電路)



Vs Voltage source
R6 Load resister

串聯 Serial connection
R1 + R2
同流分壓
VR = VR1 + VR2
iR = iR1 = iR2
R = R1 + R2

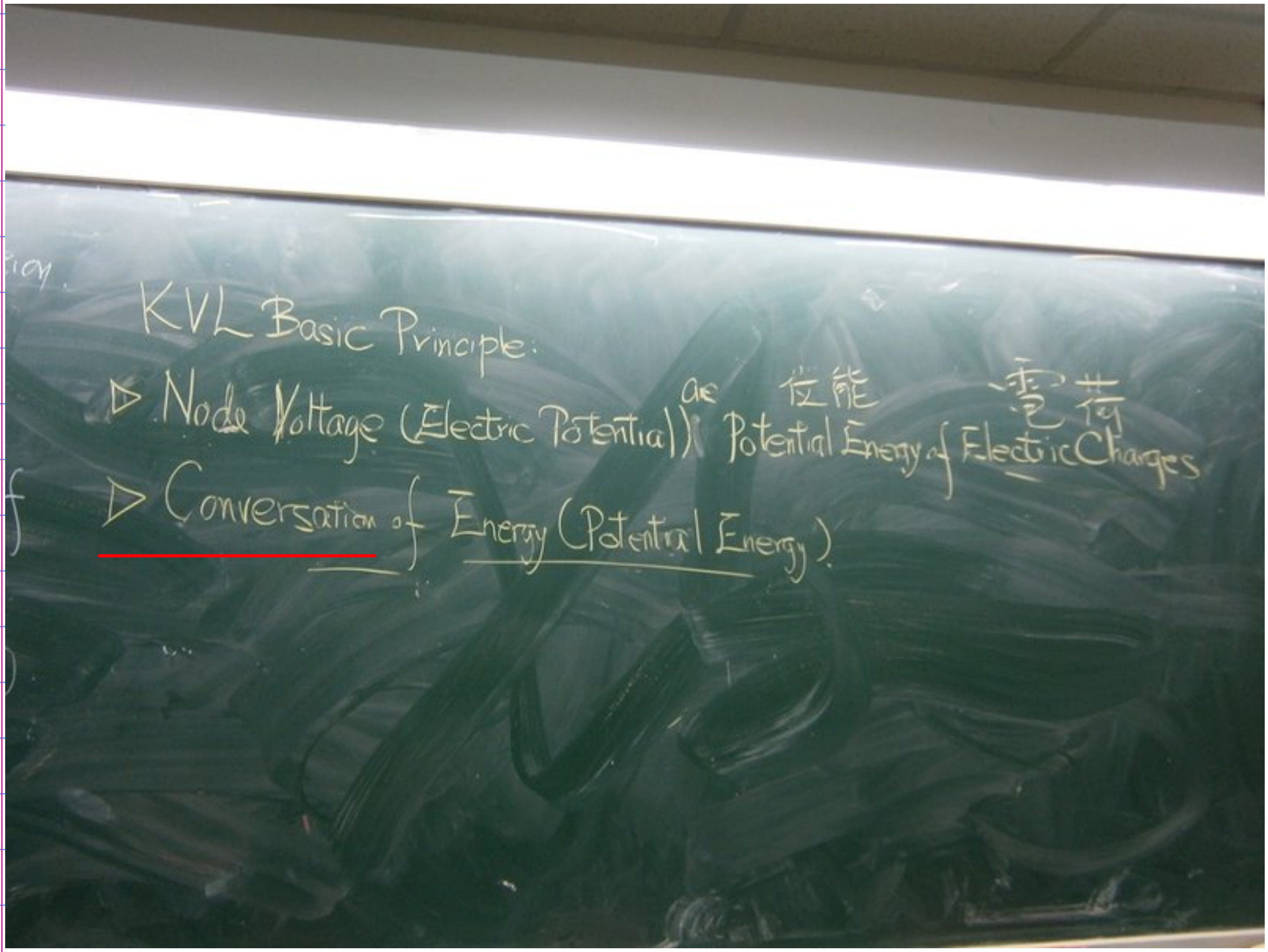
並聯 Parallel connection
R1 || R2
同流分壓
VR = VR1 = VR2
iR = iR1 + iR2
1/R = 1/R1 + 1/R2

R = R1R2 / (R1+R2)

Relation between Voltage of Nodes

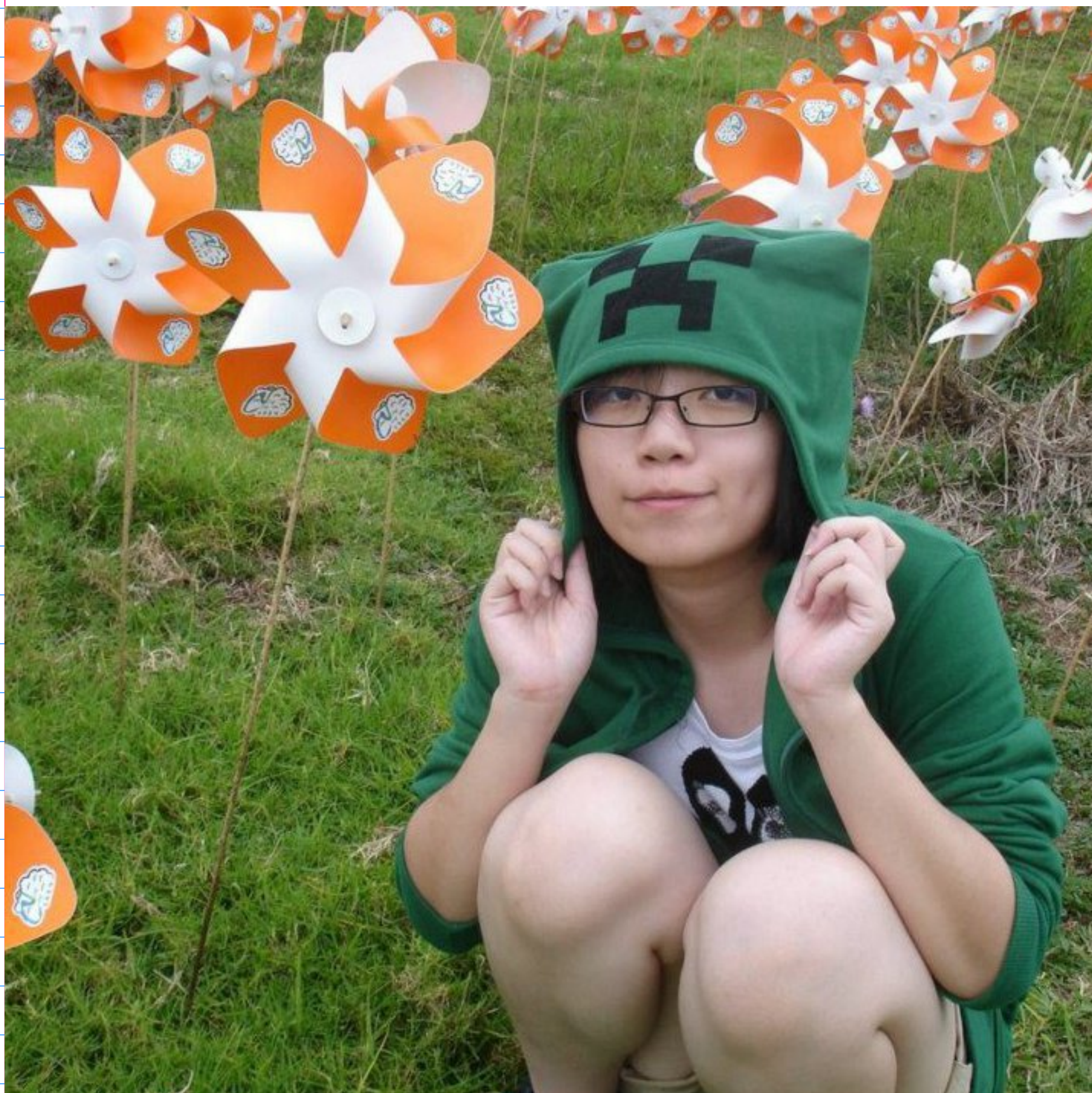
KVL
- find loops => will solve loop currents
- the algebraic sum of voltage difference between the nodes in a solved loop of a circuit should always be zero

- Basic Principle
  - Node Voltage are Potential Energe of Electric charges
  - Conservation of Energe (Electrical Potential)


KVL Basic Principle:
▷ Node Voltage (Electric Potential) are Potential Energy of Electric Charges
位能
電荷
▷ Conversation of Energy (Potential Energy)

能量的對話（誤

放個小趴照片 >////<



10/9

Rules for writing orginized and correct circut equations

KVL :

- For every closed loop (l), in an electric circuit the algebraricsum of voltage difference in the loop shall always be zero

loop:

- a path from one node back to itself without traversing any edge than once.

KVL use rules:

- identify all nodes in the circuit, start with the Ground node, other end of every component is a disdinct node repeat the procedure untill ALL components (edges) have been visited, AND ALL Nodes have been marked

- identify all loops in the circuit. Start from with Ground Node OR Upper Left Node. Identify a loop by traversiong components connected to previous nodes in clockwise direction untill you go back to the original node. Identify another new loop by including at least one new component again in clockwise direction untill no new components can be included.

- Identify voltage difference accross each components. Assign polarity (極性) which end node is position start from UPPER LEFT node which is likely to be the node with the Highest potential.

  尋找方向：[左上 => 右下]

- Name the voltage difference using nodes or components. E.g. V_AB

- write current Equations using KVL. One equation from each loop along the loop current direction.

KCL:

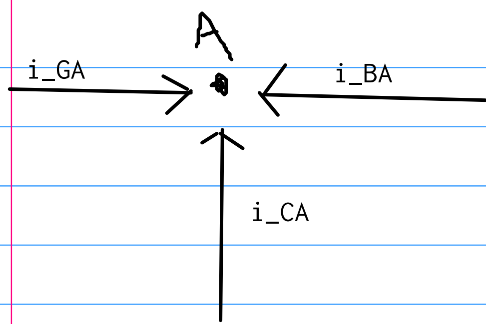
- for each node N in a circuit, the algebraric sum of all currents follwing into and out of this node shall always be zero.

$$\sum_{K\in N} i_{NK} = 0$$

Underlying Principle:

- conservation of electirc charges
- No charge shall be generated or destroyed in a circuit node

- identify all noeds, using the same Rules as KVL
- assign every node with a distinct Node voltage
- one equation for every node



$$i_{GA} + i_{CA} + i_{BA} = 0$$

$$i_I + \frac{V_C - V_A}{R_1} + \frac{V_B - V_A}{R_2}$$

solve the Equiation

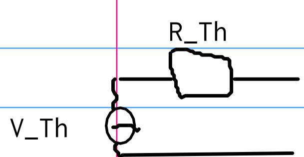
10/11

Equivalent Circuits
    Thevenin Equivalent
    Norton   Equivalent

求解：
    voltage accross and current pass through a pair of circuit nodes

circuit port:
    a pair of distinct circuit nodes
    solve voltage and current of that port (=> one port) node

Thevenin Equivalent circuit



Equivalent voltage source

=> Equivalent Resistance / Inpedance

把複雜電路包裝成內部的獨立電壓源 V_Th 和與其串聯的等效電阻 R_Th

（從外部看的話是抽象的黑盒子）

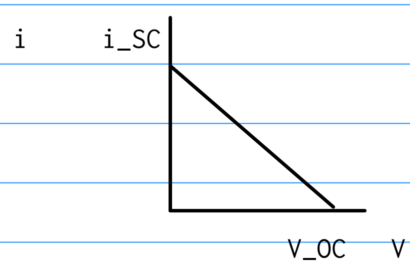
For any linear circuits, the electric characteristics (v-i) of a specific point (a pair of distinct nodes) can always be modeled sa an ideal voltage source V_Th and a serially connected passive element

Load Resistance

open circuits (斷路)
- resistance => infinity.
- $i = 0$ (no current pass through)

shot circuits (短路)
- resistance => -
- $v = 0$ (no voltage difference between two terminals)
(M and N are not distinguishable nodes => merge into one node)

Principles:



v-i characteristic => 線性組合

v_{OC}
- open circuit voltage
- $V_{NN} |i_{MN} = 0$ (V_{NN} @ $i_{MN} = 0$)

i_{SC}
- short circuit current
- $i_{SC} |V_{MN} = 0$

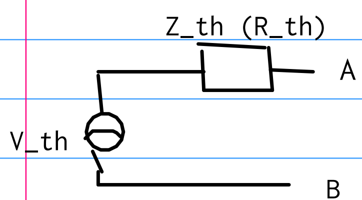
$R_{Th} = V_{OV} / i_{SC}$

線性 model: 只需要測量兩種極端情況 => 潮爽ㄉ直接得到簡化後的電路特性

10/16

Thevenin & Norton Equivalent circuits for linear circuits
Principles and applicatoins

Thevenin & Norton Equivalent circuits principle
- Linear circuits obey law of superposisin
- Serially connected Linear Passive Elements



Voltage source

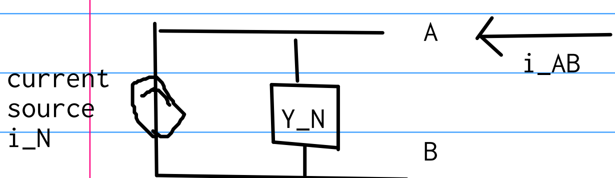
V_Th = V_AB = open circuit voltage
i_SC = short circuit current

impedance : Z_th
Resistance: R_th = v_OC / i_SC

The voltage-and-current (v-i) chartaristics of a port of any linear electric circuit can always be modeled as an equivalent source (V_th) connected in series with a Linear passive element with impedance (Z_th) or resistance (R_th)

The Dual Model (Norton):

Norton Equivalent circuit
Parallel connected passive elements



Admittance T_N
conductance (電導) G_N : i / v = 1 / R_Th

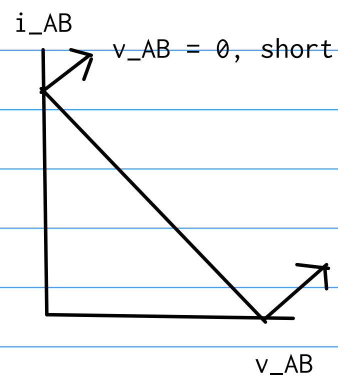
The voltage and current characteristics of port of any linear electric circuit can always be modeled as an equivalent source (i_N) connected in Parallel with a linear passive element with amittance (Y_N) or Conductance (G_N)

Rational (WHY?)

linear circuit, port

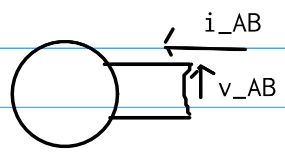
short circuit of a port when voltage accross the two circuit nodes becomes ZERO
v_AB = 0, R_L = 0

open circuit of a port when current go through the two circuit nodes becomes ZERO
i_AB = 0, R_L = infinity.

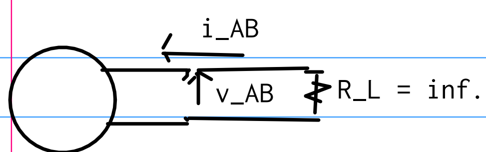


Short circuit

R_L = 0



open circuit



$$KVL: \qquad (R : R_L)$$

$$-V_{Th} + V_R + V_{AB} = 0$$

$$V_{AB} = 0$$

$$-V_{Th} + V_R + V_{AB} = 0$$

$$V_R = V_{Th} \;\; => R_{Th}\, i_{OC} = V_{OC}$$

$$=> R_{Th} = \frac{V_{OC}}{i_{SC}}$$

Ideal Voltage Source
- No interal (energy) loss
- No interal impedance / resistance (R_th = 0)

Ideal Current Source
- No interal (energy) loss
- No interal admitance / conductance (G_N = 0)