Spring 2019 Purdue University

ECE 255: L14

MOSFET IV

(Sedra and Smith, 7th Ed., Sec. 5.2)

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Purdue University
West Lafayette, IN USA

PURDUE UNIVERSITY

COOK® RESEARCH

FREE PIZZA!

Company Information Session

Monday, February 11th
7:00 - 8:00 PM
MJIS 1001
Presentation followed by Q&A

Learn about the history of our company, an overview of our current areas, and what we look for in a BME or EE intern, co-op, and new employee!

www.cookresearchinc.com

Visit our booth at the Professional Practice Career Fair
Tuesday February 19, 10 AM-3 PM, in PMU Ballrooms

Mon 2/18 Information Sessions HCRS 1076

8:30am Fulbright U.S. Student Program Overview
11:30am Fulbright U.S. Student Program Overview

Mon 2/18 Fulbright Program Mixer Duhme Hall Atrium

6:00pm Join us for food and drink with Purdue Fulbright alumni to hear about their experiences in the program.

Tues 2/19 Information Sessions HCRS 1066

3:30pm Research & Study Grants – guidance for graduate students
4:15pm 2020-21 English Teaching Assistant Grants
5:00pm 2020-21 Research and Study Grants

Wed 2/20 Information Sessions HCRS 1066

5:00pm 2020-21 Research and Study Grants
5:45pm 2020-21 English Teaching Assistant Grants
6:30pm Research & Study Grants – guidance for graduate students

Thurs 2/21 Information Sessions HCRS 1066

5:00pm 2020-21 English Teaching Assistant Grants
5:45pm 2020-21 Research and Study Grants

FULBRIGHT

FEB. 18-21

Juniors begin applications now for a Fulbright U.S. Student Program grant after graduation in one of 140+ countries. Seniors look ahead a year to 2020-21. Graduate students conduct thesis/ dissertation research abroad. Freshmen and sophomores explore options.

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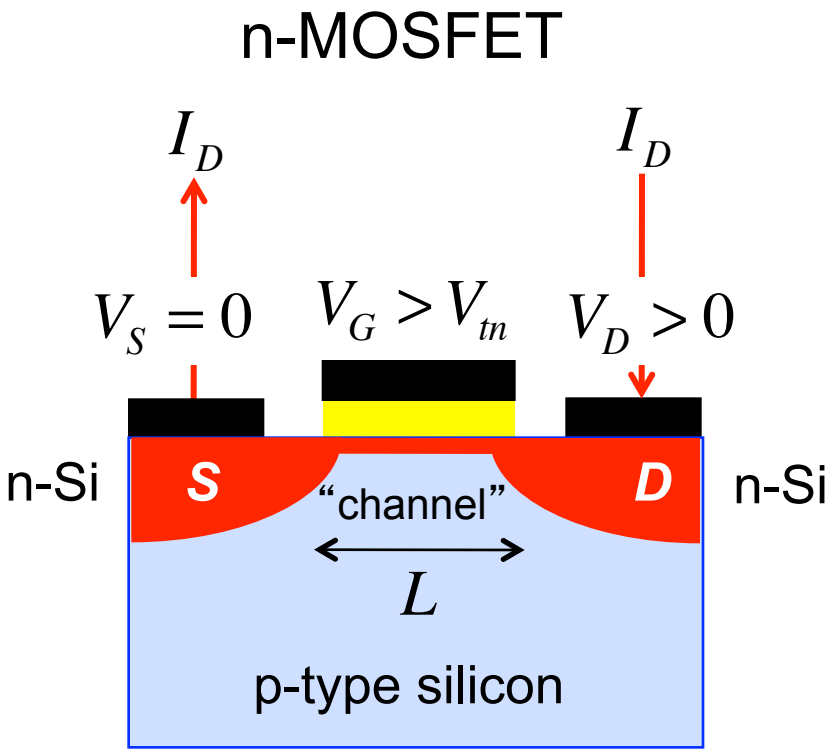
PURDUE HONORS COLLEGE

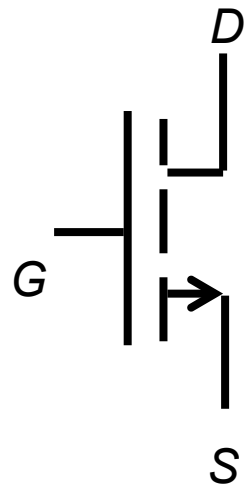
MOSFET IV

1) IV characteristics of N and P-channel MOSFETs
2) Regions of operation

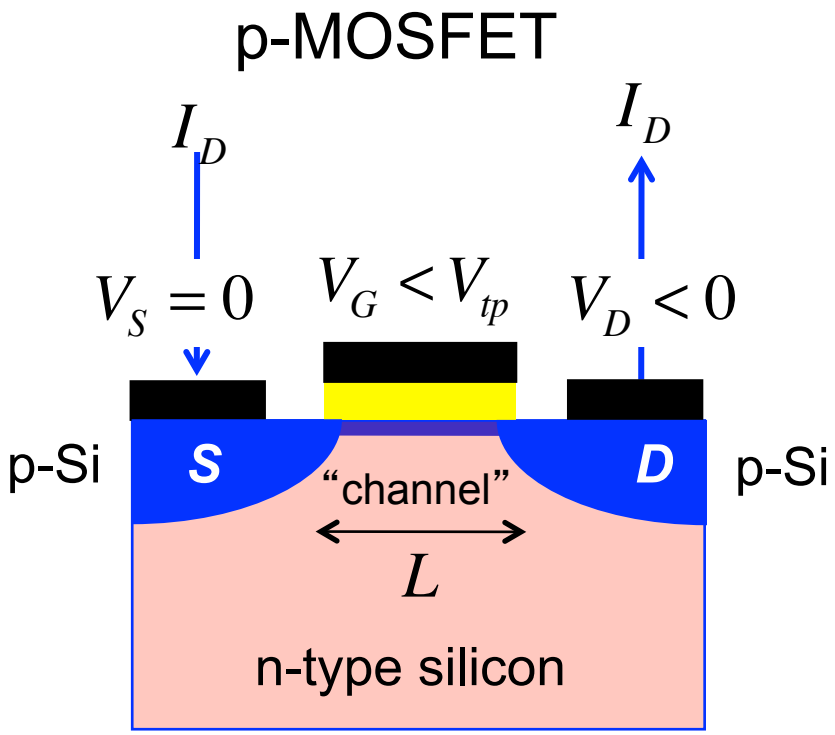
N-channel (enhancement mode) MOSFET



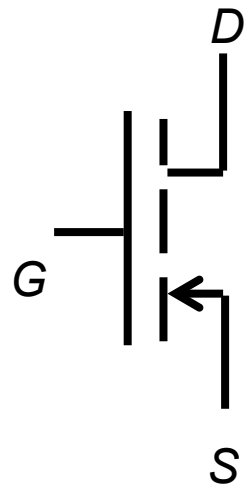
side view



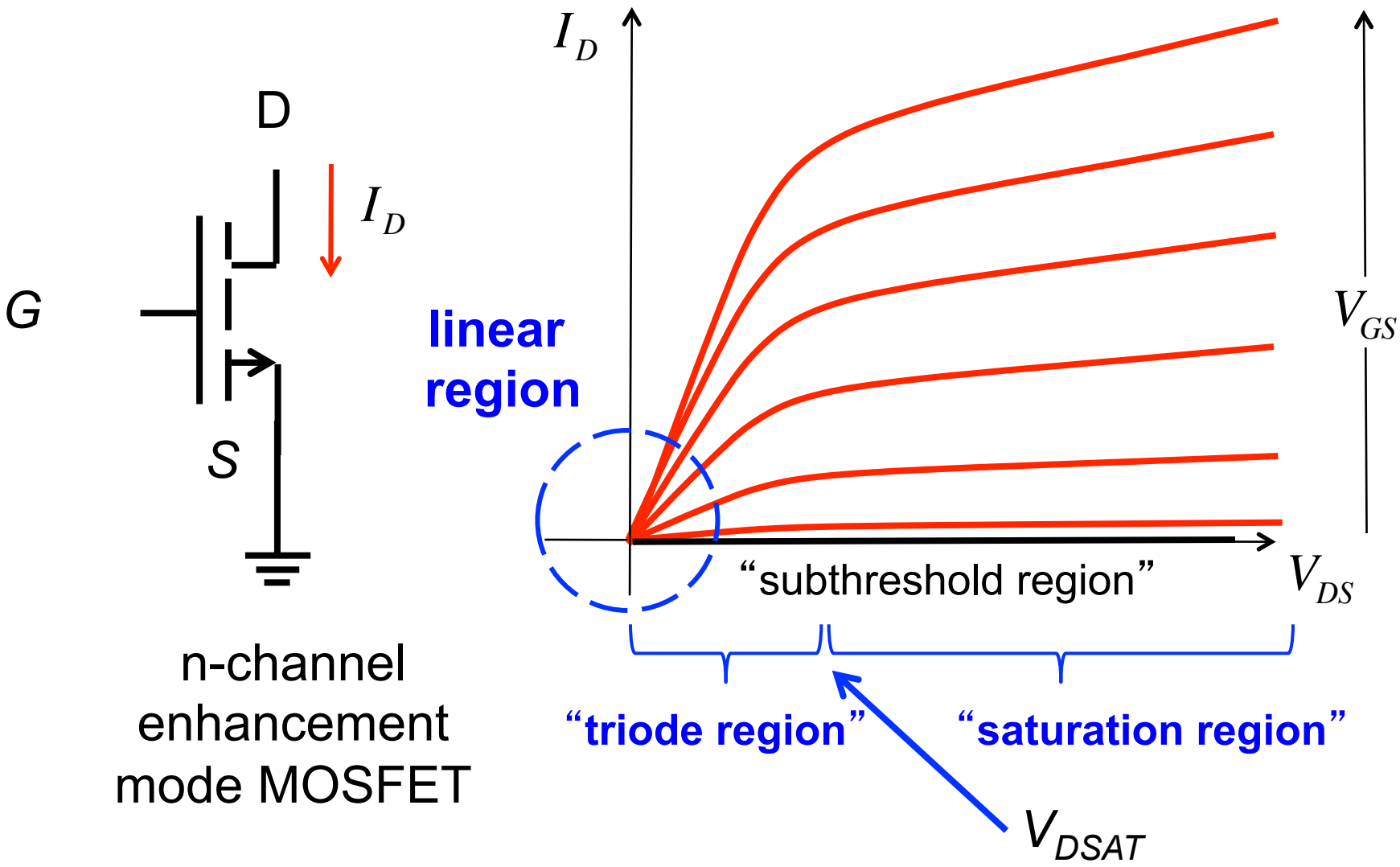
P-channel (enhancement mode) MOSFET



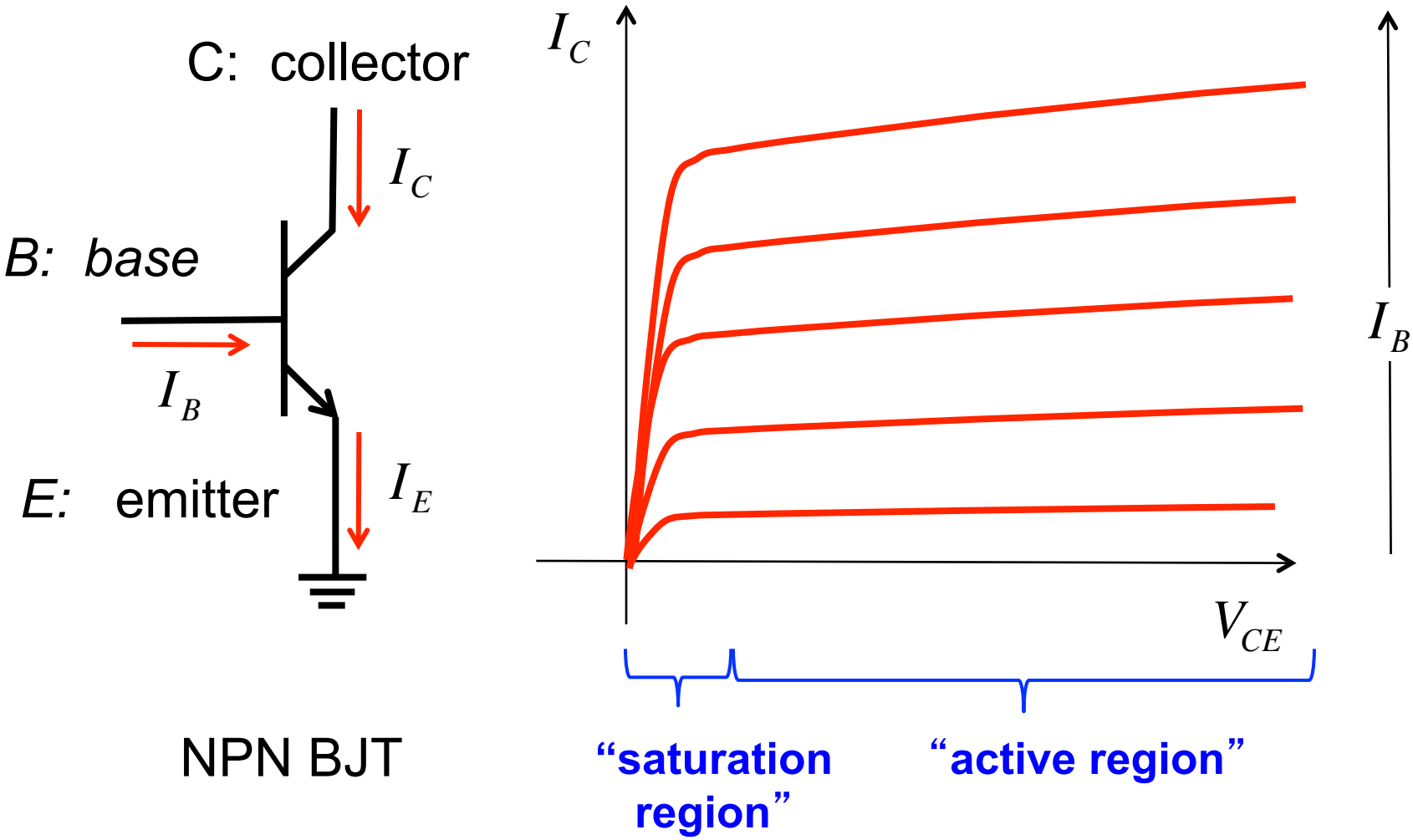
side view



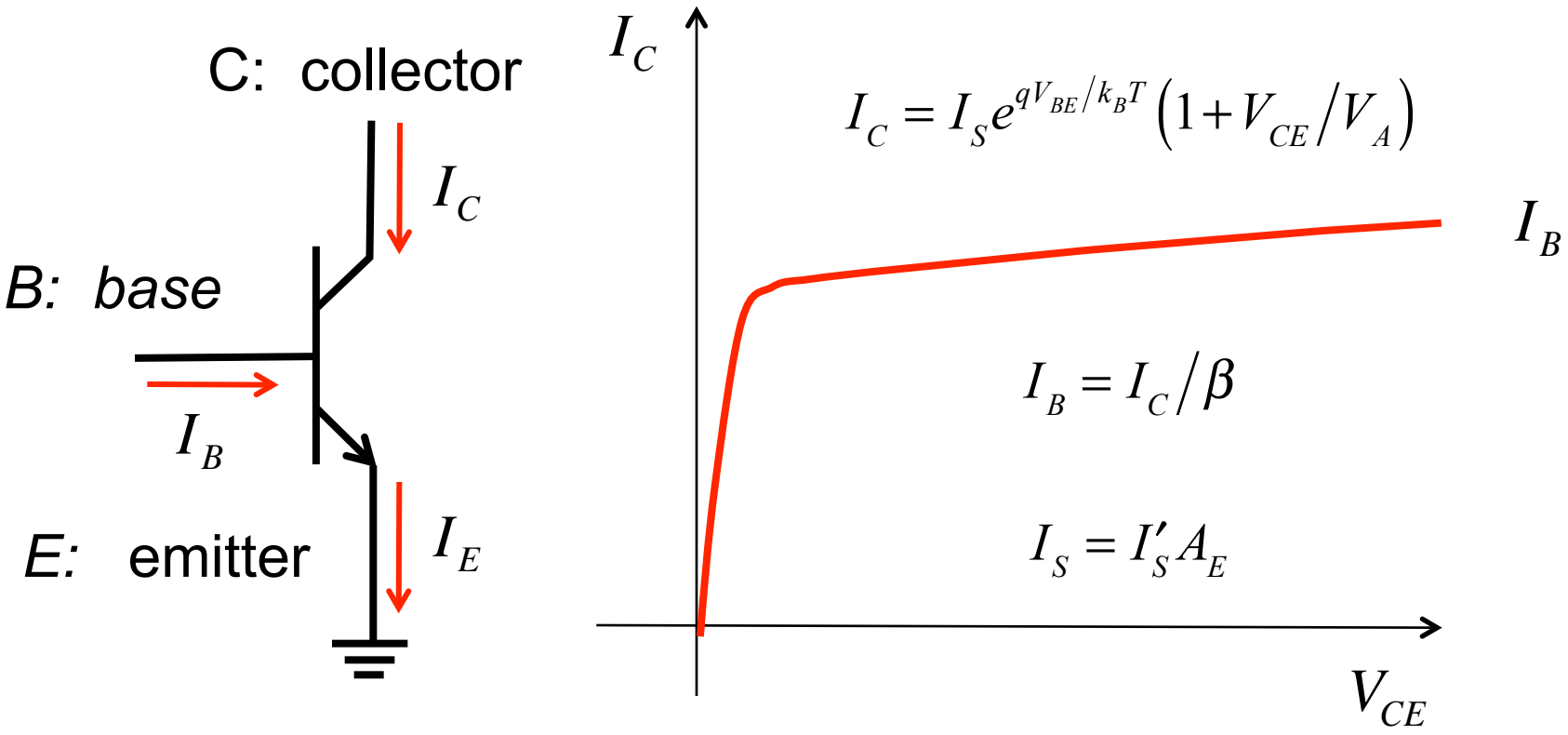
IV characteristics: output characteristics



BJT Characteristics



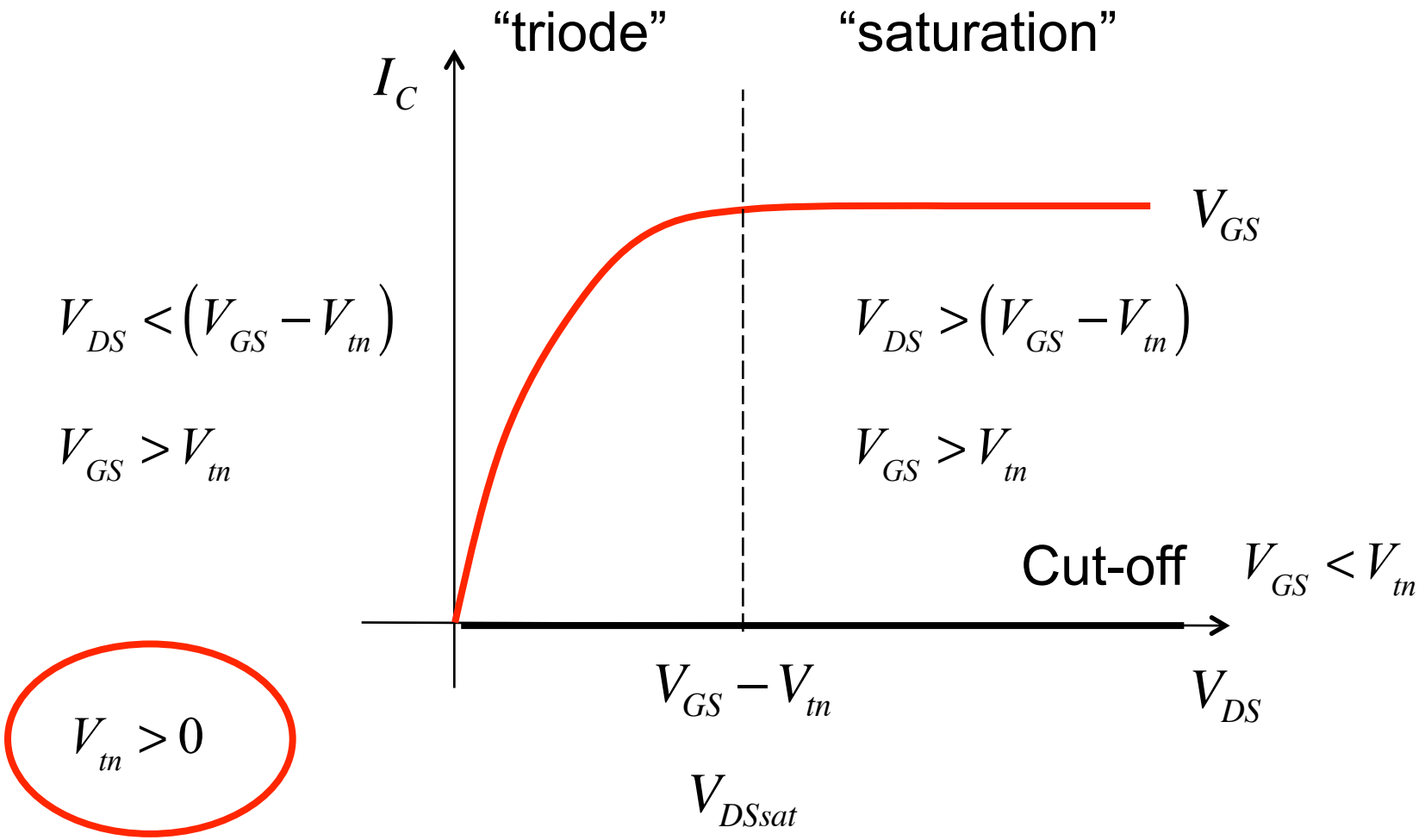
BJT Active region: mathematical model



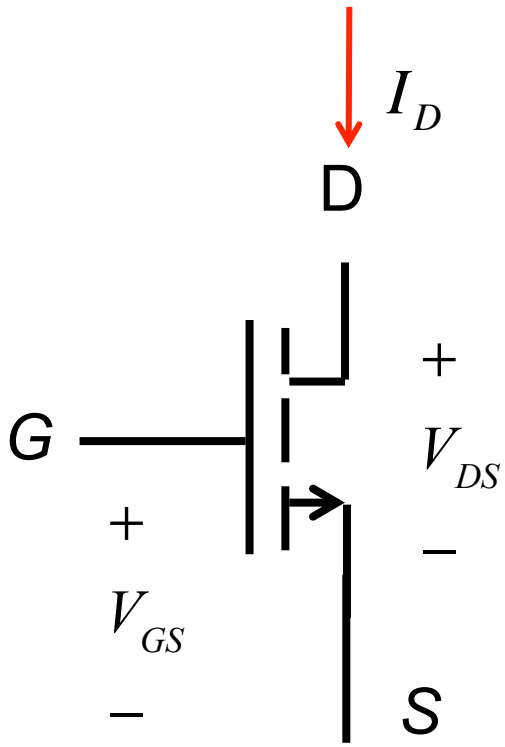
NPN BJT

I'_S: "technology constant"

Long channel N-MOSFETs



N-channel operating regions



Cut-off: $V_{GS} < V_{tn}$

Triode: $V_{GS} > V_{tn}$

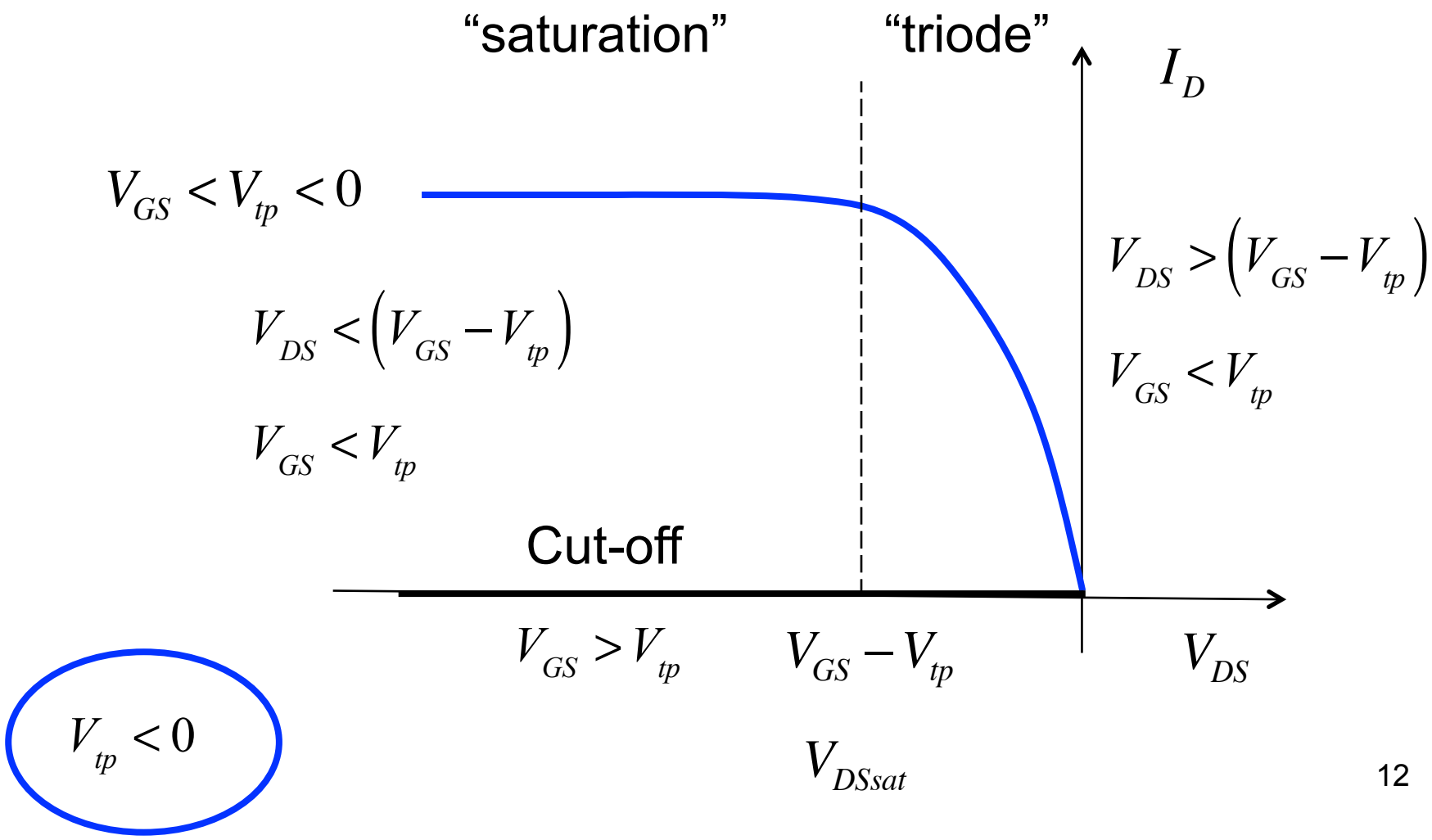
$V_{DS} < V_{DSAT} = V_{GS} - V_{tn}$

Saturation: $V_{GS} > V_{tn}$

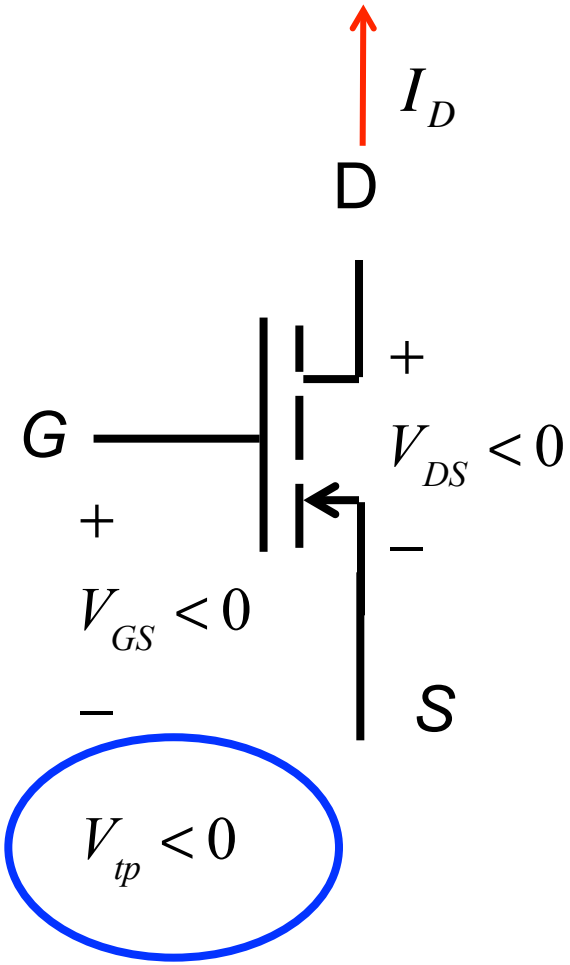
$V_{DS} > V_{DSAT} = V_{GS} - V_{tn}$

$V_{tn} > 0$ (enhancement mode)

Long channel P-MOSFETs



P-channel operating regions



(enhancement mode)

Cut-off: $V_{GS} > V_{tp}$

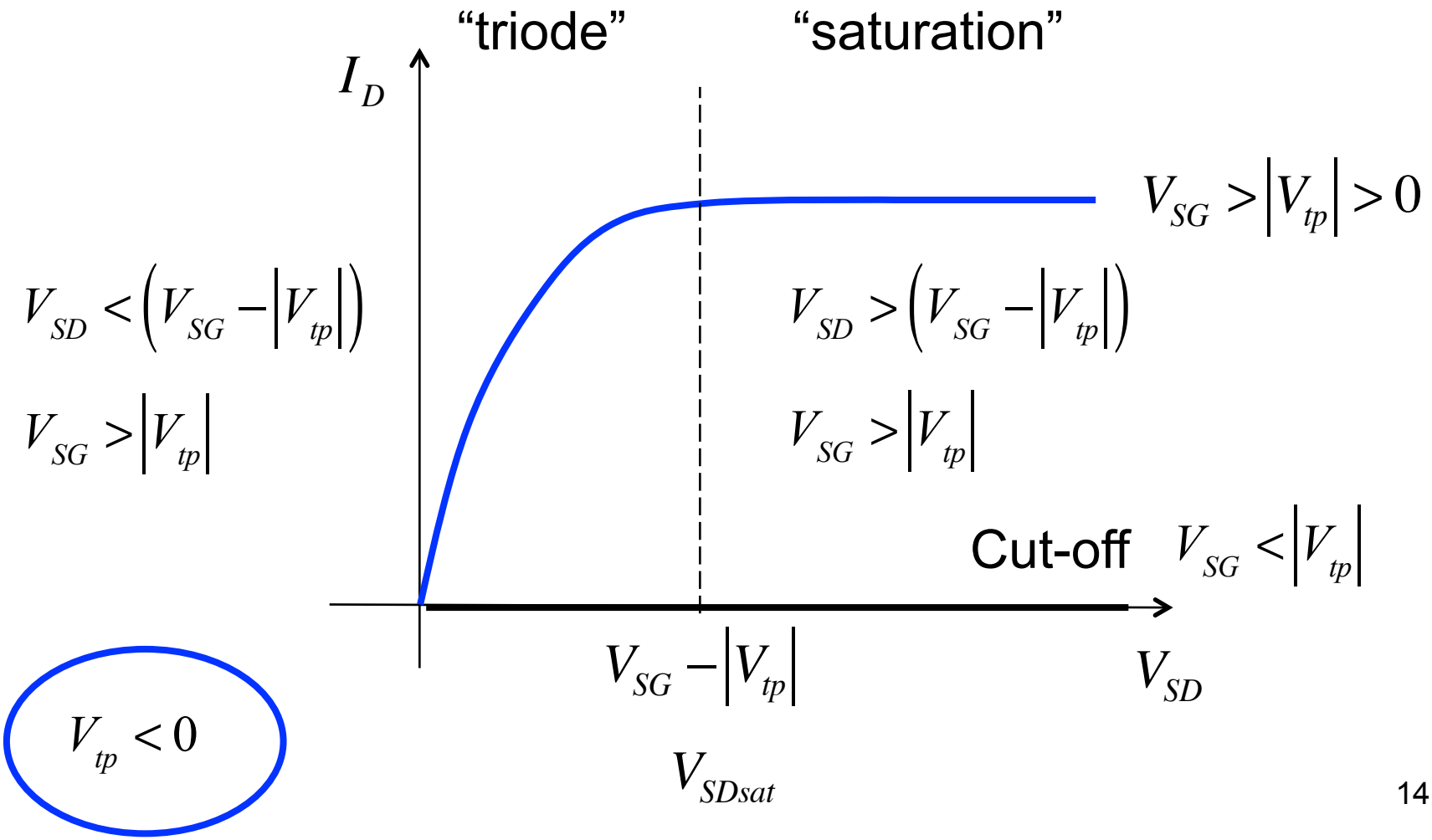
Triode: $V_{GS} < V_{tp}$

$V_{DS} > V_{DSAT} = V_{GS} - V_{tp}$

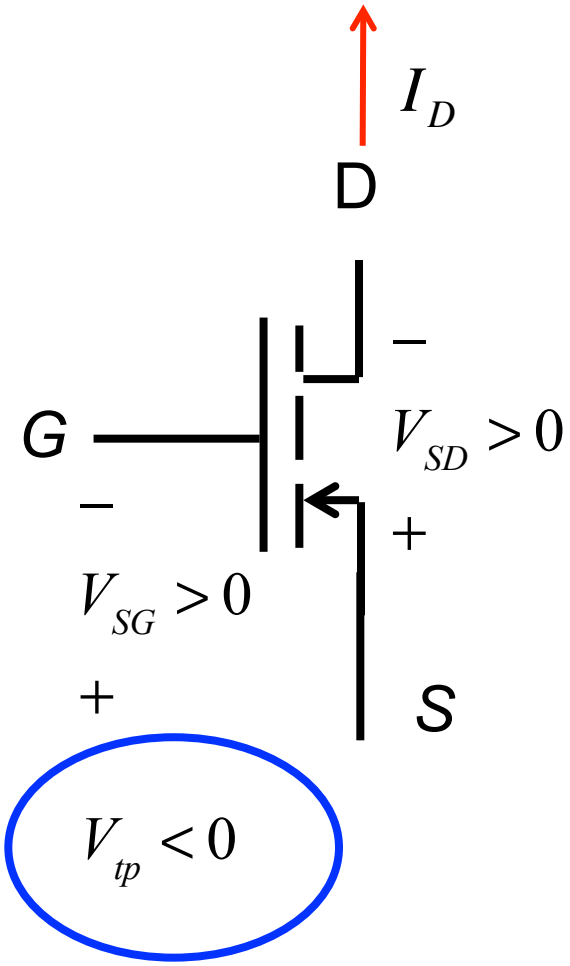
Saturation: $V_{GS} < V_{tp}$

$V_{DS} < V_{DSAT} = V_{GS} - V_{tp}$

Long channel P-MOSFETs



P-channel operating regions



(enhancement mode)

Cut-off: $V_{SG} < |V_{tp}|$

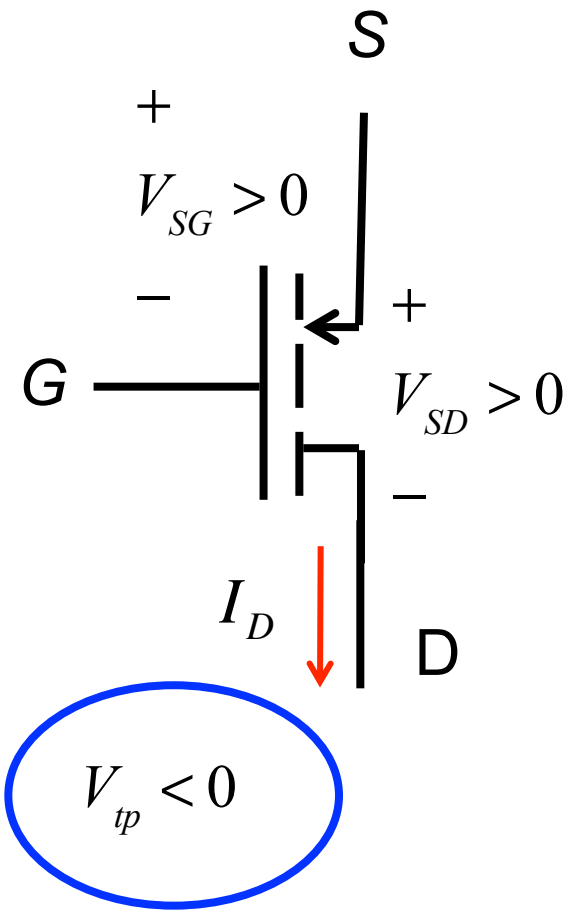
Triode: $V_{SG} > |V_{tp}|$

$V_{SD} \leq V_{SG} - |V_{tp}|$

Saturation: $V_{SG} > |V_{tp}|$

$V_{SD} > V_{SG} - |V_{tp}|$

P-channel operating regions



(enhancement mode)

Cut-off: $V_{SG} < |V_{tp}|$

Triode: $V_{SG} > |V_{tp}|$

$V_{SD} \leq V_{SG} - |V_{tp}|$

Saturation: $V_{SG} > |V_{tp}|$

$V_{SD} > V_{SG} - |V_{tp}|$

Mathematical model (N-channel)

triode **saturation**

$V_{GS} > V_{tn}$ $V_{DS} < \left(V_{GS} - V_{n}\right)$ $V_{DS} > \left(V_{GS} - V_{tn}\right)$ $V_{GS} > V_{tn}$

$$I_D = \frac{W}{L}\mu_n C_{ox}\left[\left(V_{GS} - V_{tn}\right)V_{DS} - \frac{V_{DS}^2}{2}\right] \qquad I_D = \frac{W}{2L}\mu_n C_{ox}\left(V_{GS} - V_{tn}\right)^2$$

$$I_D = k_n'\frac{W}{L}\left[\left(V_{GS} - V_{tn}\right)V_{DS} - \frac{V_{DS}^2}{2}\right] \qquad I_D = \frac{k_n'}{2}\frac{W}{L}\left(V_{GS} - V_{tn}\right)^2$$

Mathematical model with output resistance

saturation

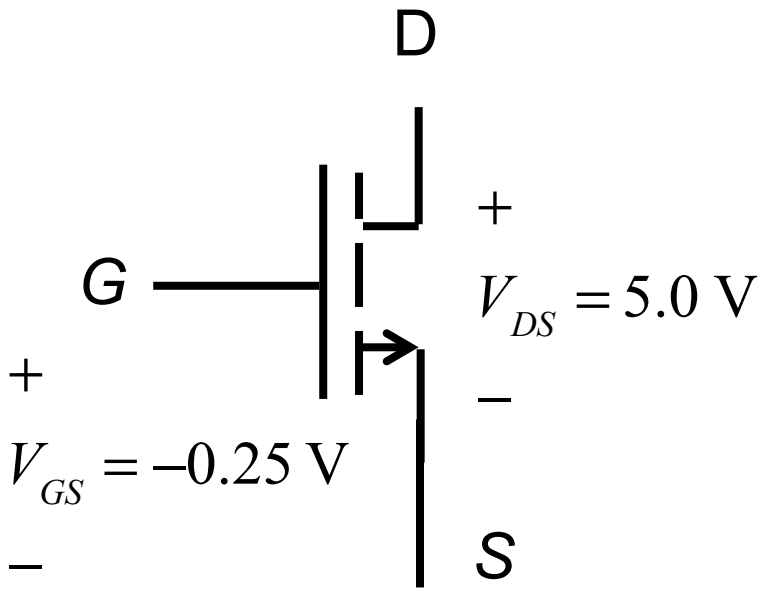
$$V_{DS} > \left(V_{GS} - V_{tn}\right) \qquad V_{GS} > V_{tn}$$

$$I_D = \frac{W}{2L}\mu_n C_{ox}\left(V_{GS} - V_{tn}\right)^2\left(1 + \lambda V_{DS}\right) \qquad \lambda = \frac{1}{V_A}$$

$$I_D = \frac{k_n'}{2}\frac{W}{L}\left(V_{GS} - V_{tn}\right)^2\left(1 + \lambda V_{DS}\right)$$

Quiz

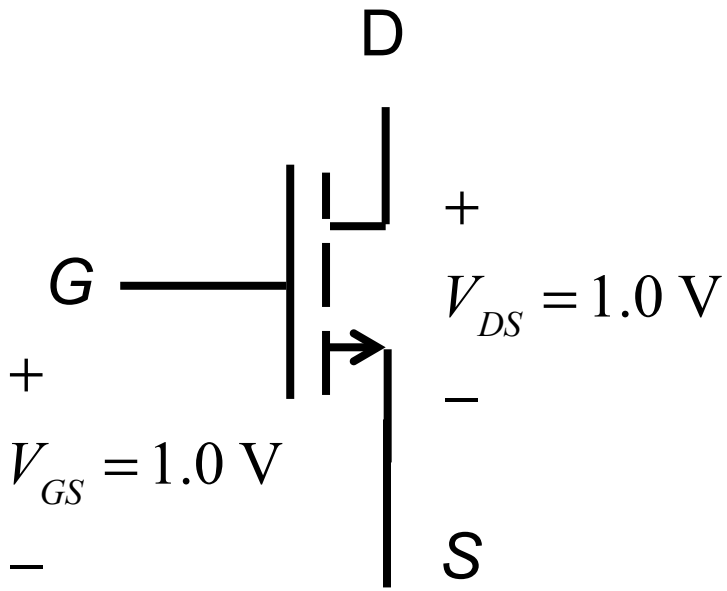
$V_{tn} = 0.5\ \text{V}$



Region?

Quiz

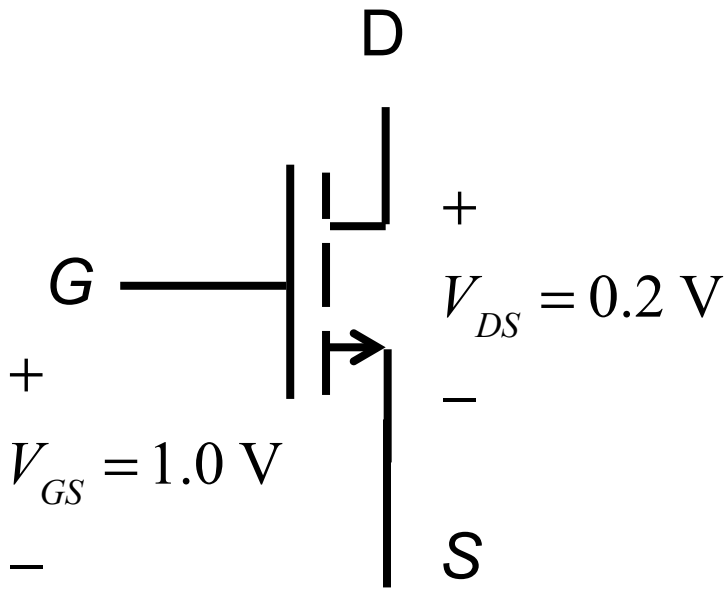
$V_{tn} = 0.5\ \text{V}$



Region?

Quiz

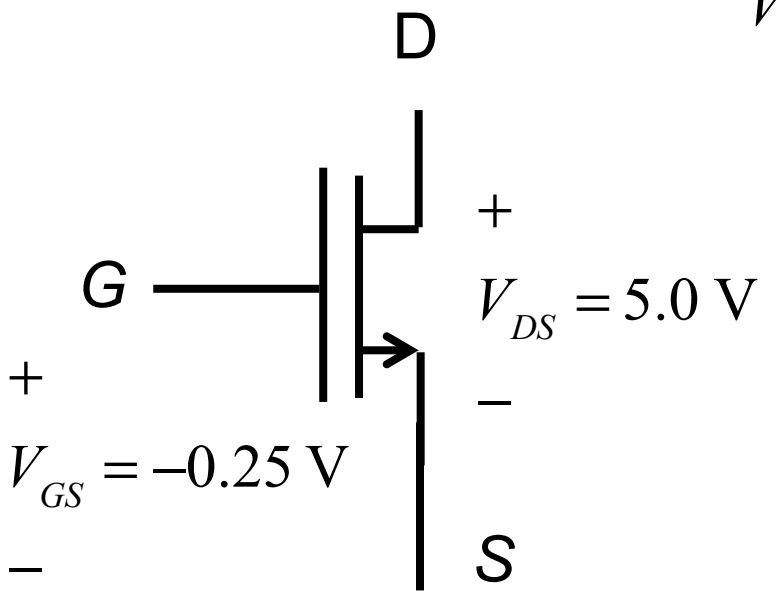
$V_{tn} = 0.5$ V



Region?

Quiz

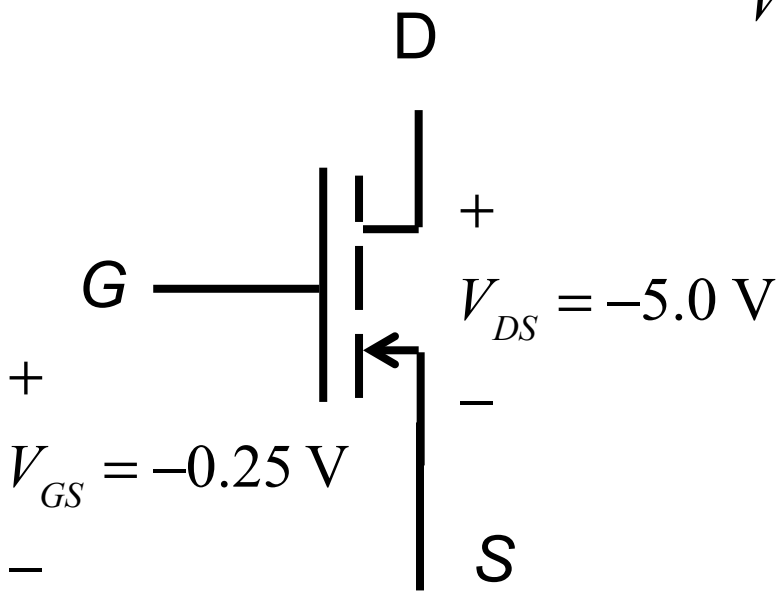
$V_{tn} = -0.5$ V



Region?

Quiz

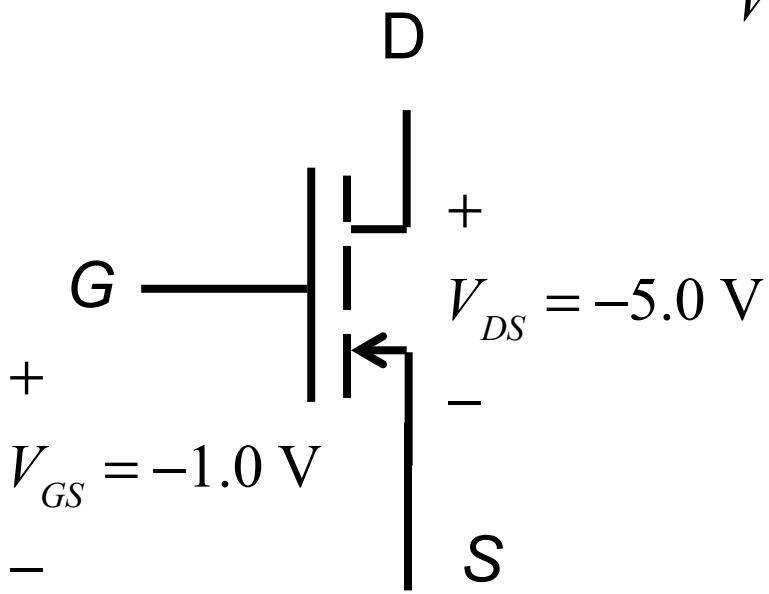
$V_{tp} = -0.5$ V



Region?

Quiz

$V_{tp} = -0.5$ V



Region?

Summary

N-channel saturation

$V_{GS} > V_{tn} \qquad V_{tn} > 0\ \text{V}$

$V_{DS} > V_{DSsat} \qquad V_{DSsat} = V_{GS} - V_{tn}$

$$I_D = \frac{k'_n}{2}\frac{W}{L}\left(V_{GS} - V_{tn}\right)^2$$

$$I_D = \frac{k'_n}{2}\frac{W}{L}\left(V_{GS} - V_{tn}\right)^2\left(1 + \lambda V_{DS}\right)$$

P-channel saturation

$V_{GS} < V_{tp} \qquad V_{tp} < 0\ \text{V}$

$V_{DS} < V_{DSsat} \qquad V_{DSsat} = V_{GS} - V_{tp}$

$$I_D = \frac{k'_p}{2}\frac{W}{L}\left(V_{GS} - V_{tp}\right)^2$$

$$I_D = \frac{k'_p}{2}\frac{W}{L}\left(V_{GS} - V_{tp}\right)^2\left(1 + \lambda\left|V_{DS}\right|\right)$$

Summary

N-channel saturation

$V_{GS} > V_{tn} \qquad V_{tn} > 0\ \text{V}$

$V_{DS} > V_{DSsat} \qquad V_{DSsat} = V_{GS} - V_{tn}$

$$I_D = \frac{k_n'}{2}\frac{W}{L}\left(V_{GS} - V_{tn}\right)^2$$

$$I_D = \frac{k_n'}{2}\frac{W}{L}\left(V_{GS} - V_{tn}\right)^2\left(1 + \lambda V_{DS}\right)$$

P-channel saturation

$V_{SG} > \left|V_{tp}\right| \qquad V_{tp} < 0\ \text{V}$

$V_{SD} > V_{SDsat} \qquad V_{SDsat} = V_{SG} - \left|V_{tp}\right|$

$$I_D = \frac{k_p'}{2}\frac{W}{L}\left(V_{SG} - \left|V_{tp}\right|\right)^2$$

$$I_D = \frac{k_p'}{2}\frac{W}{L}\left(V_{SG} - \left|V_{tp}\right|\right)^2\left(1 + \lambda V_{SD}\right)$$

MOSFET IV

1) IV characteristics of N and P-channel MOSFETs
2) Regions of operation