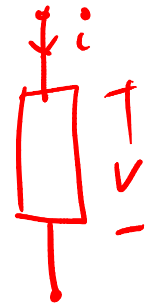
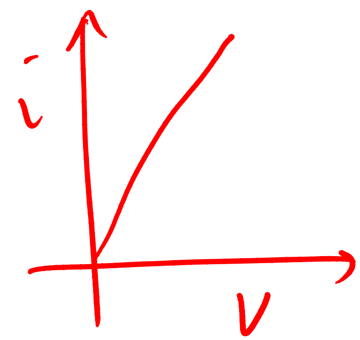
Circuit analysis with Nonlinear Elements And Review of Part2

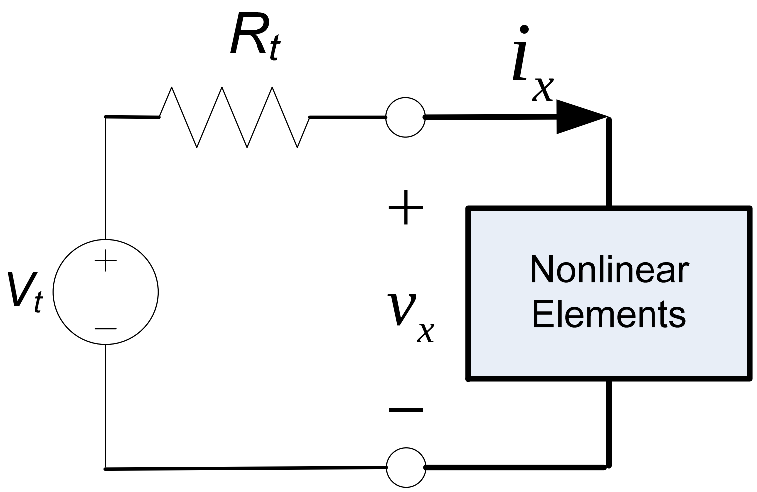
Linear elements

- Resistor $i = \frac{v}{R}$
- Inductor $v = L \cdot \frac{di}{dt}$
- Capacitor $i = C \cdot \frac{dv}{dt}$





Nonlinear elements



$i_x = e^{v_x}$: Nonlinear — ①

From KVL ;

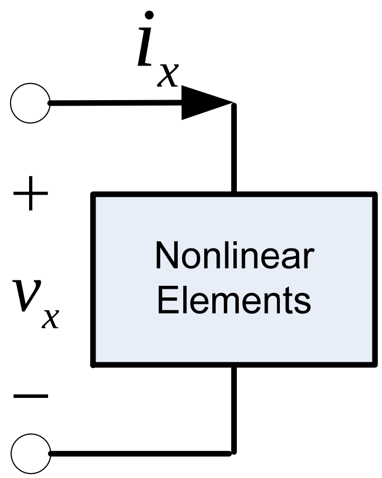
$V_t - i_x \cdot R_t = V_x$ — ②

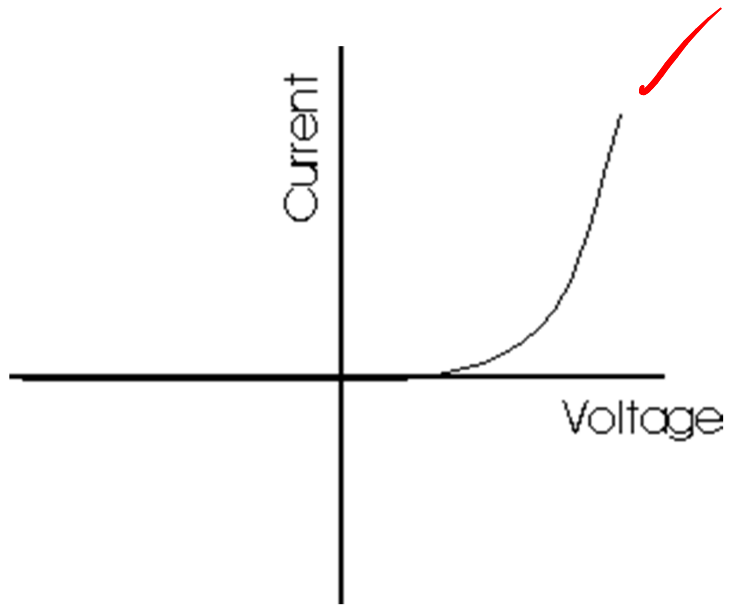
Replace i_x by e^{V_x} : $V_t - e^{V_x} \cdot R_t = V_x$

V_x ?

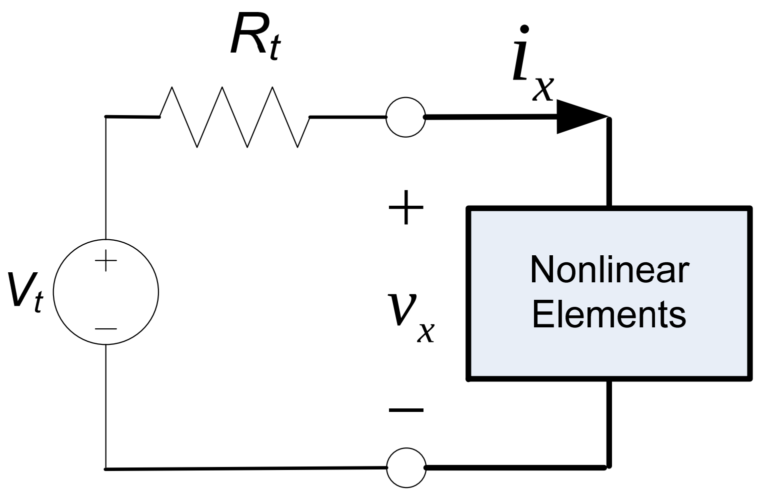
Nonlinear elements

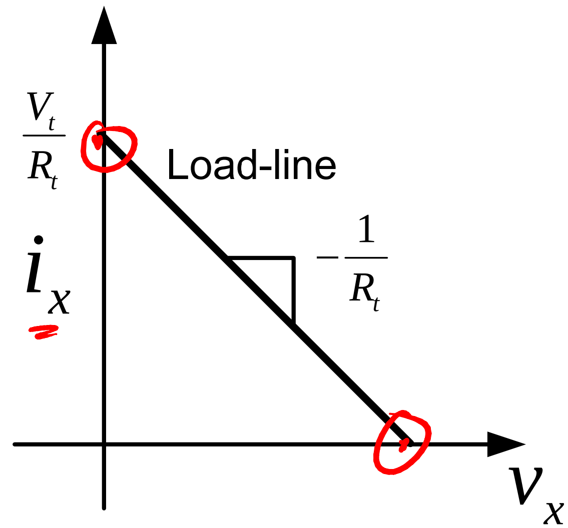
- Nonlinear elements may not have an analytical function





Load line





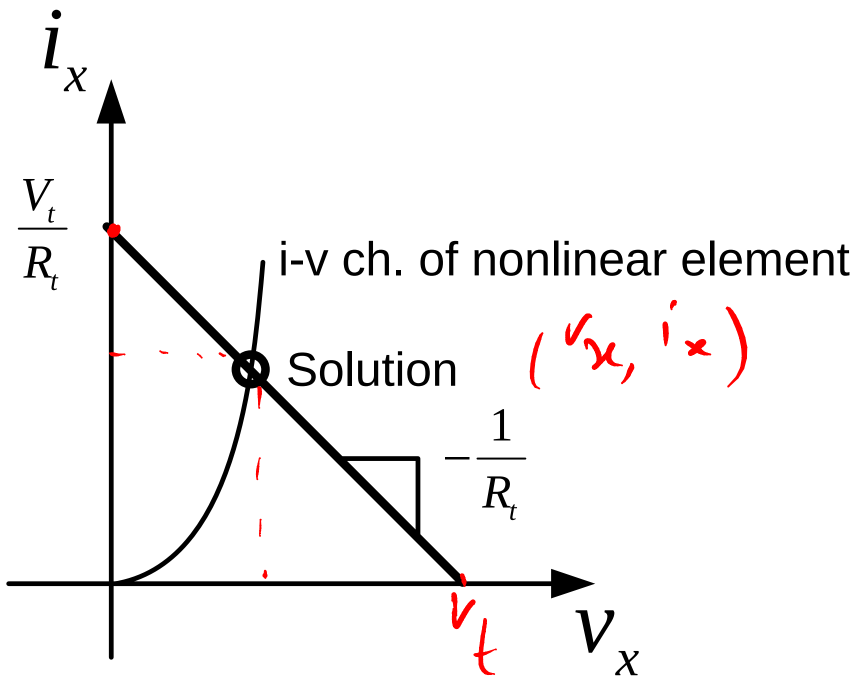
KVL : $V_t - R_t \cdot i_x = V_x$

$V_x = 0 \Rightarrow V_t - R_t \cdot i_x = 0 \Rightarrow i_x = \frac{V_t}{R_t}$

$i_x = 0 \Rightarrow V_t = V_x$

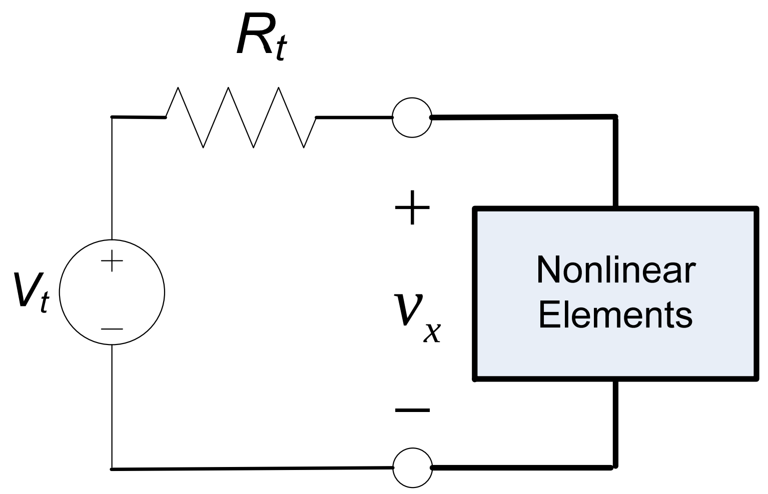
Graphical (Load-line) analysis

- Merge the load line onto the i-v curve of the nonlinear element
- The solution is at the intersection point



Solving circuits with one Nonlinear element

- Replace the circuit by its Thevenin's equivalent considering the nonlinear element as the load
- Use graphical analysis technique



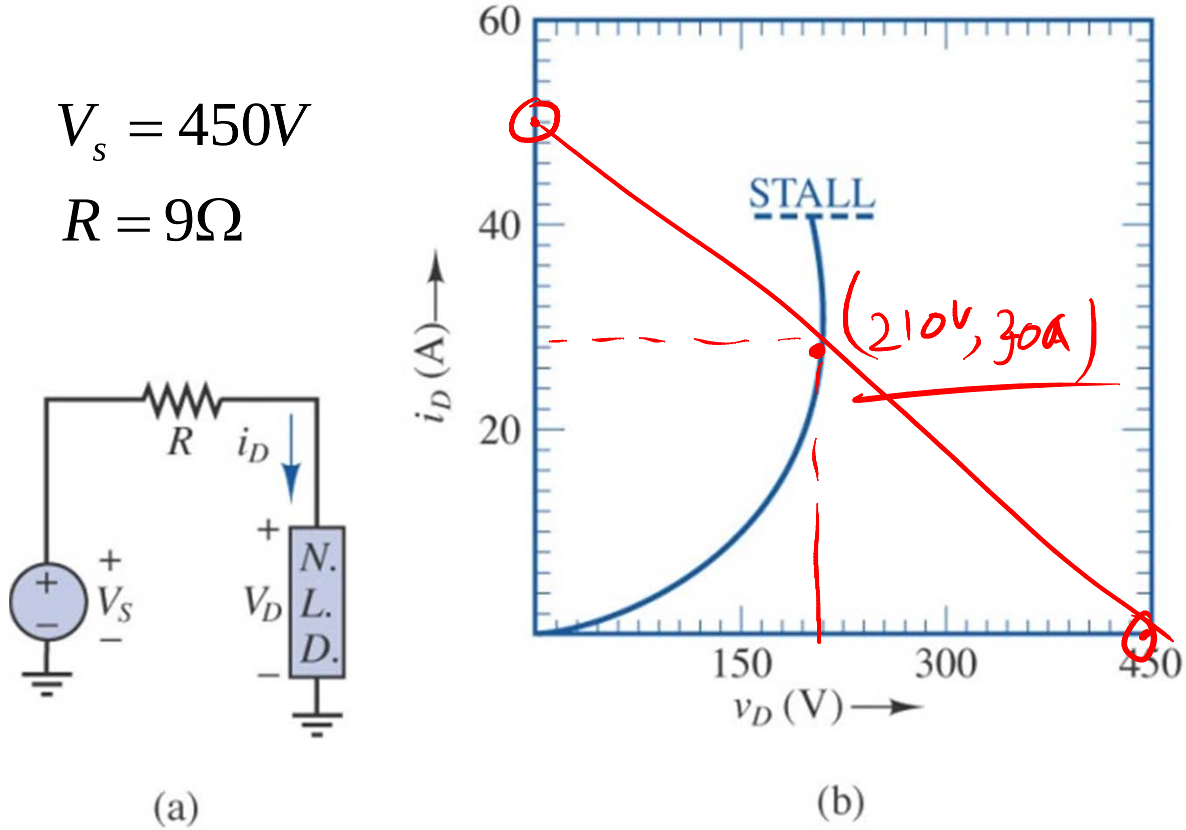
Example

Find the current through the NLD.

$$\frac{V_s}{R} = \frac{450}{9} = 50\ A$$

$$V_s = 450V$$

$$R = 9\Omega$$



Popular nonlinear devices

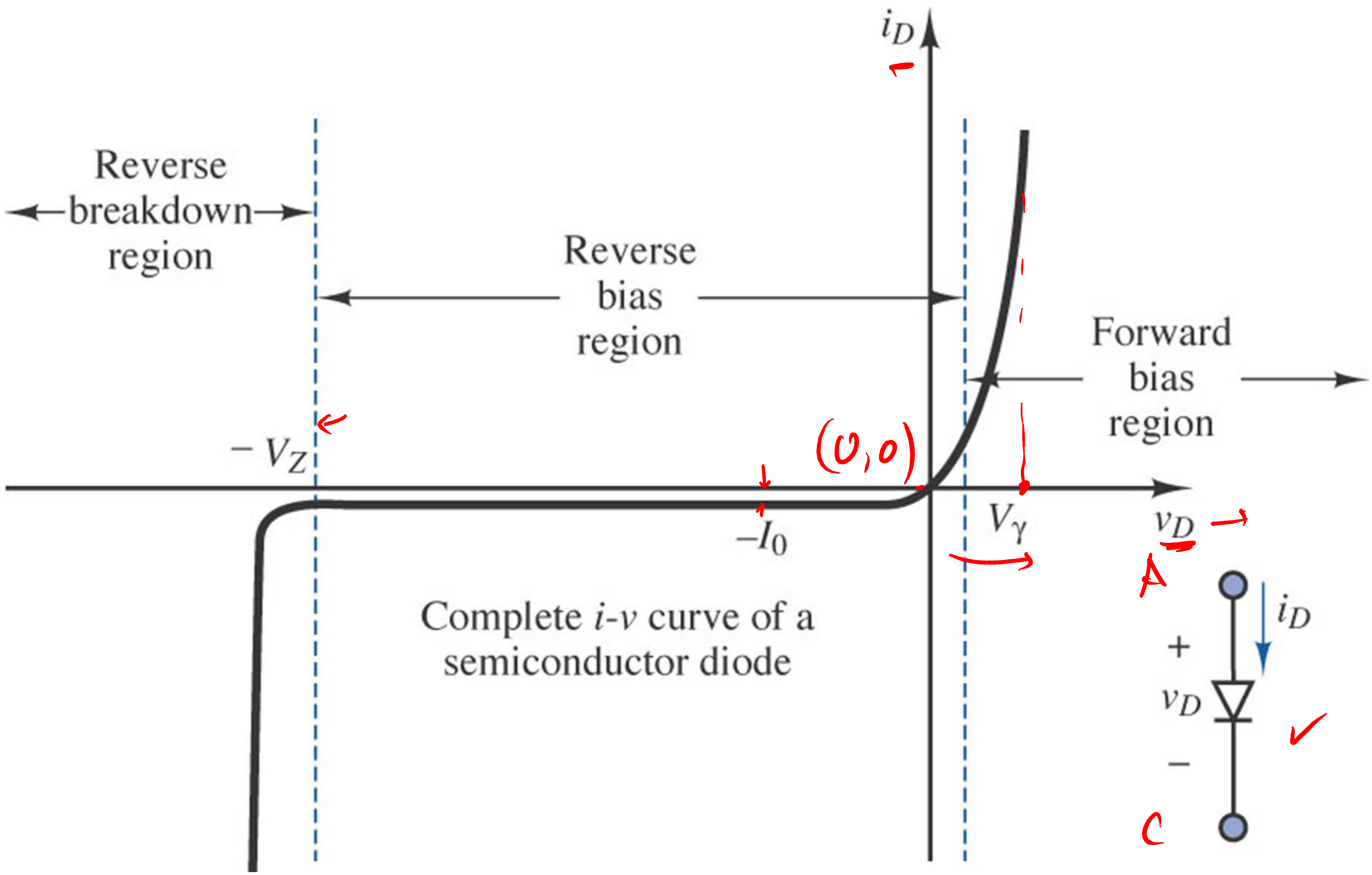
- Diode

- BJT(Bipolar Junction Transistor)

- MOSFET (Metal Oxide Semiconductor Field Effect Transistor)

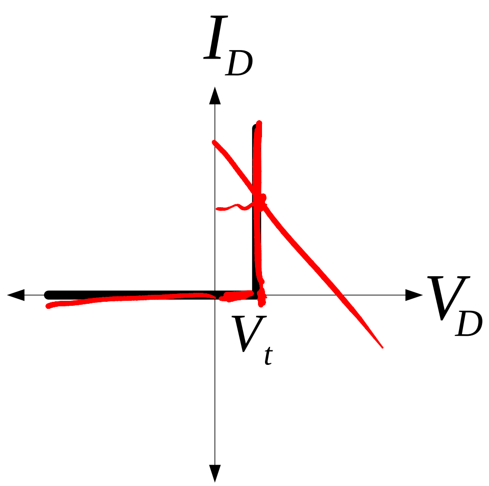
We learn about their terminal characteristics without getting to know their physics

Diode

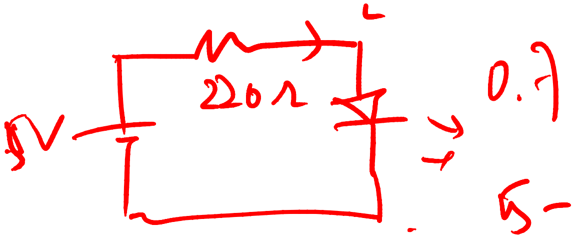


Complete *i*-*v* curve of a semiconductor diode

Simplified diode model



V_t : cut-in voltage

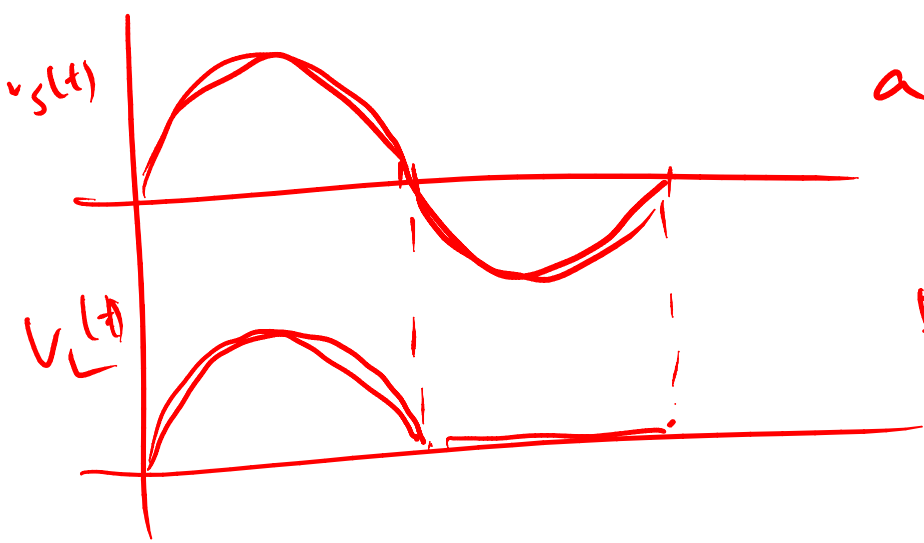


$i = \frac{5-0.7}{220\Omega}$

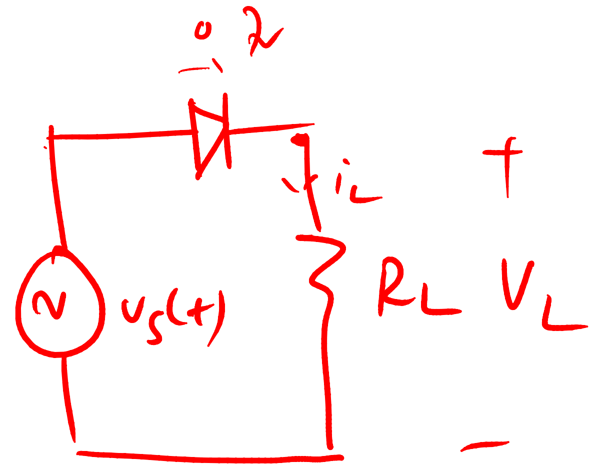
- In a normal silicon diode at rated currents, the arbitrary "cut-in" voltage is defined as 0.6 to 0.7volts - used in rectification
- Schottky diodes can be rated as low as 0.2 V
- Red or blue light-emitting diodes(LEDs) can have values of 1.4 V and 4.0 V respectively.

Some applications of diode

- Rectification (ac to dc)
- LED ✓
- Over-voltage protection



ac
↓
Dc



$V_s(t) = 100 \sin 100t$

$V_L(t) = i_L(t) \times R$

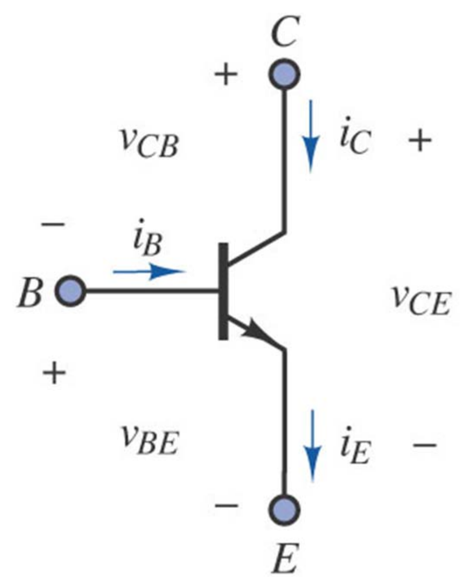
BJT Symbol

(Bipolar Junction Transistor)

- 3-terminal device
  - Base - B
  - Collector - C
  - Emitter - E

- Base current controls the behavior of the BJT

The operation of the BJT is defined in terms of two currents and two voltages: i_B, i_C, v_{CE}, and v_{BE}.

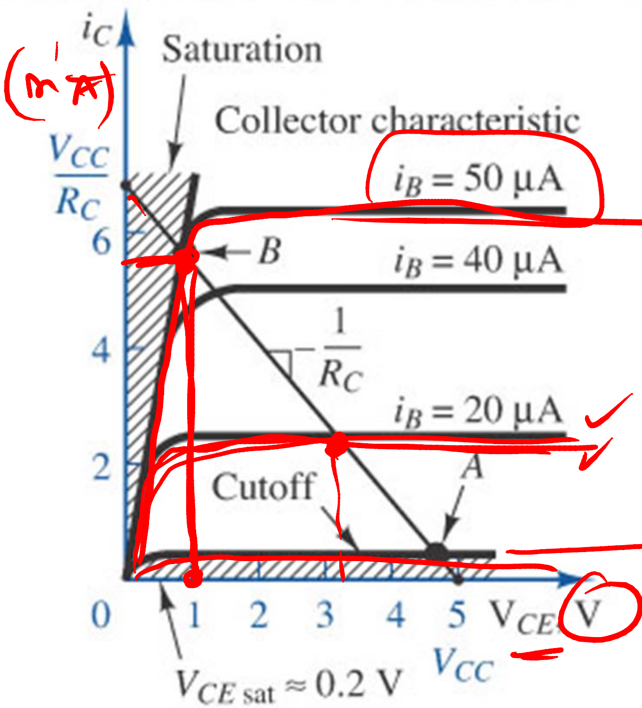


KCL: $i_E = i_B + i_C$
KVL: $v_{CE} = v_{CB} + v_{BE}$

BJT in Circuit

$V_{out} = \left(-100 \times \frac{R_C}{R_B}\right) \Delta V_{in}$

- Separate i-v curve for each value of base current



$i_B = 20\mu A$

$i_C = 2mA$

$i_C = \beta i_B$

β is large

$\beta = \frac{2\times10^{-3}}{20\times10^{-6}}$

$= 100$

$\Delta i_C = \beta \cdot \Delta i_B$

$= 100 \times \Delta i_B$

$V_{out} = V_{CC} - i_C R_C$

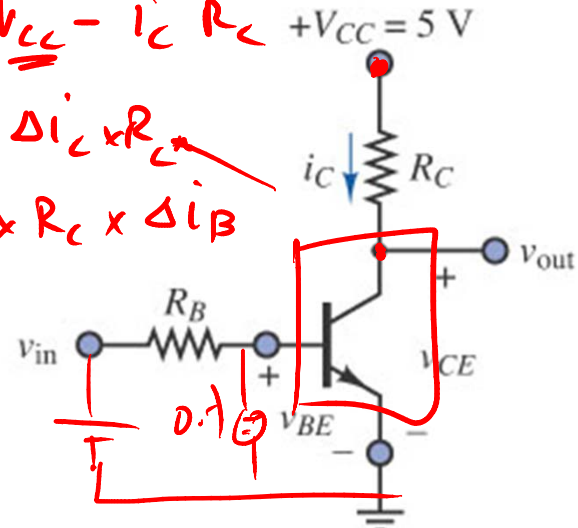
- Two modes of operation:
  - Amplifier
  - Switch

$\Delta V_o = -\Delta i_C \times R_C$

$= -100 \times R_C \times \Delta i_B$

$i_B = \frac{V_{in} - 0.7}{R_B}$

$\Delta i_B = \frac{\Delta V_{in}}{R_B}$

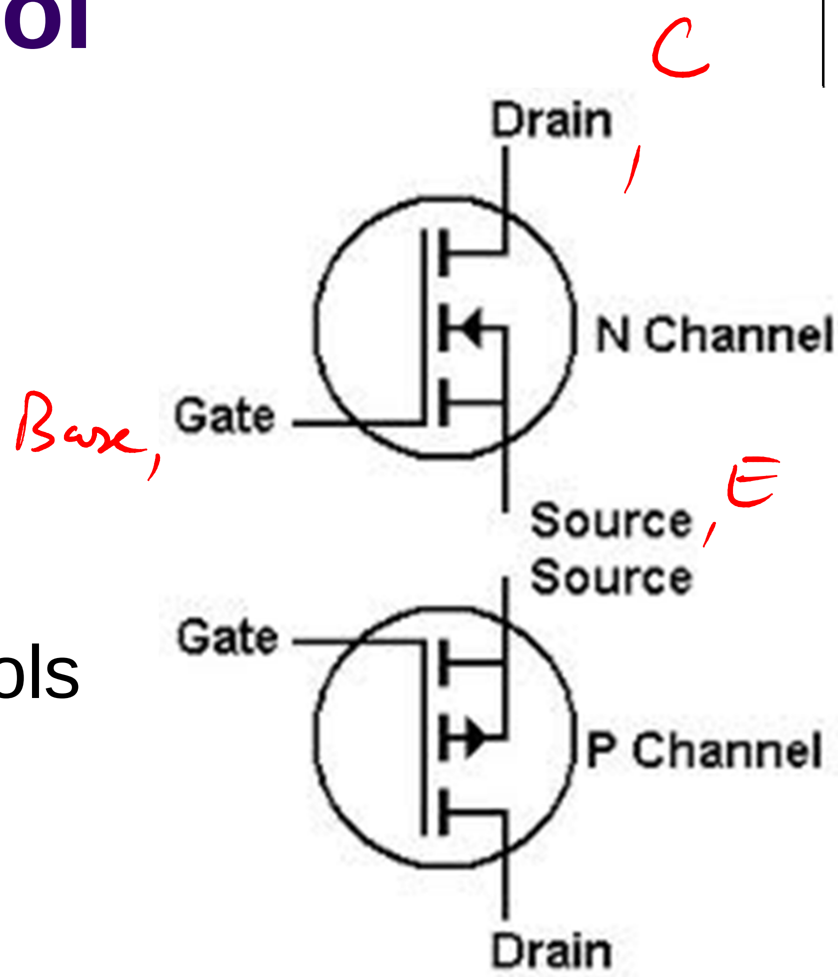


Elementary BJT inverter

MOSFET symbol

- 3-terminal device
  - Gate
  - Drain
  - Source

- Gate voltage controls the behavior of the MOSFET



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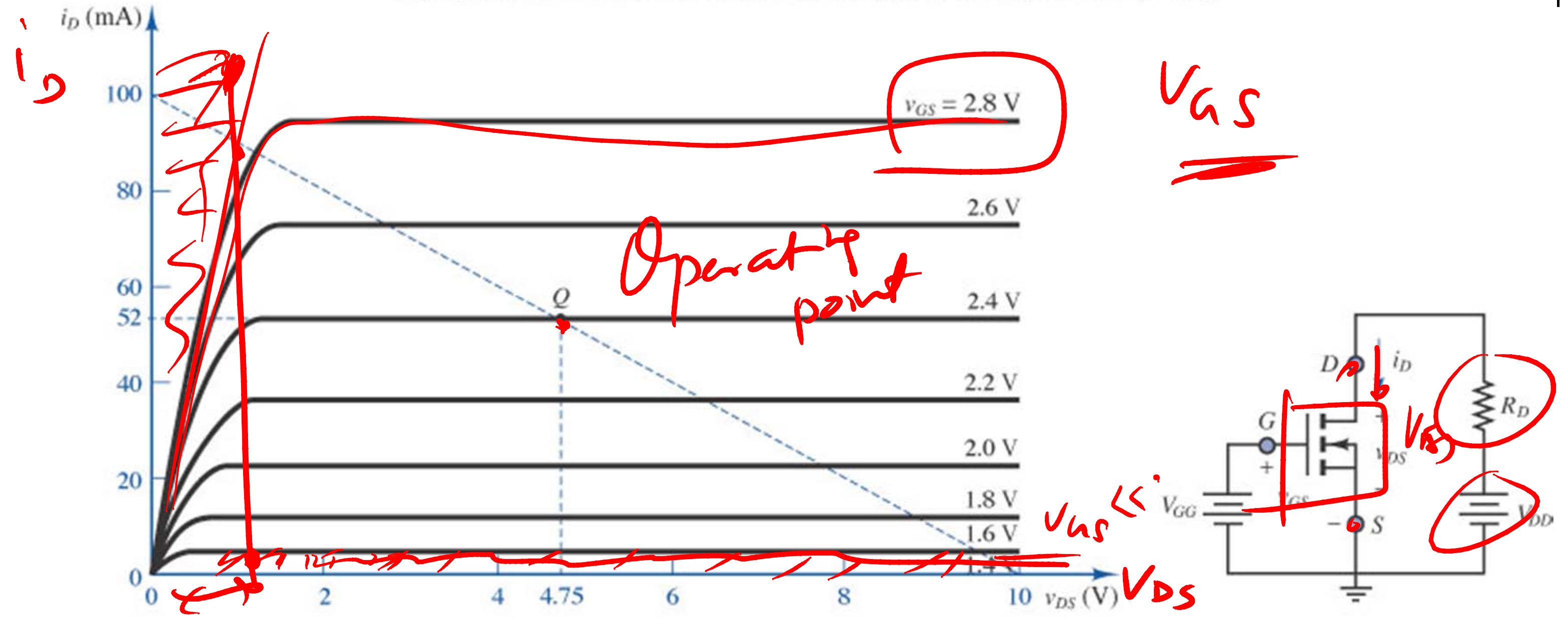
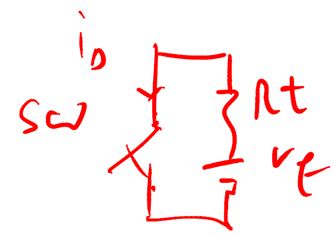


- Separate i-v curve for each value of base current

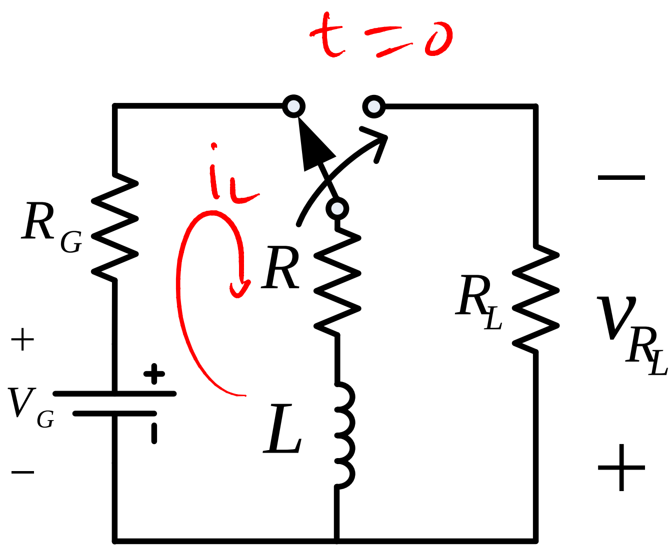
- Two modes of operation:
  - Amplifier
  - Switch



Examinable Syllabus for part 2

1. DC transients analysis
2. AC steady-state analysis
3. Digital Logic
4. Circuits with Nonlinear elements

Mid-term question Q4



$V_G = 12V$

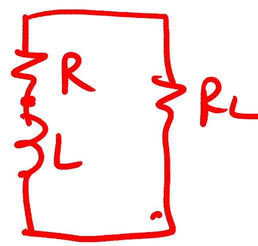
$R_G = 0.2\Omega$

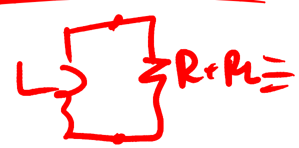
$R_L = 1k\Omega$

$\frac{12}{0.2+R} = 12 \Rightarrow R = 0.8\,\Omega$

$i_L(\infty)_{t<0} = \frac{V_G}{R_G+R} = 12$

(L is short)





$v_L = 12\,kV$

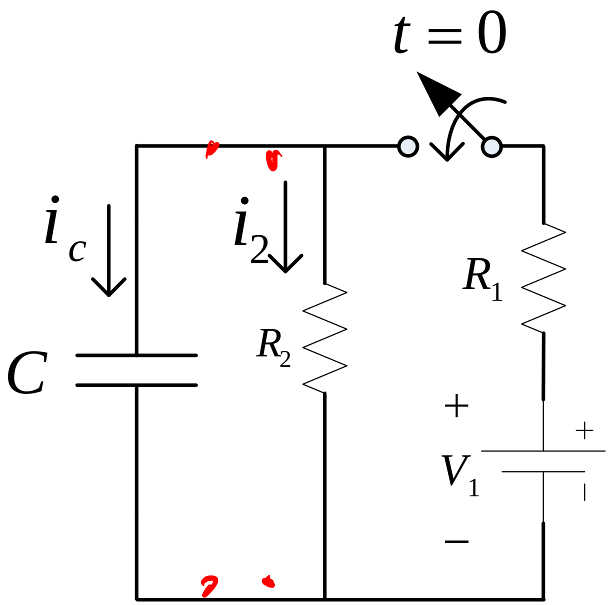
$i_L(0^-) = i_L(0^+) = \frac{12kV}{1k\Omega} = 12A$

- The load requires 12KV to start with and it decays at time constant $\tau = 10\mu s$

$\tau = \frac{L}{R+R_L} \Rightarrow L = \tau \times (R+R_L)$

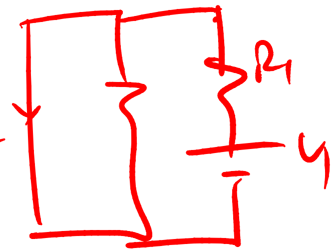
- Find the value of L and R in the circuit.

Mid-term question ~~Q4~~ 5



$V_1 = 12\,V$
$R_1 = 100\ \Omega$
$R_2 = 100\ \Omega$
$C = 10\ \mu F$

At $t=0$

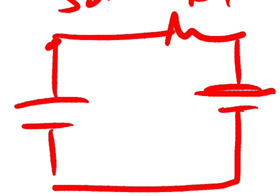


$i_c = \frac{12}{100}$

$= 0.12\,A.$

$i_2(t) = \frac{v_c(t)}{R_2}$

Soln: R_T



$v_T = 6V$

$i_2(t) = \frac{v_c(t)}{R_2} = \frac{1}{R_2}\left(6 \times \left(1 - e^{-t/R_T C}\right)\right)$

- i_c immediately after the switch is closed
- $i_2(t)$ after switch is closed

Review of AC steady-state

- Review of Complex numbers

  $+ , - , / , *$ Rect $\leftrightarrow$ Polar

- Phasors sinusoidal voltage and current

- Impedance for the R,L and C

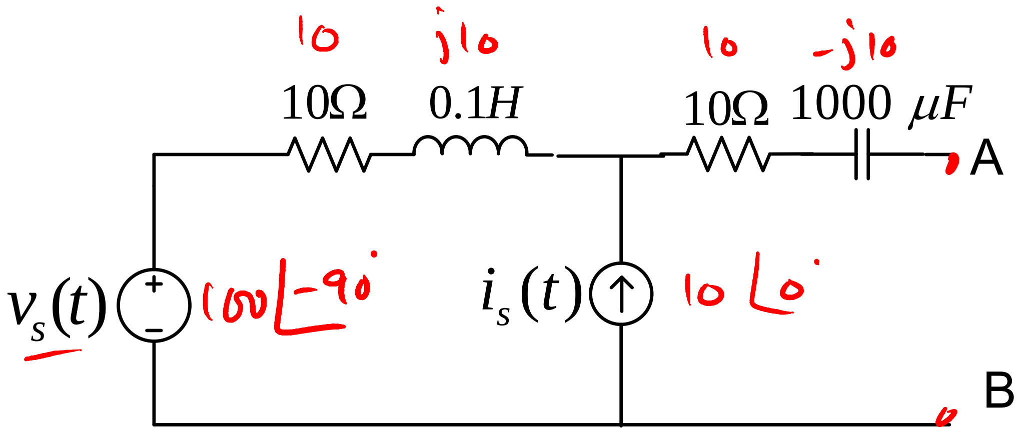
  $Z_R = R$, $Z_L = j\omega L = \omega L \angle 90^\circ$

- Solve circuits using all the techniques for DC circuit analysis

  $Z_C = \frac{1}{j\omega C} = -j\frac{1}{\omega C}$

  $= \frac{1}{\omega C} \angle -90^\circ$

AC steady-state review Qn



$$v_s(t) = 100\sin(100t)\,V$$

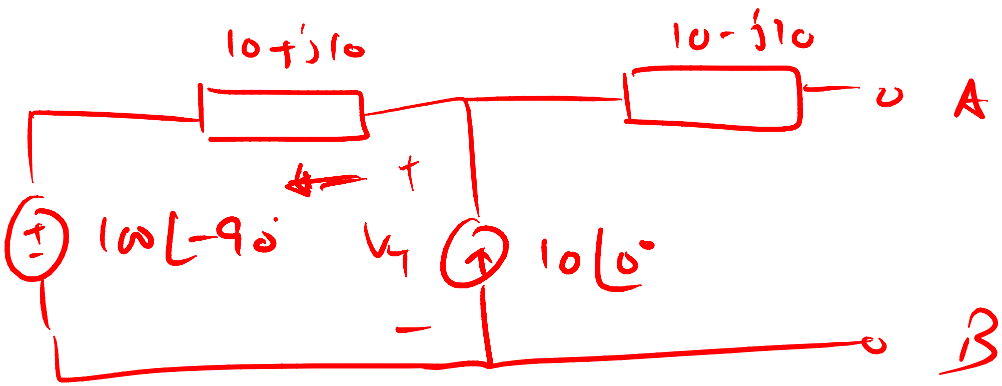
$$i_s(t) = 10\cos(100t)\ A.$$

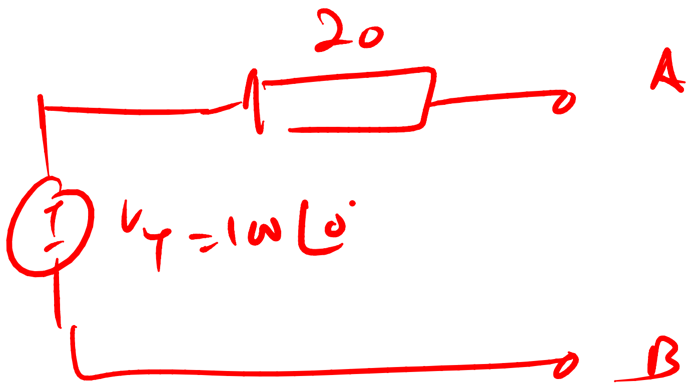
- Find the Thevenin equivalent between A and B

- Draw the Phasor diagram showing the voltage source, current source and the Thevenin voltage

$0.1\,H \quad j \times 100 \times 0.1 = j10 \qquad -j\frac{1}{\omega C} = -j \cdot \frac{1}{100 \times 10^{-3}}$

$= -j10$





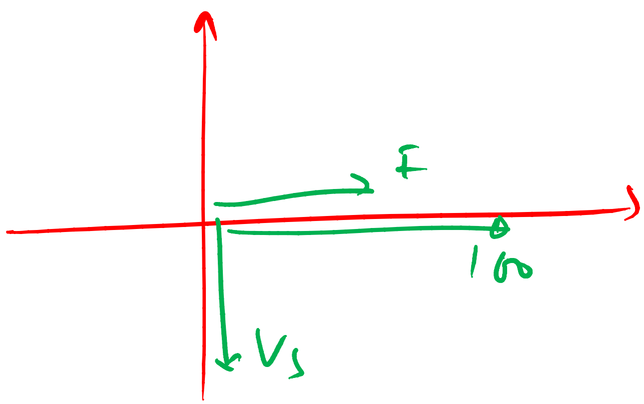
$$V_T = 100\angle -90^\circ + i_x(10+j10)$$

$$= -j100 + 10\angle 0^\circ \times (10+j10)$$

$$= -j100 + 10(10+j10)$$

$$= \cancel{-j100} + 100 + \cancel{j100} = 100$$

$$V_T = 100\angle 0^\circ$$



Digital Design

- Basic Boolean operation
- Logic gates – AND,OR, NOT, NAND, NOR
- Truth table for a digital system
- SOP and POS expression from Truth table
- Minimization of logic expression using K-map
- Realization of logic expression using NAND/NOR gates only with 'alternate gate representation'