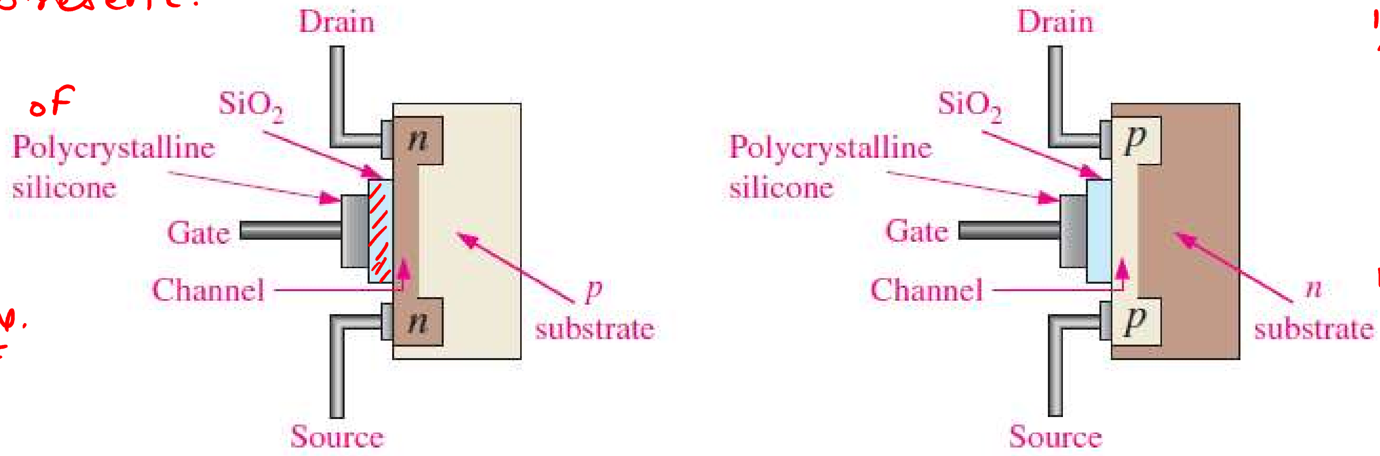
D-MOSFET

→ can operate in Depletion and Enhancement Mode
→ DE-MOSFET

- The drain and source are diffused into the substrate material and then connected by a narrow channel adjacent to the insulated gate. Both n-channel and p-channel devices are shown in the figure.

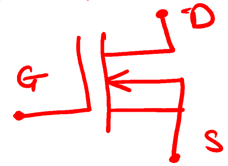
Symbols:

* channel is present.
⇓
w/o application of V_{GS}, it acts as closed s/w.
⇓
Normally ON.

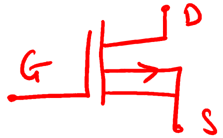


(a) *n* channel (b) *p* channel

i) n-channel D-MOSFET



ii) p-channel D-MOSFET



D-MOSFET…

(n channel)

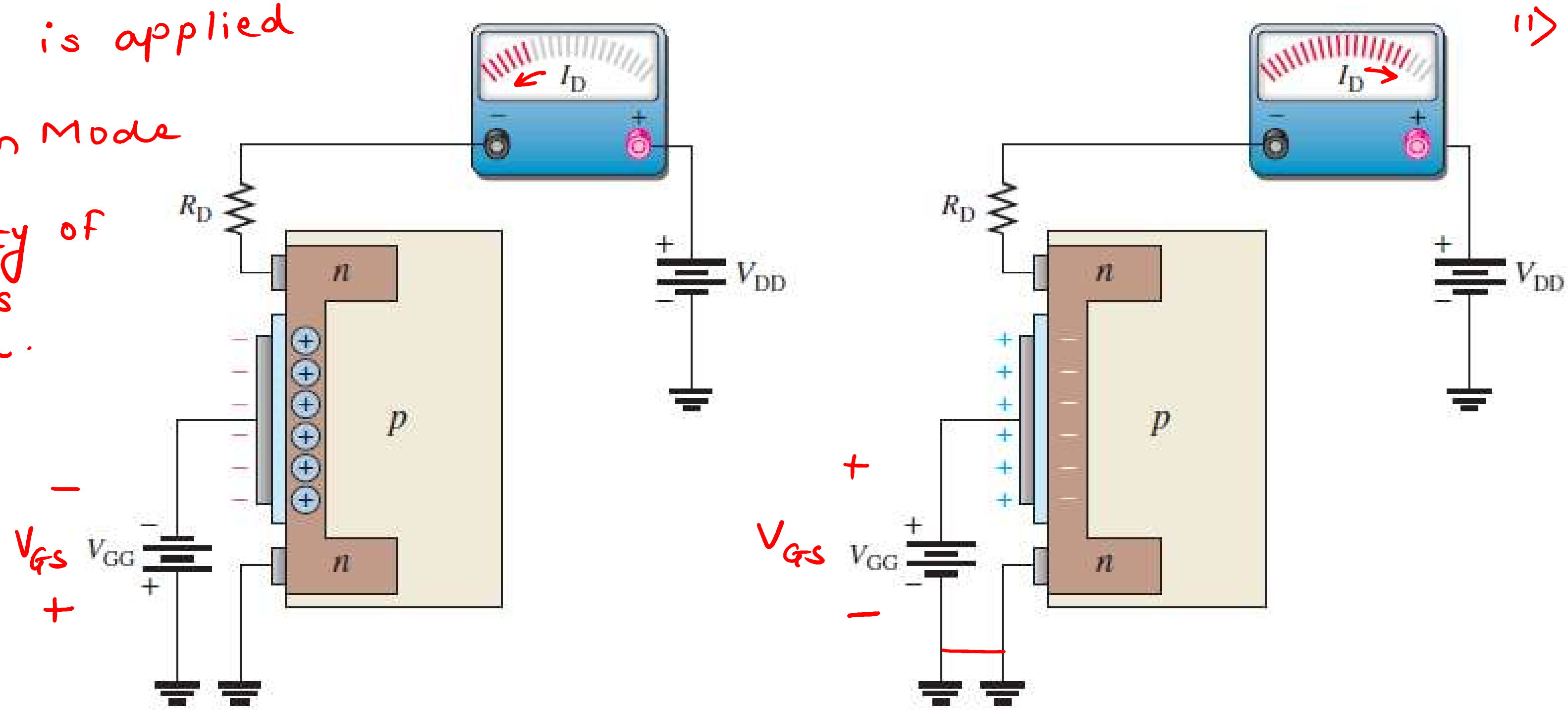
- Biasing..

i) $-V_{GS}$ is applied
↓
Depletion Mode
↓
conductivity of channel is reduced.
↓
I_D ↓

I_D is less

I_D is more

ii) $+V_{GS}$ is applied
↓
conductivity of channel is enhanced.
↓
Enhancement Mode
↓
I_D ↑



(a) Depletion mode: V_{GS} negative and less than $V_{GS(off)}$

(b) Enhancement mode: V_{GS} positive

D–MOSFET…

- The D-MOSFET can be operated in either of two modes, the depletion mode or the enhancement mode, and is sometimes called a depletion/enhancement MOSFET.

$+V_{GS} / -V_{GS}$

- Since the gate is insulated from the channel, either a positive or a negative gate voltage can be applied.
- The n-channel D- MOSFET operates in the depletion mode when a negative gate-to-source voltage is applied and in the enhancement mode when a positive gate-to-source voltage is applied.
- These devices are generally operated in the depletion mode.

Depletion Mode

- Visualize the gate as one plate of a parallel-plate capacitor and the channel as the other plate. The silicon dioxide insulating layer is the dielectric.
- With a negative gate voltage, the negative charges on the gate repel conduction electrons from the channel, leaving positive ions in their place. Thereby, the n channel is depleted of some of its electrons, thus decreasing the channel conductivity.
- The greater the negative voltage on the gate, the greater the depletion of n-channel electrons. At a sufficiently negative gate-to-source voltage, $V_{GS(off)}$, the channel is totally depleted, and the drain current is zero.

$$V_{GS(OFF)} = V_{GS}\Big|_{I_D=0}$$

Enhancement Mode

- With a positive gate voltage, more conduction electrons are attracted into the channel, thus increasing (enhancing) the channel conductivity.

*	n-channel D-MOSFET	p-channel D-MOSFET
Depletion Mode	$-V_{GS}$	$+V_{GS}$
Enhancement Mode	$+V_{GS}$	$-V_{GS}$

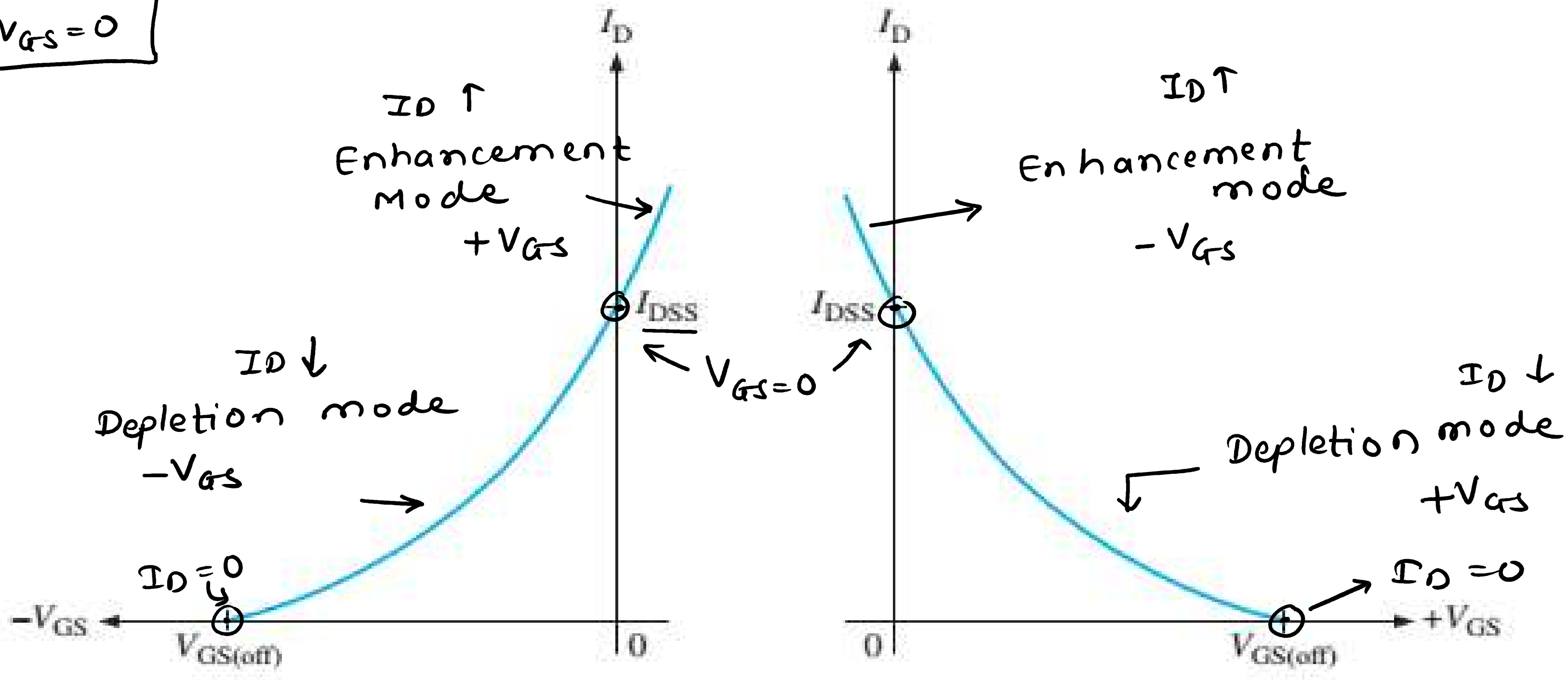
D–MOSFET characteristics

- D-MOSFET can operate with either positive or negative gate voltages.

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

$I_{DSS} \rightarrow$ Drain to source saturation current

$$\boxed{I_{DSS} = I_D\big|_{V_{GS}=0}}$$



(a) n channel (b) p channel

D–MOSFET characteristics…

- This is indicated on the general transfer characteristic curves in for both n-channel and p-channel MOSFETs.
- The point on the curves where $V_{GS}=0$ corresponds to I_{DSS}. The point where, $I_D=0$ corresponds to $V_{GS(off)}$.

$$V_{GS(off)} = -V_P.$$

↳ Pinch off voltage

Numerical Problem

- **For a certain D-MOSFET, IDSS 10 mA and VGS(off) = -8 V.**

  (a) Is this an n-channel or a p-channel?

  (b) Calculate ID at VGS –3 V

  (c) Calculate ID at VGS 3 V

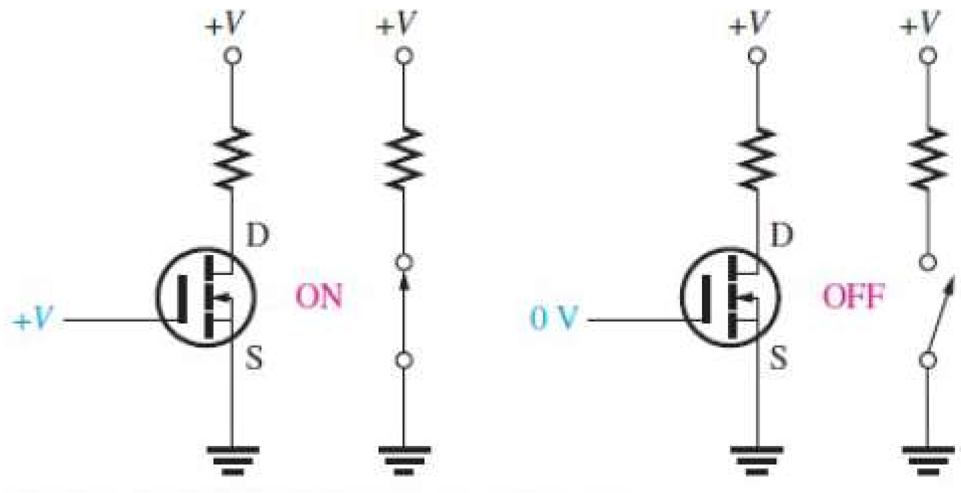
a)The device has a negative VGS(off); therefore, it is an **n-channel** MOSFET.

b) $I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_{GS(OFF)}}\right)^2 = (10mA)\left(1 - \frac{-3V}{-8V}\right)^2 = \underline{3.91mA}$

c) $I_D = (10mA)\left(1 - \frac{+3V}{-8V}\right)^2 = \underline{18.9mA}$

BJT	MOSFET
It is a **current controlled** device.	It is a **voltage controlled** device.
It is a **bipolar** device (Current flows due to both majority & minority carriers).	It is a **unipolar** device (Current flows due to only majority carriers).
Thermal Runaway can damage the BJT	Thermal Runaway does not take place
Input resistance (**R_i**) is very **low**.	Output resistance (**R_o**) is very **high**.
Transfer characteristics are **linear** in nature.	Transfer characteristics are **non-linear** in nature.
BJT is More sensitive than MOSFET	MOSFET is less Sensitive
AC Voltage Gain is HIGH	AC Voltage Gain is Less
Bigger in size.	**Smaller** in size.
Regions of operation: Saturation – ON Switch , Cut off – OFF Switch Active – Amplifier	**Regions of operation:** Ohmic – ON Switch ,Saturation – Amplifier , Cut off – OFF Switch
Switching speed is less.	**Switching speed is high.**
Symbol	**Symbol**

MOSFET as a Switch



- Enhancement mode type N-channel MOSFET device. As shown, the MOSFET is switched ON when positive voltage is applied as V_{GS}.
- When zero voltage is applied to the device at V_{GS}, it will be powered OFF.

MOSFET as an Amplifier → Single stage RC coupled small signal amplifier

n-channel E-MOSFET

I) $V_{GS} > V_{GS(TH)}$

II) Bias the MOSFET in saturation region.

* Amplification Factor

$$\boxed{gm = \frac{\Delta I_D}{\Delta V_{GS}}}$$

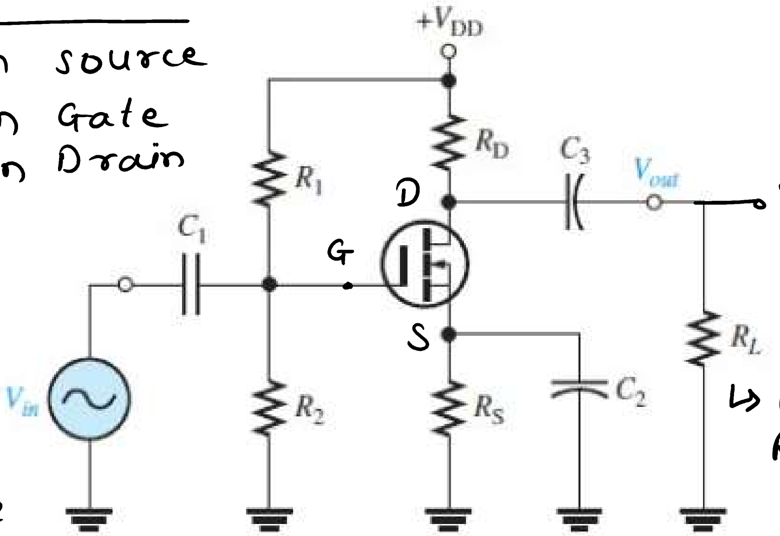
gm = Transconductance of MOSFET

Unit = mA/V
= mS

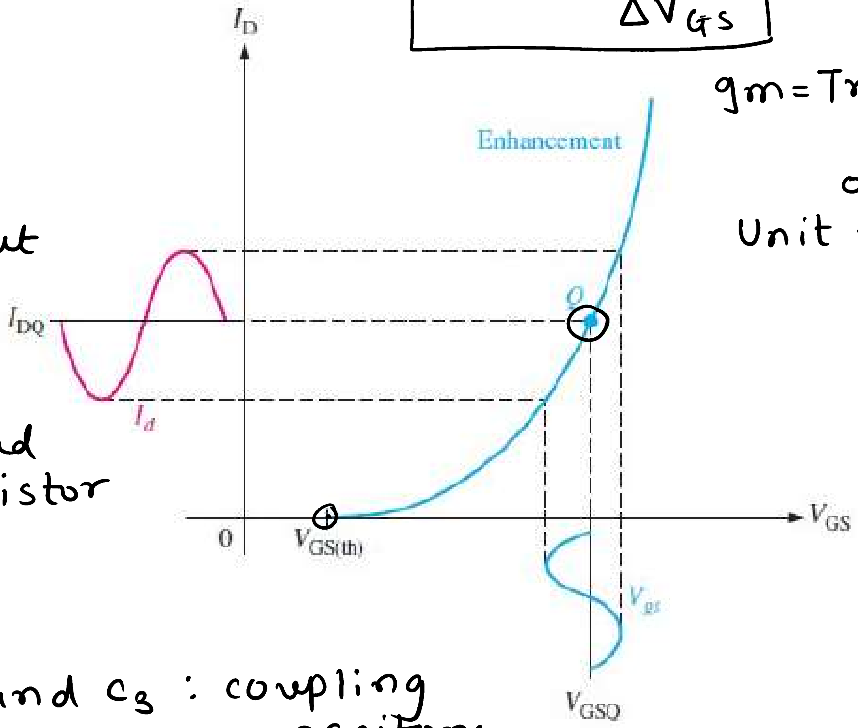
* common source
* common Gate
* common Drain

Input : Gate & source

Output : Drain & source



↳ Load Resistor



$\boxed{\text{Common Source}}$

R_1 and R_2 → Biasing resistors
→ Voltage divider bias
↳ Q point stability

C_1 and C_3 : coupling capacitors

C_2 : Bypass capacitor

$I_C = \beta_{dc} I_B$
↳ A.F.

MOSFET as an Amplifier

- The gate is biased with a positive voltage such that $V_{GS} > V_{GS(TH)}$
- The signal voltage produces a swing in V_{GS} above and below its Q-point value, V_{GSQ}.
- This, in turn, causes a swing in I_D above and below its Q-point value, I_{DQ}, as illustrated in Figure
- Operation is entirely in the enhancement mode.

Acknowledgements

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2. Web Resources

Thank You..