EEE-2103: Electronic Devices and Circuits

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Characteristics of JFETs

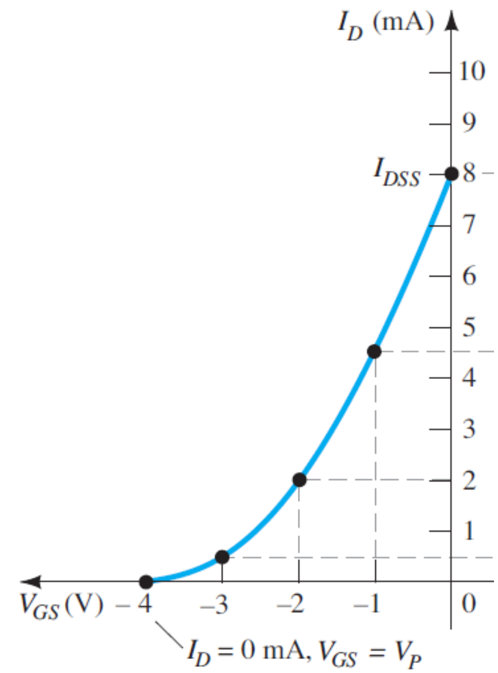
Applying Shockley's Equation:

Obtaining transfer curve →

$$V_{GS} = 0 \text{ V gives } I_D = I_{DSS}\left(1-\frac{V_{GS}}{V_P}\right)^2 = I_{DSS}\left(1-\frac{0}{V_P}\right)^2 = I_{DSS}$$

$$V_{GS} = V_P \text{ yields } I_D = I_{DSS}\left(1-\frac{V_P}{V_P}\right)^2 = I_{DSS}(1-1)^2 = 0$$

$$V_{GS} = \text{-1 V gives } I_D = I_{DSS}\left(1-\frac{-1}{-4}\right)^2 = 8\times10^{-3}\left(1-\frac{1}{4}\right)^2 = 4.5 \text{ mA}$$



Equation for resulting level of V_{GS} for given level of I_D →

$$V_{GS} = V_P\left(1-\sqrt{\frac{I_D}{I_{DSS}}}\right)$$

$$I_D = 4.5 \text{ mA gives } V_{GS} = V_P\left(1-\sqrt{\frac{I_D}{I_{DSS}}}\right) = -4\left(1-\sqrt{\frac{4.5\times10^{-3}}{8\times10^{-3}}}\right)$$

$$= -4(1-0.75) = \text{-1 V}$$

Characteristics of JFETs

Problem-34:

Sketch the transfer curve for an *n*-channel JFET defined by I_{DSS} = 12 mA and V_P = -6 V.

2 plot points are

I_{DSS} = 12 mA and V_{GS} = 0 V

I_D = 0 mA and $V_{GS} = V_P$ = -6 V

Another 2 points are

At $V_{GS} = V_P/2 = -6/2 = -3$ V

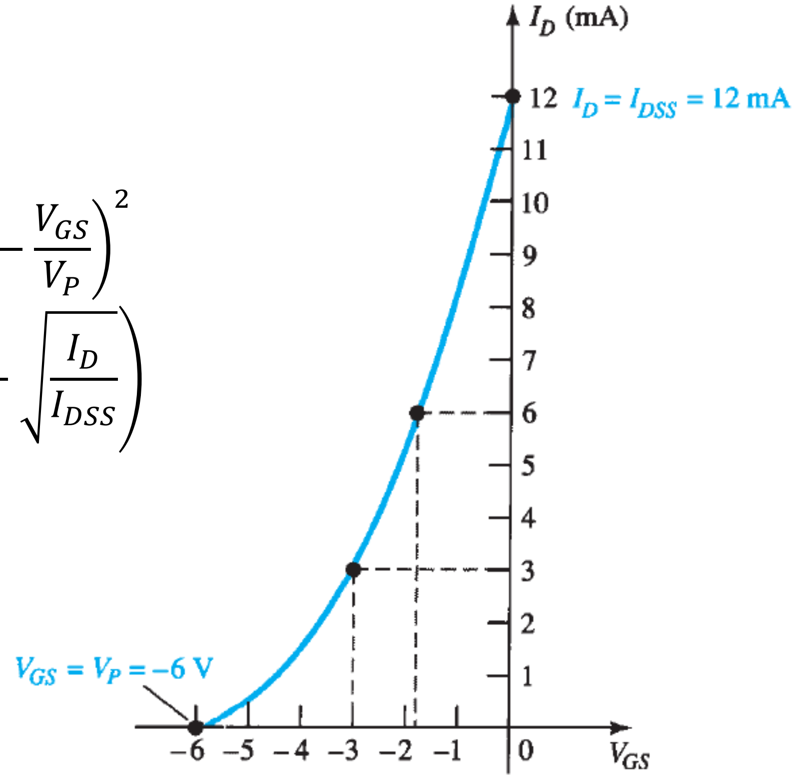
$I_D = I_{DSS}/4 = 12/4 = 3$ mA.

At $I_D = I_{DSS}/2 = 12/2 = 6$ mA

$V_{GS} = 0.3V_P = 0.3(-6) = -1.8$ V.

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

$$V_{GS} = V_P\left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right)$$



Characteristics of JFETs

Problem-35:

Sketch the transfer curve for a *p*-channel JFET with I_{DSS} = 4 mA and V_P = 3 V.

2 plot points are

I_{DSS} = 4 mA and V_{GS} = 0 V

I_D = 0 mA and $V_{GS} = V_P$ = 3 V

Another 2 points are

At $V_{GS} = V_P/2 = 3/2 = 1.5$ V

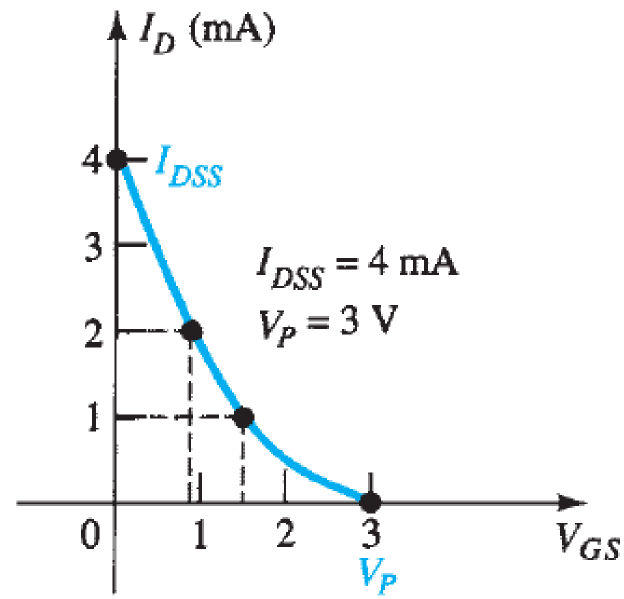
$I_D = I_{DSS}/4 = 4/4 = 1$ mA.

At $I_D = I_{DSS}/2 = 4/2 = 2$ mA

$V_{GS} = 0.3V_P = 0.3(3) = 0.9$ V.

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

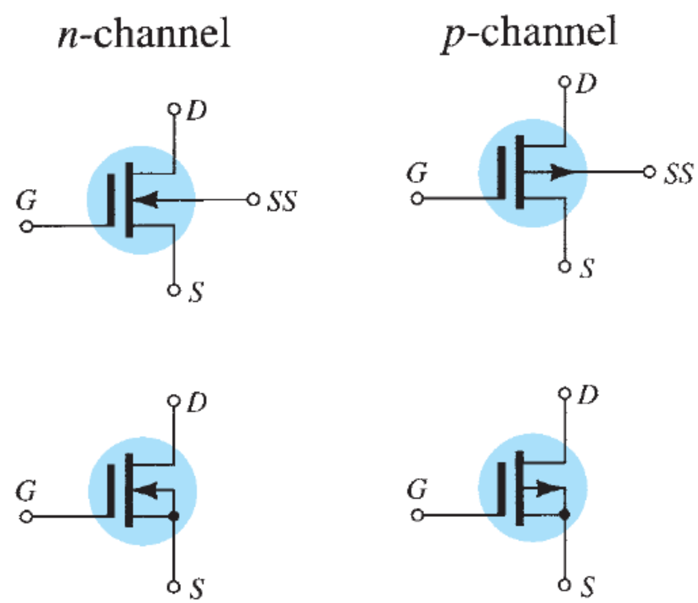
$$V_{GS} = V_P\left(1 - \sqrt{\frac{I_D}{I_{DSS}}}\right)$$

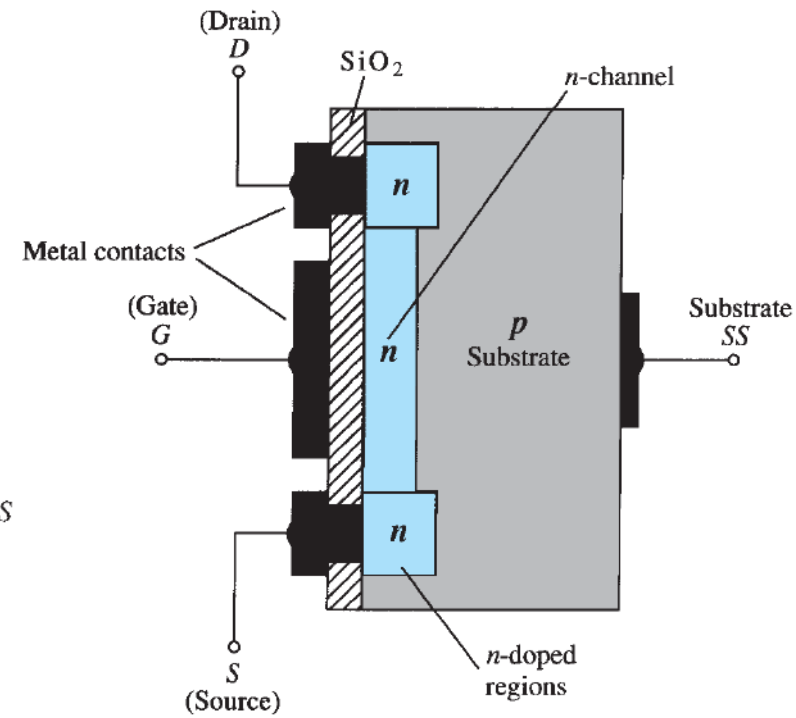


Depletion-Type MOSFET

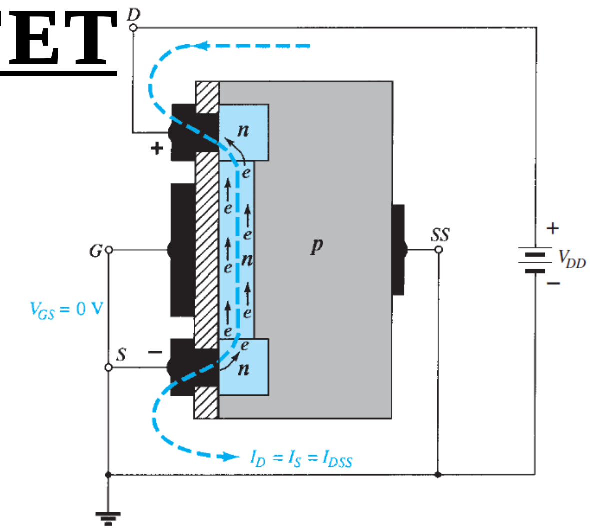
Construction of *n*-channel DMOSFET:

SiO_2 insulator = dielectric.
Exposed to externally applied field →
sets up opposing electric fields within dielectric.
Very desirable high input impedance.





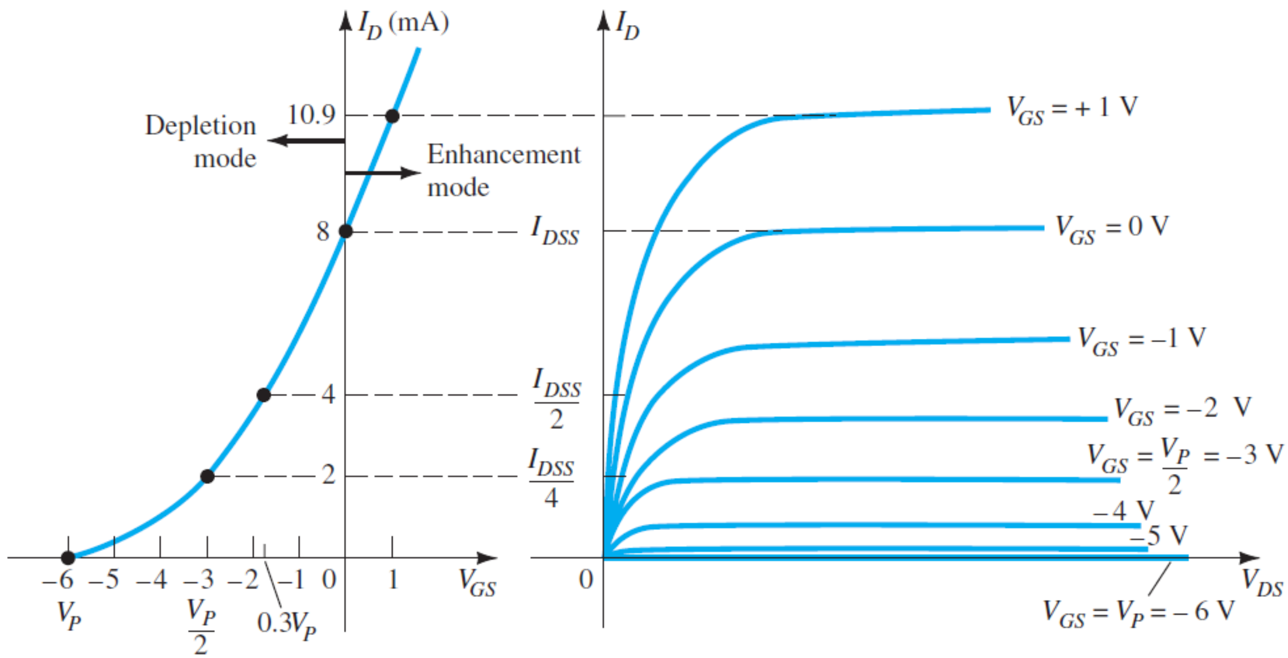
Depletion-Type MOSFET

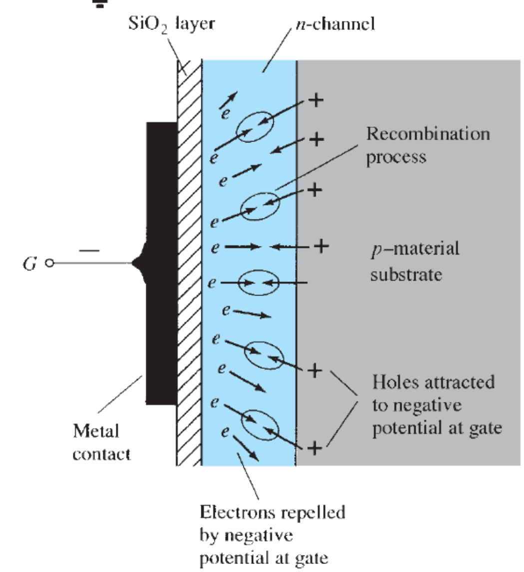


Basic operation and characteristics:

Enhancement region → region of +ve gate voltages on drain or transfer characteristics.

Depletion region → region between cutoff and saturation level of I_{DSS}.

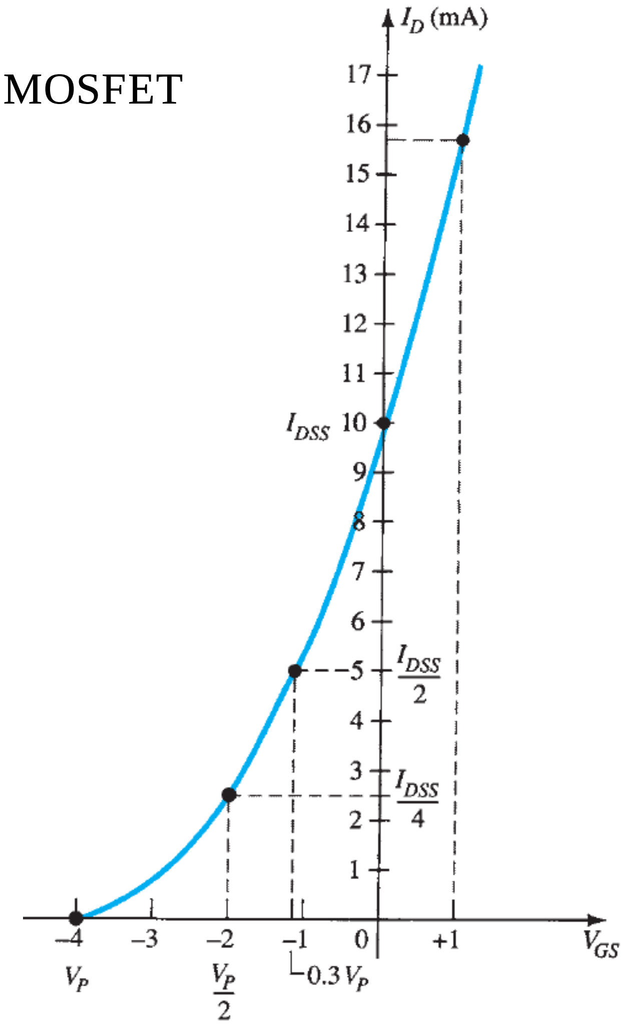




Depletion-Type MOSFET

Problem-36:

Sketch the transfer characteristics for an *n*-channel depletion-type MOSFET with I_{DSS} = 10 mA and V_P = -4 V.



V_{GS} = 0 V, $I_D = I_{DSS}$ = 10 mA

$V_{GS} = V_P$ = -4 V, I_D = 0 mA

$V_{GS} = V_P/2$ = -4/2 = -2 V, $I_D = I_{DSS}/4$ = 10/4 = 2.5 mA

$I_D = I_{DSS}/2$, $V_{GS} = 0.3V_P$ = 0.3(-4) = -1.2 V

V_{GS} = +1 V →

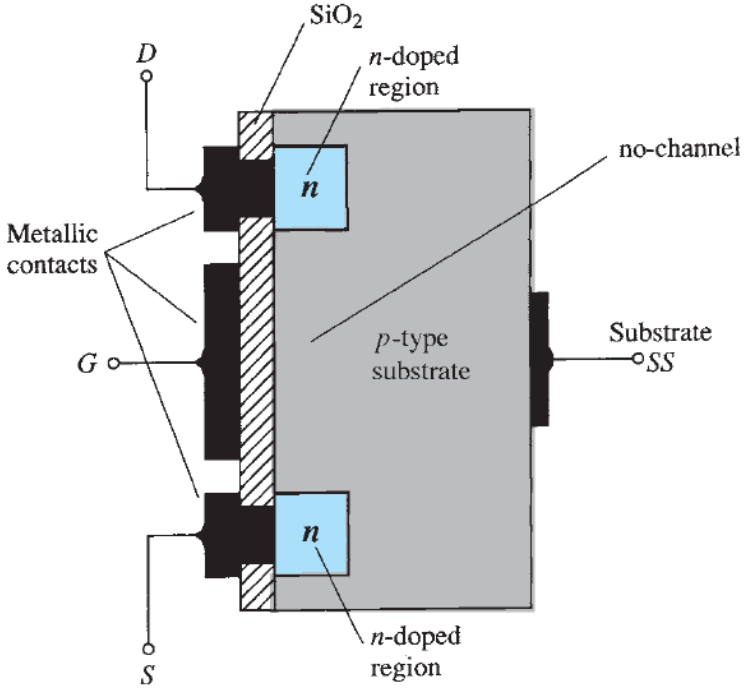
$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2 = 10 \times 10^{-3}\left(1 - \frac{+1}{-4}\right)^2 = 15.63 \text{ mA}$$

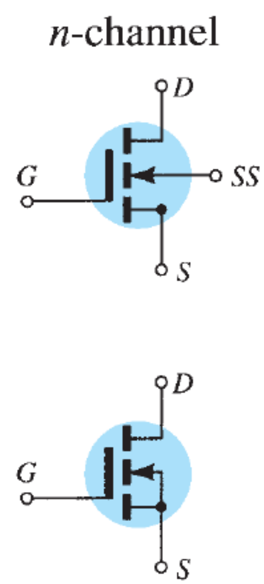
Enhancement-Type MOSFET

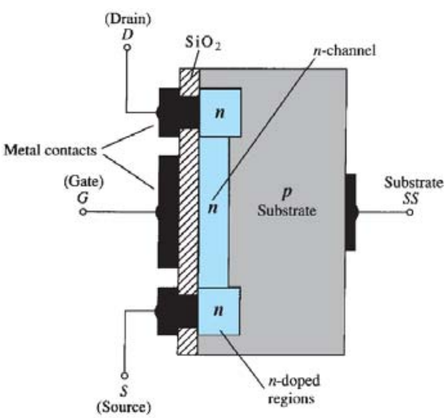
Construction of *n*-channel EMOSFET:

Channel is nonexistent with V_{GS} = 0 V.

Enhanced by application of +ve gate-to-source voltage.

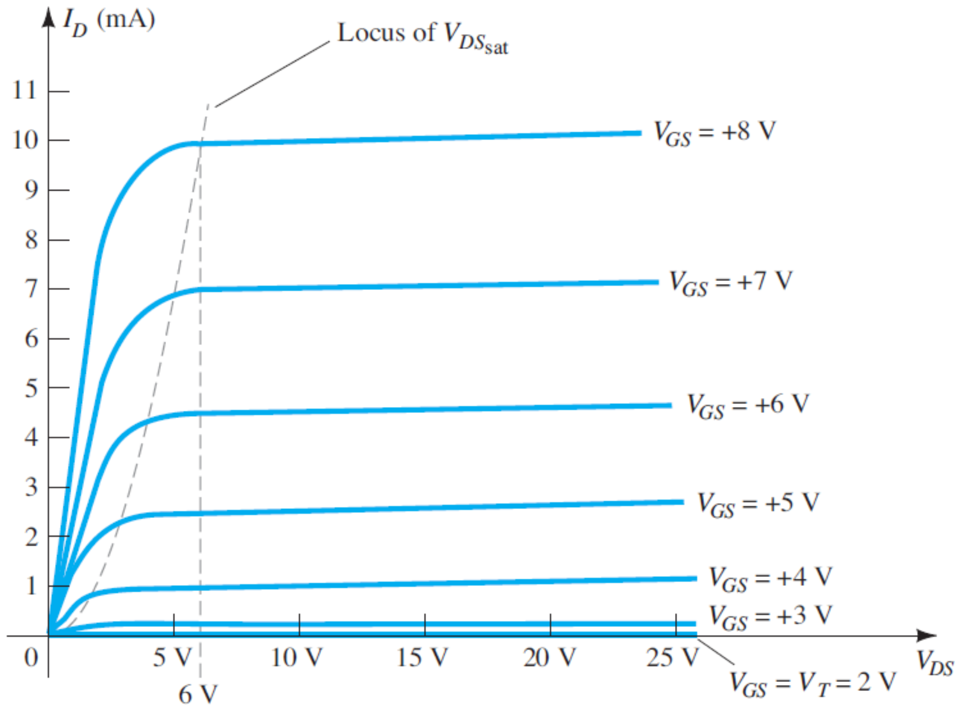


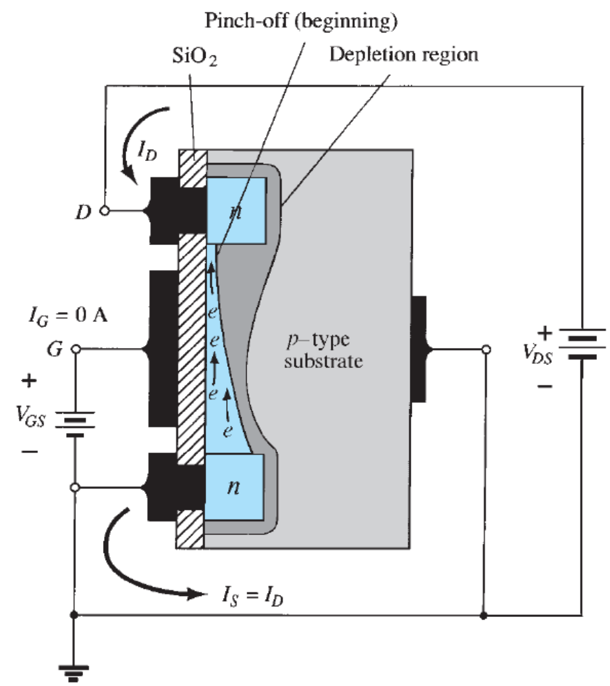




Enhancement-Type MOSFET

Basic operation and characteristics:





Enhancement-Type MOSFET

Basic operation and characteristics:

Threshold voltage $V_T = V_{GS}$ that results in significant increase in I_D.

Pinch-off and saturation condition →

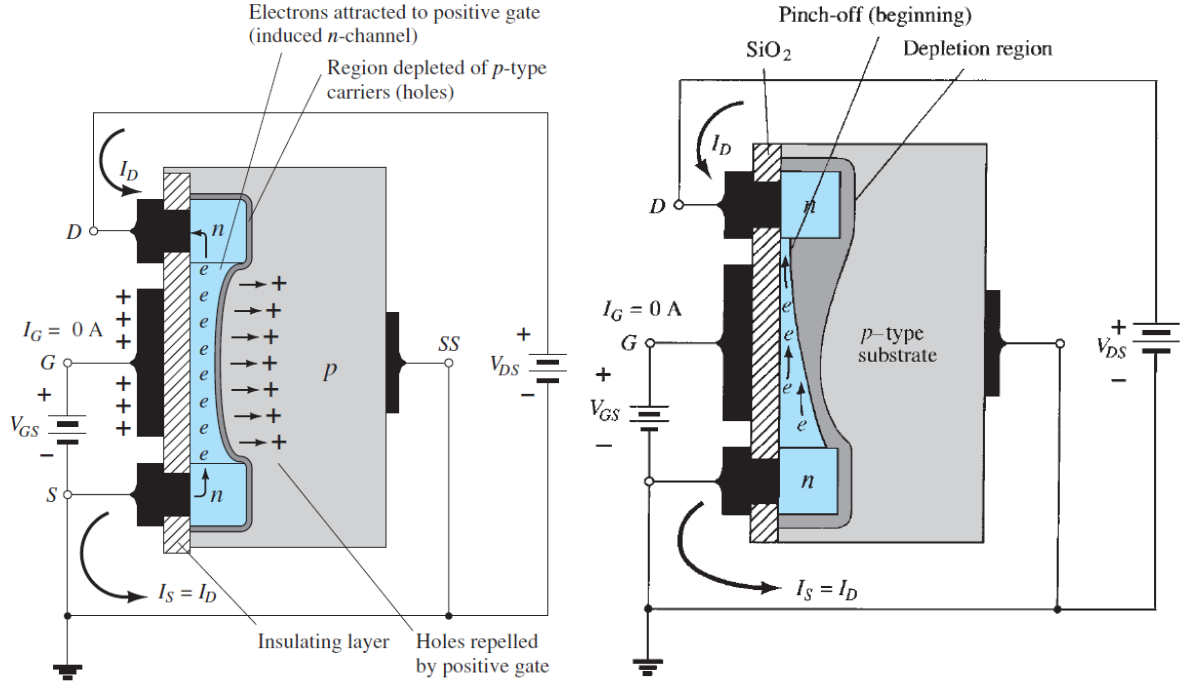
$V_{DG} = V_{DS} - V_{GS}$

V_{GS} = fixed at +ve voltage.

V_{DS} is increased →

gate becomes less +ve,
attractive forces for
free carriers reduces →
channel width reduces.

Further increase in V_{DS}
will not affect I_{DSS}.



Enhancement-Type MOSFET

Basic operation and characteristics:

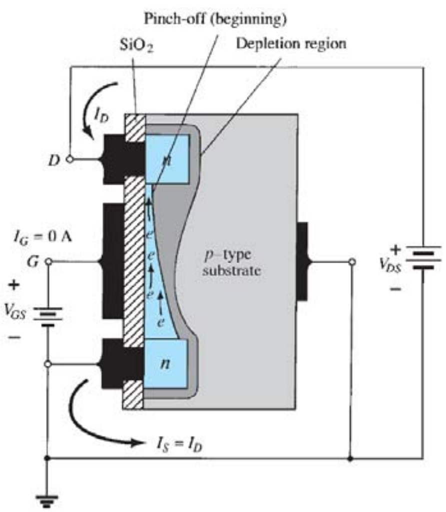
For $V_{GS} > V_T$ →

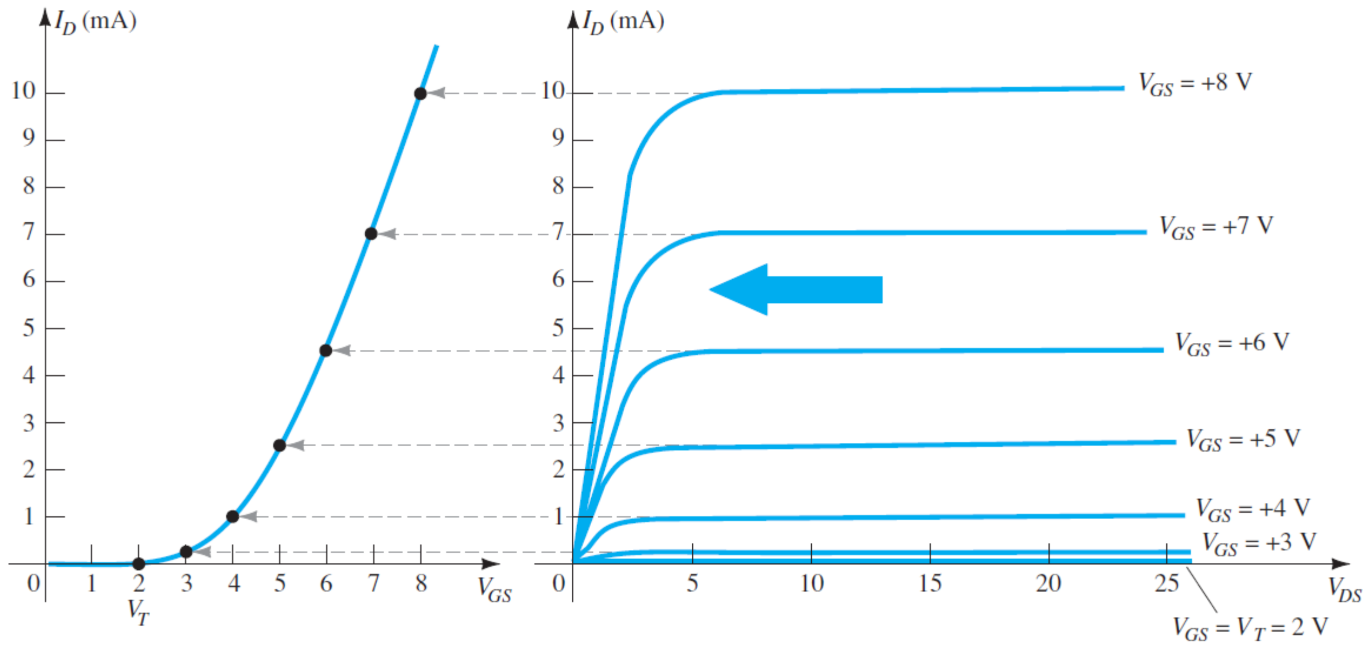
$$I_D = k(V_{GS} - V_T)^2$$

k = constant = function of construction of device.

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

Drain and transfer characteristics →





Enhancement-Type MOSFET

Problem-37:

Assuming $I_{D(on)}$ = 3 mA, $V_{GS(on)}$ = 7 V and an average threshold voltage of $V_{GS(Th)}$ = 3 V, determine:

a) The resulting value of k for the MOSFET.

b) The transfer characteristics.

a) $k = \frac{I_{D(on)}}{\left(V_{GS(on)} - V_T\right)^2} = \frac{3\times10^{-3}}{(7-3)^2}$ = 0.61×10^{-3} A/V^2

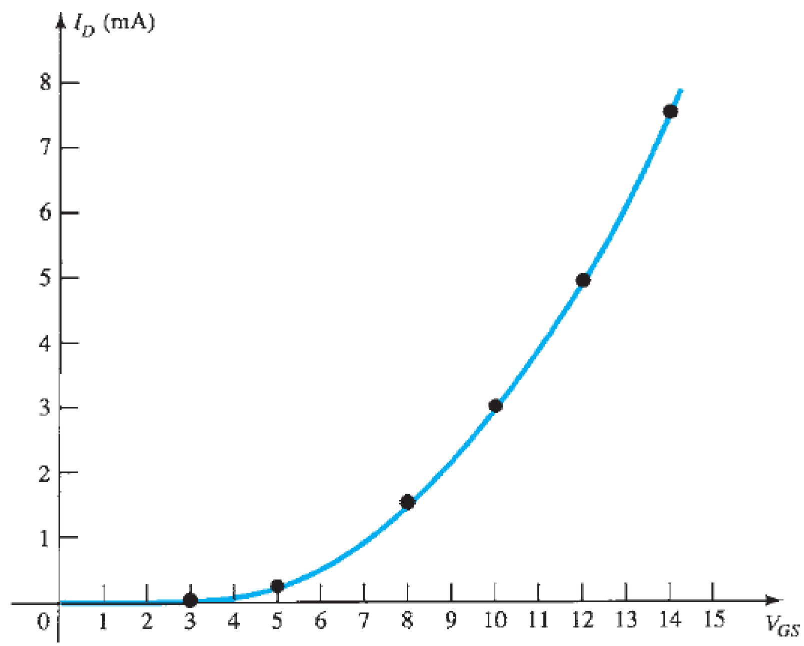
b) $I_D = k(V_{GS} - V_T)^2$ = 0.061×10^{-3}(V_{GS} – 3V)^2

For V_{GS} = 5 V,

I_D = 0.061×10^{-3}(5 – 3)^2 = 0.244 mA

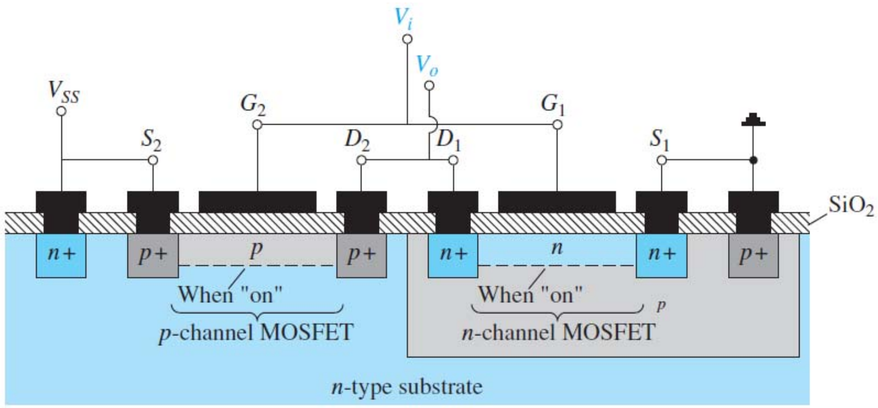
For V_{GS} = 8, 10, 12, and 14 V,

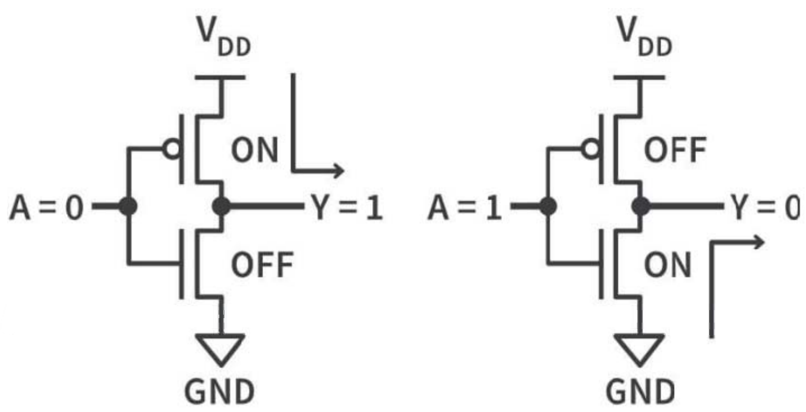
I_D = 1.525, 3, 4.94, and 7.38 mA, respectively.



Complementary MOSFET (CMOS)

Construction:





CMOS as inverter: