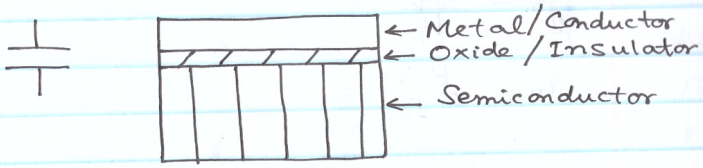
E-field

Field Effect Transistor (FET)

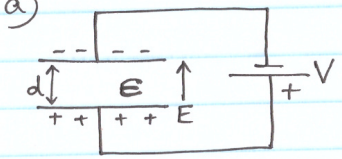
Metal Oxide Semiconductors: MOS



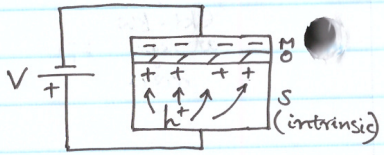
Metal: Gold, aluminum
Oxide/Insulator: Silicon dioxide/Silicon nitride
Semiconductor: Silicon/germanium (doped preferably)

MOS is a special capacitor.

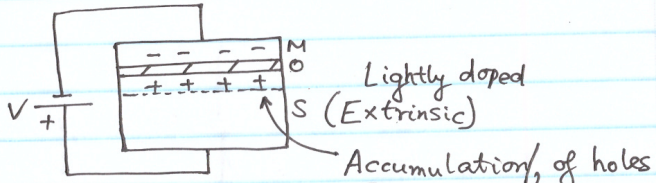
a)



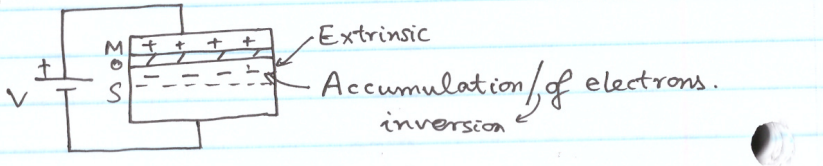
Standard capacitor biasing:



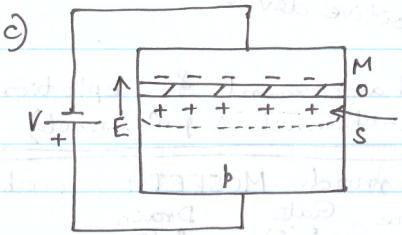
MOS biasing



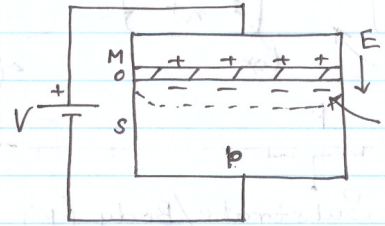
b)



c)

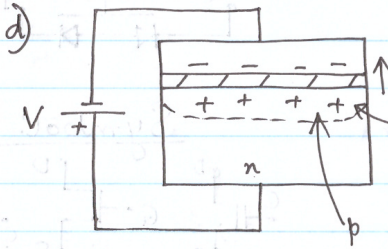


p^+ (Accumulation) of h^+

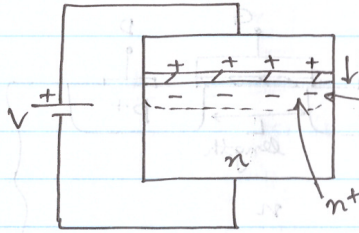


n (Inversion) of p-region

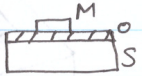
d)



(Inversion) of n-region



(Accumulation) of e^-



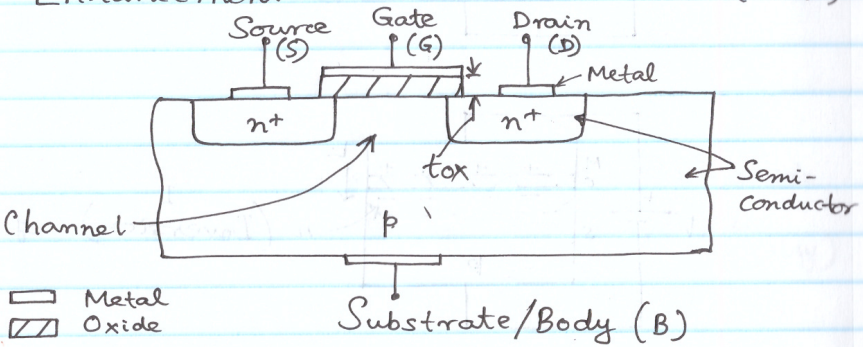
V → E → A/I → Conductivity → Conductor / Semi-conductor / Insulator

E-field

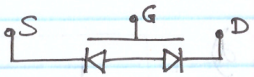
→ V-sensitive device

e. MOSFET: Enhancement & Depletion. (n-channel & p-channel)

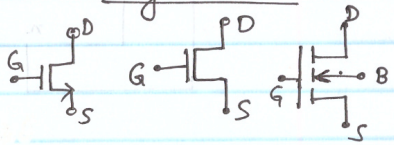
Enhancement mode MOSFETs: n-ch. (cross-section)



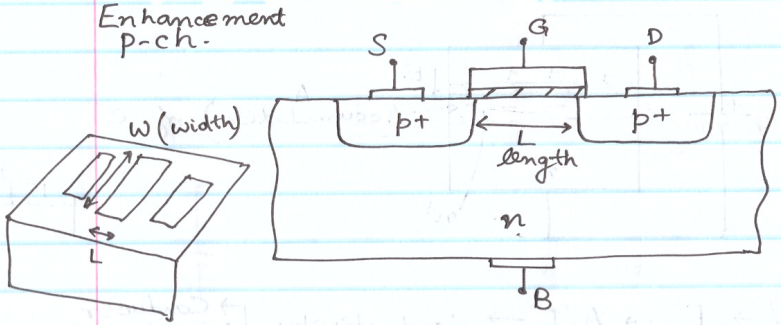
Basic Terminals:
- Source → Emitter (like)
- Gate → Base
- Drain → Collector
- Substrate → —



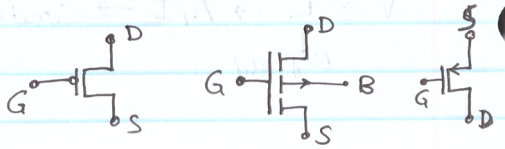
Symbol: n-ch



Enhancement p-ch.



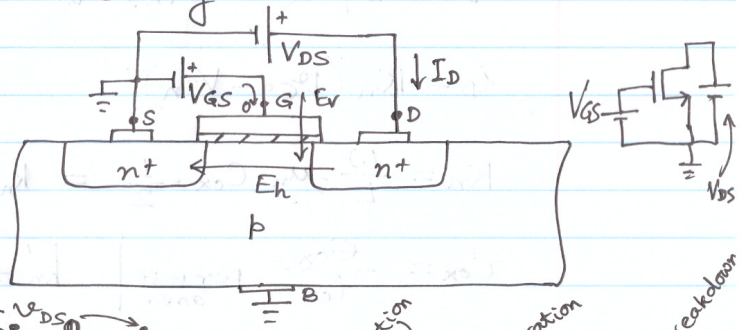
Symbol: p-ch.

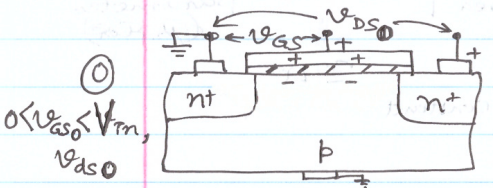


Threshold V (min. V_{GS} to form a channel)

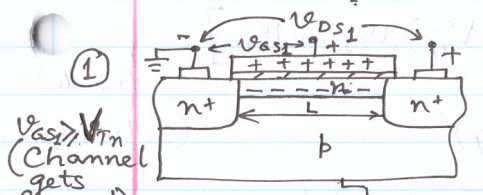
(μ = constant, V_T = constant) (assume:)

f. MOSFET biasing & V-I characteristics

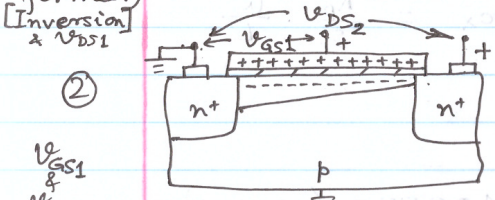




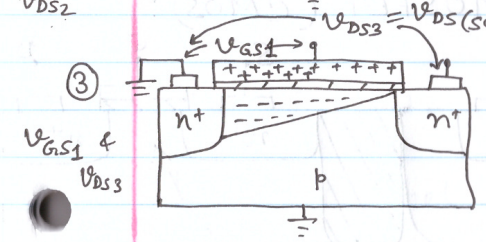
① $0 < v_{GS0} < V_{Tn}$, v_{DS0}



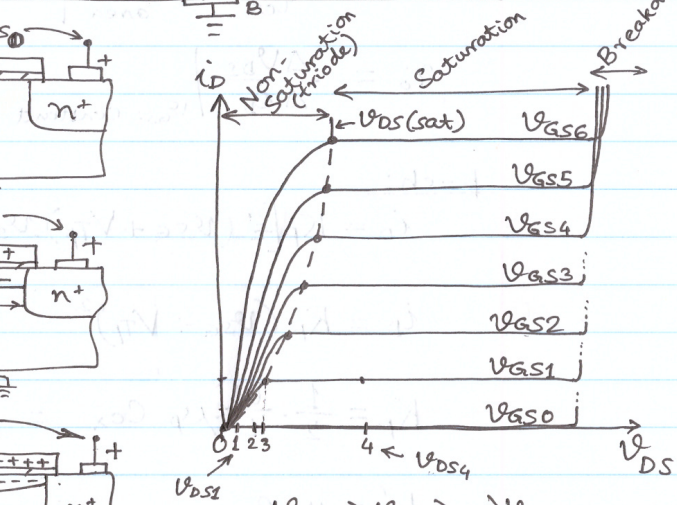
② $v_{GS1} > V_{Tn}$ (Channel gets formed) [Inversion] & v_{DS1}



③ v_{GS1} & v_{DS2}



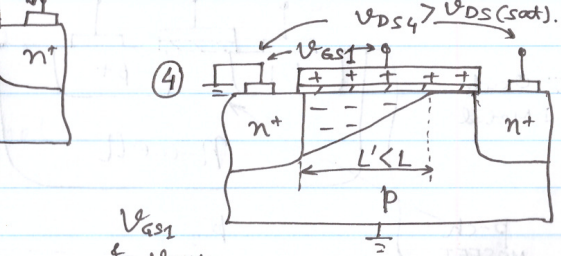
③ v_{GS1} & v_{DS3}



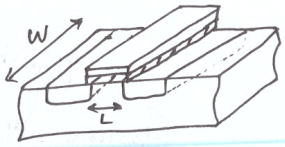
$v_{GS6} > v_{GS5} > \ldots > v_{GS0}$

$v_{GS1} > V_{Tn} > v_{GS0}$

↑ Threshold Voltage



④ v_{GS1} & v_{DS4}



3D Structure of a MOSFET

n-ch:

$$i_D = K_n \left[2 (v_{GS} - V_{Tn}) v_{DS} - v_{DS}^2 \right]$$ (Triode/ Non-sat. region)

$$i_D = K_n (v_{GS} - V_{Tn})^2$$ (Sat. region)

$$K_n = \frac{W}{L} \cdot \mu_n \cdot C_{ox} \cdot \frac{1}{2} = k_n' \cdot \frac{1}{2} \cdot \frac{W}{L}$$

$K_n \rightarrow$ Transconductance parameter

$k_n \rightarrow$ Process conduction parameter

$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$ per unit area

$$r_o = \left. \frac{\Delta v_{DS}}{\Delta i_D} \right|_{v_{GS} = \text{constant}} \cong \infty$$

p-ch:

$$i_D = K_p \left[2 (v_{SG} + V_{Tp}) . v_{SD} - v_{SD}^2 \right]$$ (Triode)

$$i_D = K_p (v_{SG} + V_{Tp})^2$$ (Saturation)

$$K_p = \frac{1}{2} \cdot \frac{W}{L} \cdot \mu_p \cdot C_{ox} = \frac{k_p'}{2} \cdot \frac{W}{L}$$

$$k_p' = \mu_p \cdot C_{ox}$$

g. Complementary MOSFET (CMOS):