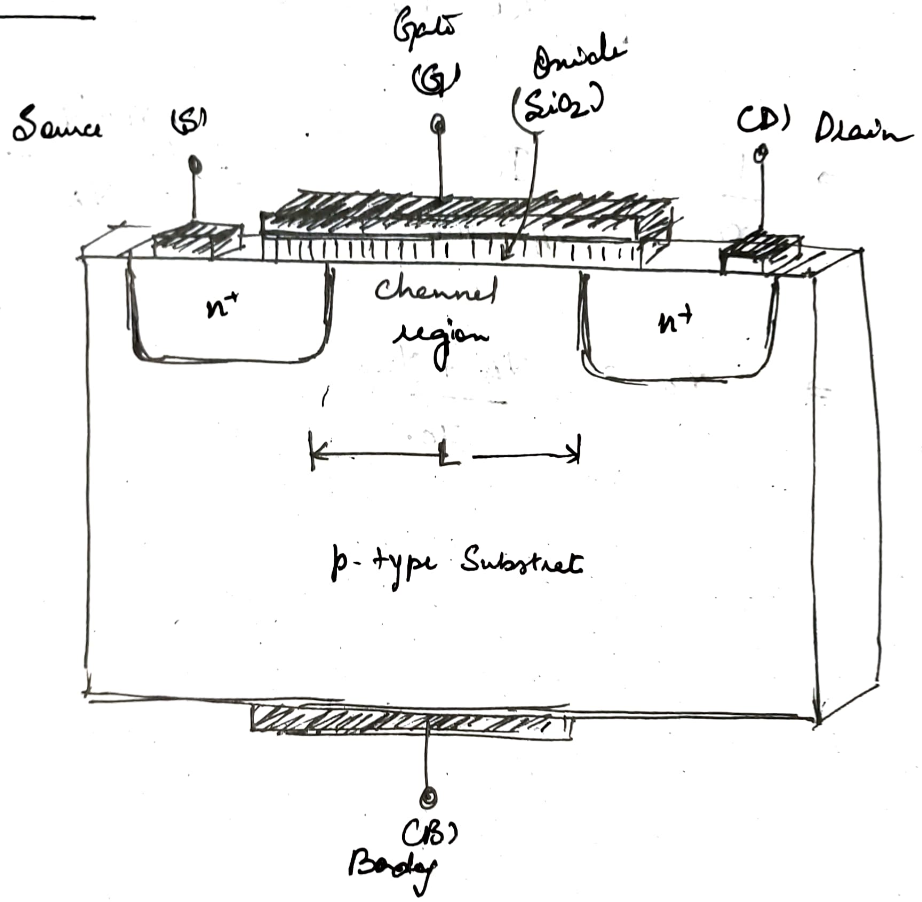
MOSFET:

Metal Oxide Semiconductor (MOS) Field-Effect Transistor

Structure:



→ Fabricated on p-type substrate.

→ Two heavily doped n-type region (source, drain)

→ Thin SiO_2 layer (thickness ≈ 1–10 nm) on surface of substrate.

→ Metal deposits on oxide for gate electrode.

→ Metal contacts present on source, drain and body.

[Note: Most modern MOSFETs use polysilicon for gate electrode]

Operation :

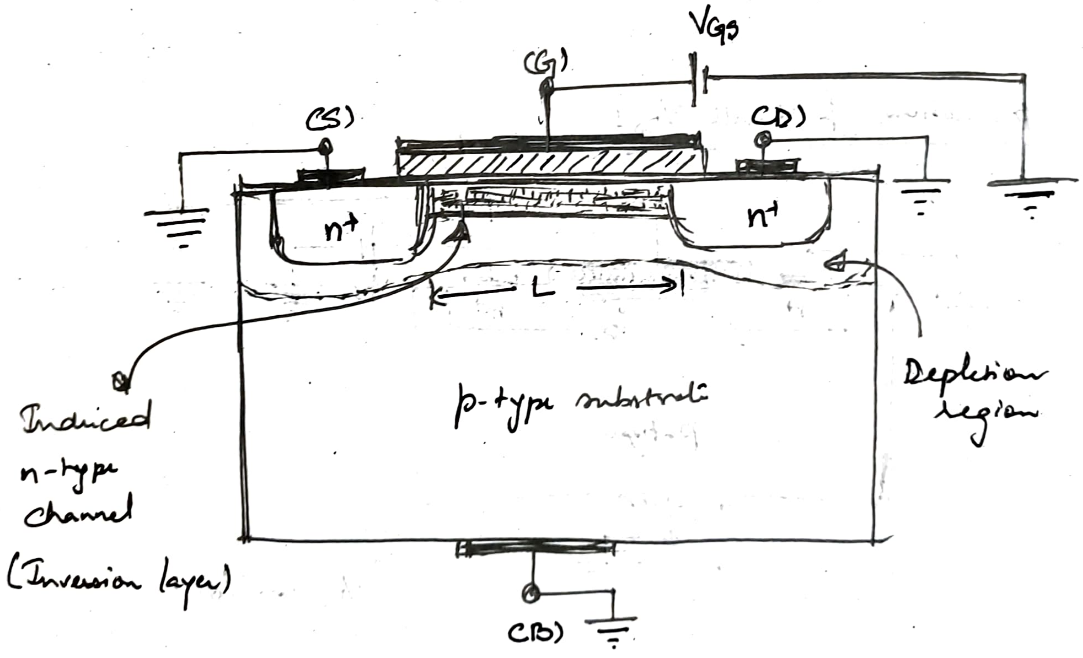
Zero voltage on gate:

Back to back n^+-p diodes prevent conduction of current, offering a very high resistance (order $10^{12}\Omega$)

Applying Voltage on Gate (Enhancement):

On applying a voltage V_{GS} on the gate terminal, the holes in the channel region are first repelled, leaving behind a carrier-depletion region, which is populated by negative charge associated with acceptor atoms.

When a sufficient no. of electrons get accumulated in the channel region, a voltage between source and drain (small voltage) will result in a current flow.



n- MOSFET

The electrons get accumulated at the inversion layer after a specific voltage called threshold voltage. (V_t). The effective voltage (Excess after threshold) is called overdrive voltage (V_{ov})

$$V_{GS} - V_t = V_{ov}$$

Charge and Capacitance of MOS:

$$|Q| = C_{ox} \cdot (W \cdot L) \cdot V_{ov}.$$

where C_{ox}: Capacitance of oxide per unit area

W: width of channel

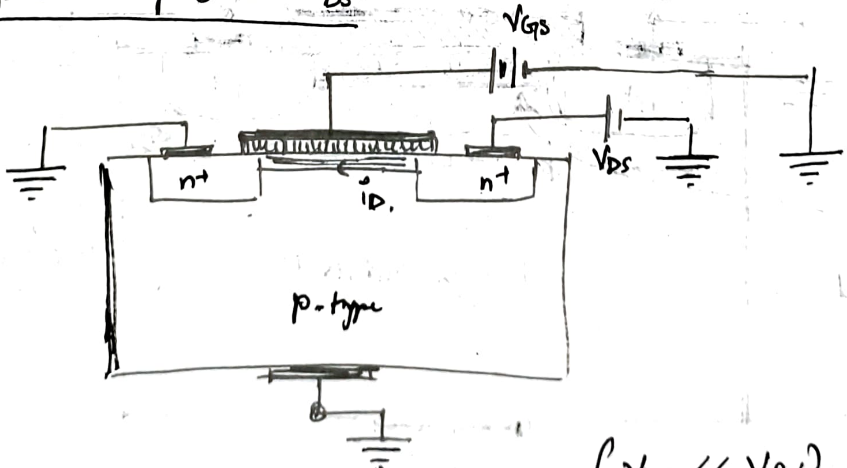
L: length of channel.

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} : \frac{\text{permittivity of oxide}}{\text{Oxide thickness}}$$

Note:

As V_{ov} is increased, magnitude of channel charge increases proportionately. Sometimes, it is depicted as an increase in depth of channel.

Application of Small V_{DS}:



$(V_{DS} << V_{ov})$

$$\frac{|Q|}{L} = C_{ox} \cdot W \cdot V_{ov} \quad \text{— from before}$$

$$|E| = \frac{V_{DS}}{L} \quad \text{— field generated by } V_{DS}$$

→ Electron drift velocity (v_d) = $\mu_n \dfrac{V_{DS}}{L}$

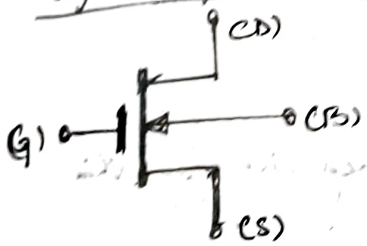
→ Current (I_D) = $\left[\mu_n C_{ox} \left(\frac{W}{L} \right) V_{ov} \right] V_{DS}$

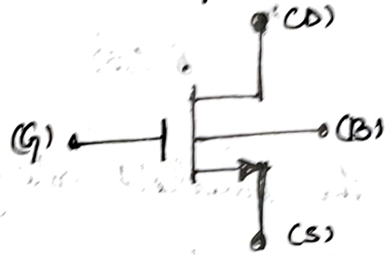
Conductance of channel:

$$g_{DS} = \mu_n C_{ox} \left(\frac{W}{L} \right) V_{ov}$$

→ R_{DS} (resistance) = $\dfrac{1}{\mu_n C_{ox} \left(\frac{W}{L} \right) V_{ov}}$

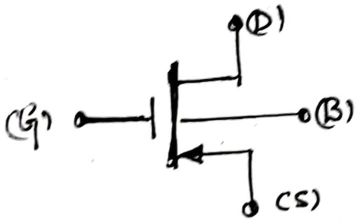
Symbol of MOSFET: (enhancement type)





n-channel

~~for p-channel, arrow is either from from S~~



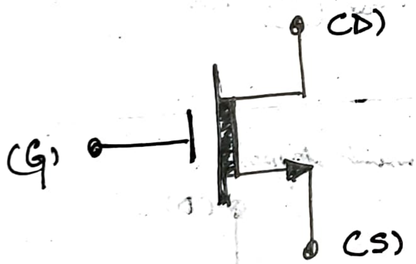
p-channel

Depletion-type MOSFET:

Has a physically implanted channel, which allows the flow of current from drain to source even if $V_{GS} = 0$.

A negative voltage V_{GS} can be applied to decrease the conductivity of the channel.

The symbol is only slightly different (with a thick portion between (D) and (S).



The threshold voltage is negative for this MOSFET.