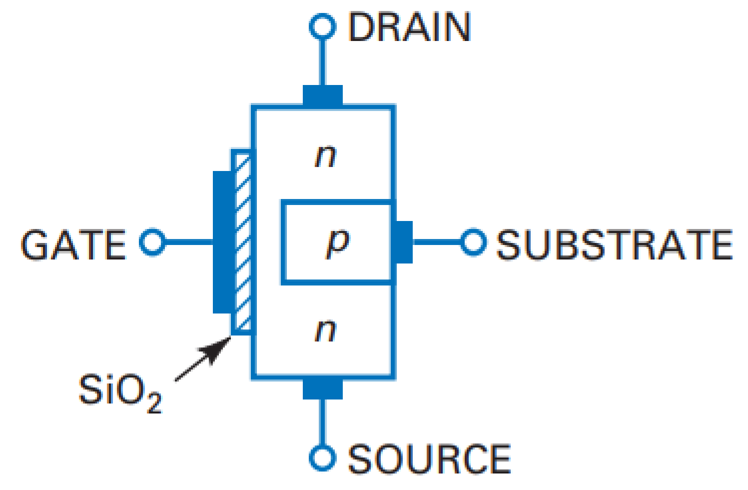
Depletion type MOSFET (D-MOSFET)

MOSFET: metal-oxide-semiconductor-field-effect transistor

- The p region is called the substrate.
- Electrons flowing from source to drain must pass through the narrow channel between the gate and the p substrate.
- A thin layer of silicon dioxide (SiO_2) is deposited on the left side of the channel.
- In a MOSFET, the gate is metallic. Because the metallic gate is insulated from the channel, negligible gate current flows even when the gate voltage is positive.



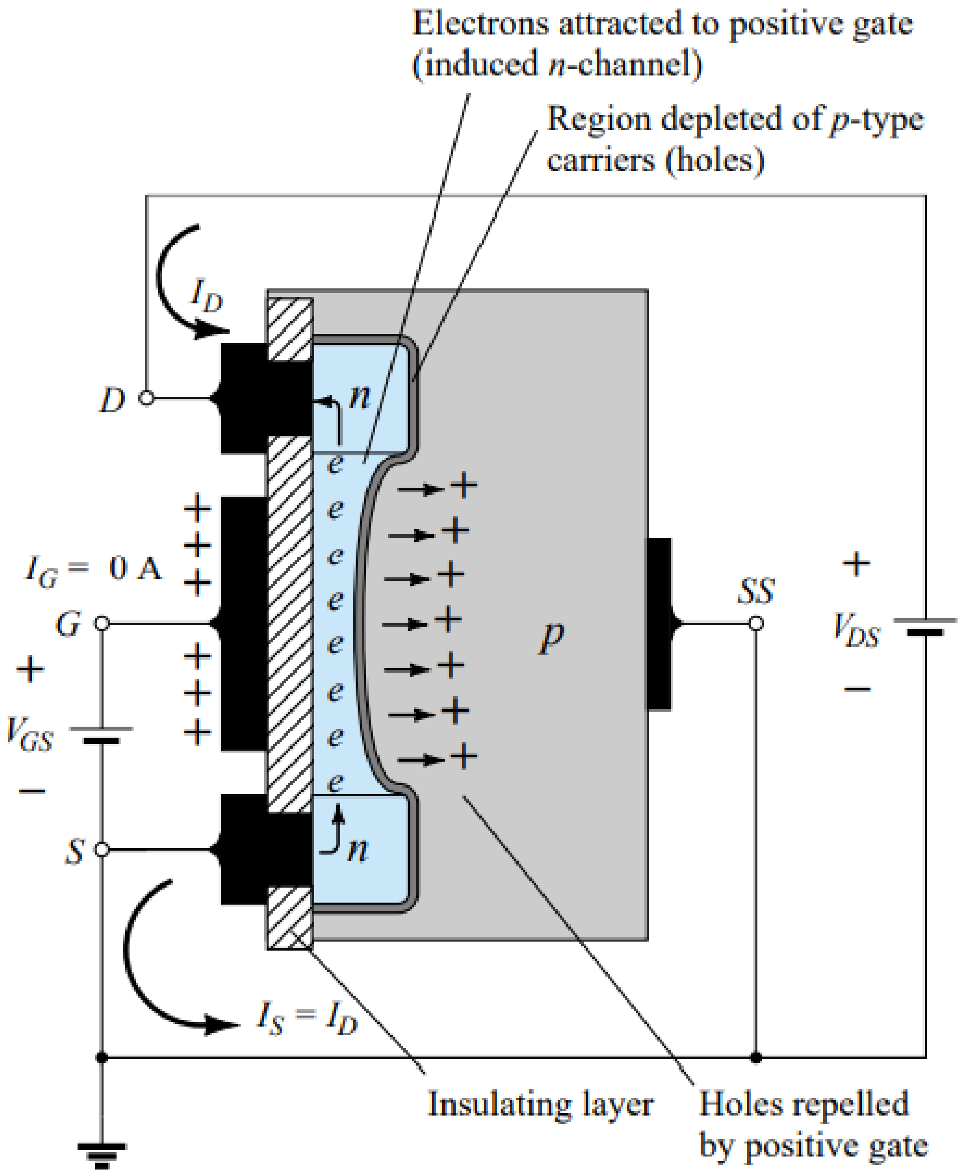
Applications:

- Switching applications
- High frequency amplifiers
- Used in used in SMPS (switch mode power supply)

Enhancement type MOSFET (E-MOSFET)

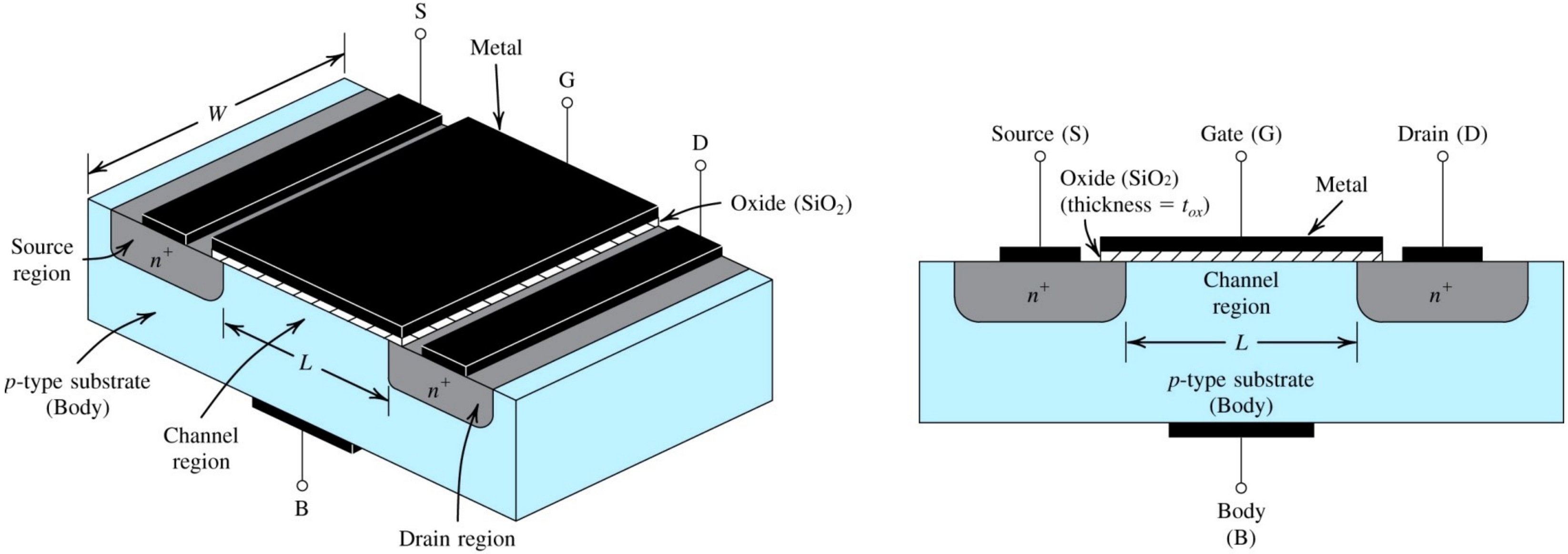
The source and drain terminals are again connected through metallic contacts to n-doped regions.

The primary difference between the construction of depletion-type and enhancement-type MOSFET is the absence of a channel as a constructed component of the device.



Device Structure and Operation (Detailed)

- Figure shows general structure of the *n*-channel enhancement-type MOSFET

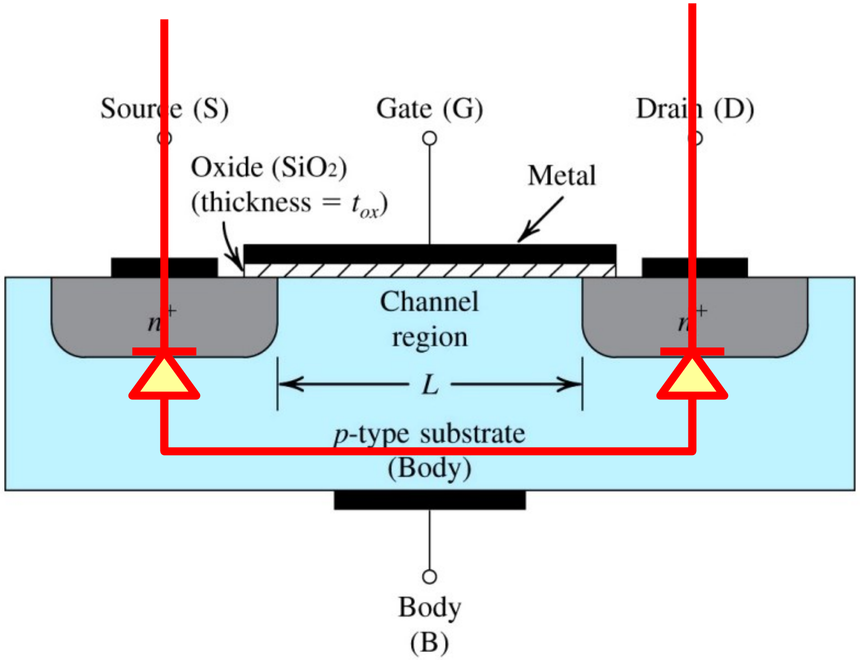


(a) (b)

Physical structure of the enhancement-type NMOS transistor: **(a)** perspective view, **(b)** cross-section. Note that typically L = 0.03*um* to 1*um*, W = 0.1*um* to 100*um*, and the thickness of the oxide layer (t_{ox}) is in the range of 1 to 10*nm*.

Operation with Zero Gate Voltage

- With zero voltage applied to gate, two back-to-back diodes exist in series between drain and source.
- "They" prevent current conduction from drain to source when a voltage v_{DS} is applied.
  - yielding very high resistance ($10^{12} ohms$)



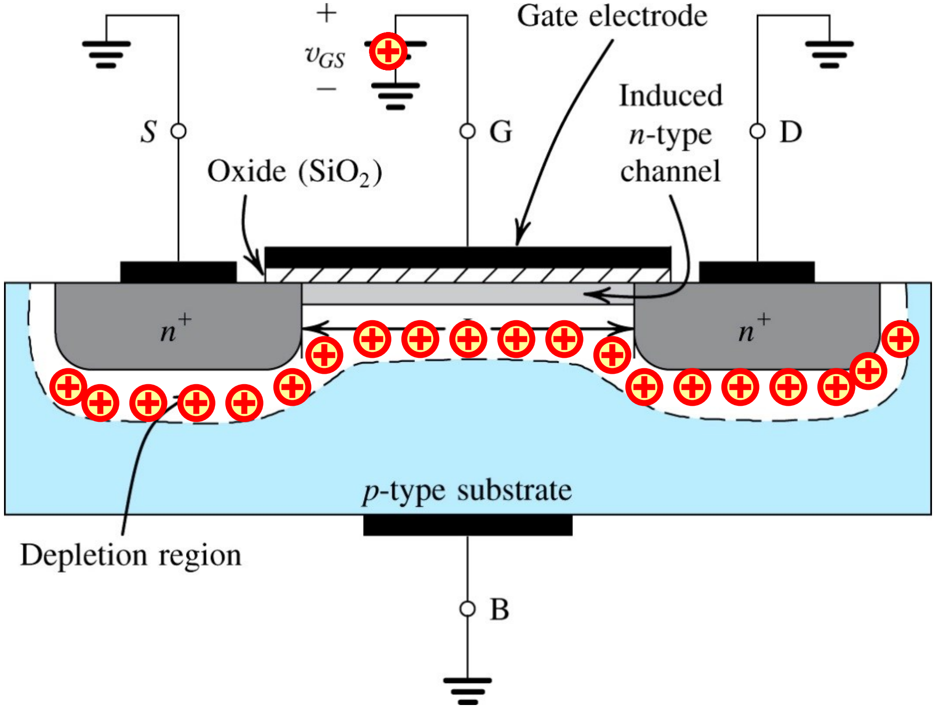
Physical structure

Creating a Channel for Current Flow

What happens if (1) source and drain are grounded and (2) positive voltage is applied to gate?

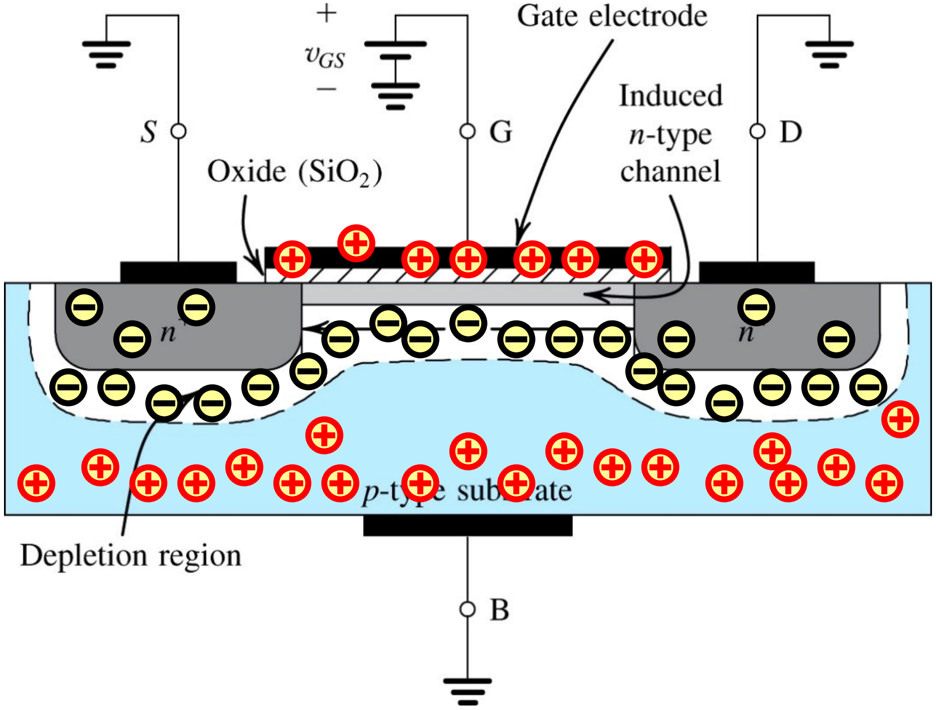
step #1: v_{GS} is applied to the gate terminal, causing a positive build up of positive charge along metal electrode.

step #2: This “build up” causes free holes to be repelled from region of *p*-type substrate under gate.



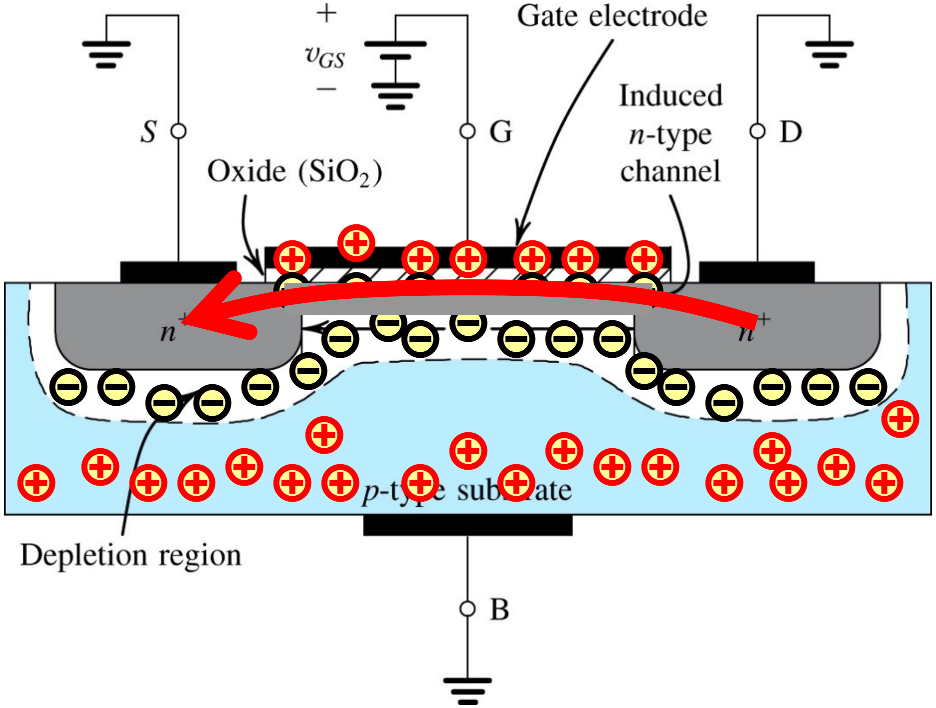
step #3: This “migration” results in the uncovering of negative **bound charges**, originally neutralized by the free holes

step #4: The positive gate voltage also attracts electrons from the n^+ source and drain regions into the channel.



step #5: Once a sufficient number of “these” electrons accumulate, an *n*-region is created connecting the source and drain regions

step #6: This provides path for current flow between *D* and *S*.



- For values of V_{GS} less than the threshold level, the drain current of an enhancement-type MOSFET is 0 mA.
- For levels of $V_{GS} > V_T$ the drain current is related to the applied gate-to-source voltage by the following nonlinear relationship:

$$I_D = k(V_{GS} - V_T)^2$$

k is a constant value for device,

$$k = \frac{I_{D(ON)}}{(V_{GS(ON)} - V_T)^2}$$