

NAME: _____

PUID: : _____

ECE 305 Exam 5 Spring 2015

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This is a closed book exam. You may use a calculator and the formula sheet at the end of this exam. Following the ECE policy, the calculator **must** be a Texas Instruments TI-30X IIS scientific calculator.

There are three equally weighted questions. To receive full credit, you must **show your work**.

The exam is designed to be taken in 50 minutes.

Be sure to fill in your name and Purdue student ID at the top of the page.

DO NOT open the exam until told to do so, and stop working immediately when time is called.

The last page is an equation sheet, which you may remove, if you want.

75 points possible, 10 per question

- 1) 25 points (5 point per part)
- 2) 25 points (5 points per part)
- 3) 25 points (5 points per part)

----- Course policy -----

I understand that if I am caught cheating in this course, I will earn an F for the course and be reported to the Dean of Students.

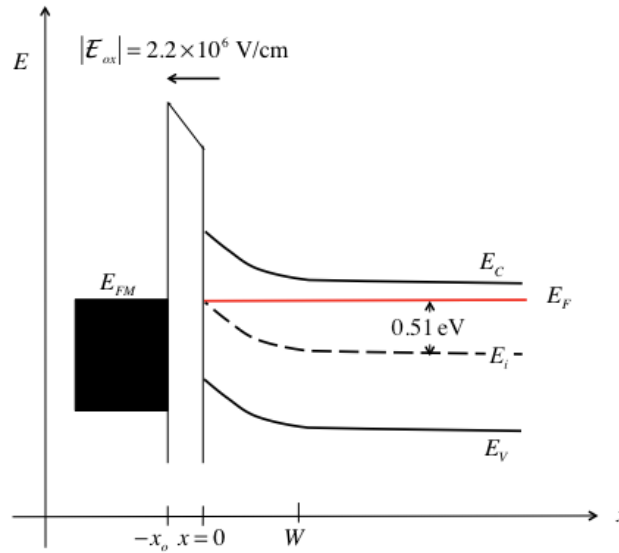
Read and understood:

signature

Answer the **multiple choice questions** below by **circling** the **one, best answer**.

- 1a) The electric field in the oxide of an MOS capacitor is typically a constant, independent of position. Why?
- Because there is typically very little charge at the oxide-semiconductor interface.
 - Because there is typically very little charge in the oxide.
 - Because there is typically very little charge at the metal-semiconductor interface.
 - Because the dielectric constant of the oxide is typically different than the dielectric constant of the semiconductor.
 - Because the minority carrier lifetime in the oxide is typically very long.
- 1b) Which of the following is true for an N-type semiconductor in accumulation?
- The surface potential is positive.
 - The surface potential is negative.
 - The surface potential is zero.
 - The surface potential is ϕ_F .
 - The surface potential is $-2\phi_F$.
- 1c) Which of the following is true of $C_{ox}(V_G - V_T)$ in an MOS capacitor with an N-type substrate? (Assume that $V_G < V_T < 0$.)
- It is the magnitude of the accumulation charge.
 - It is the magnitude of the depletion charge.
 - It is the magnitude of the inversion charge.
 - It is the magnitude of the total charge in the semiconductor.
 - It is the magnitude of the fixed charge at the oxide-semiconductor interface.
- 1d) How is an N-channel MOSFET biased under ON-current conditions?
- $V_{GS} = 0, V_{DS} = 0$.
 - $V_{GS} = 0, V_{DS} = V_{DD}$.
 - $V_{GS} = V_{DD}, V_{DS} = 0$.
 - $V_{GS} = V_{DD}, V_{DS} = V_{DD}$.
 - $V_{GS} = -V_{DD}, V_{DS} = +V_{DD}$.
- 1e) How is an N-channel MOSFET biased under OFF-current conditions?
- $V_{GS} = 0, V_{DS} = 0$.
 - $V_{GS} = 0, V_{DS} = V_{DD}$.
 - $V_{GS} = V_{DD}, V_{DS} = 0$.
 - $V_{GS} = V_{DD}, V_{DS} = V_{DD}$.
 - $V_{GS} = 0.05V_{DD}, V_{DS} = V_{DD}$.

- 2) This problem is about the MOS capacitor whose energy band diagram is show below. You may assume that the semiconductor is silicon at 300 K and that the insulator is SiO₂ with a relative dielectric constant of 3.9 and a thickness of 2 nm. You may assume that there is no charge at the oxide-semiconductor interface. Also assume that the electrostatic potential in the silicon is zero as $x \rightarrow \infty$.

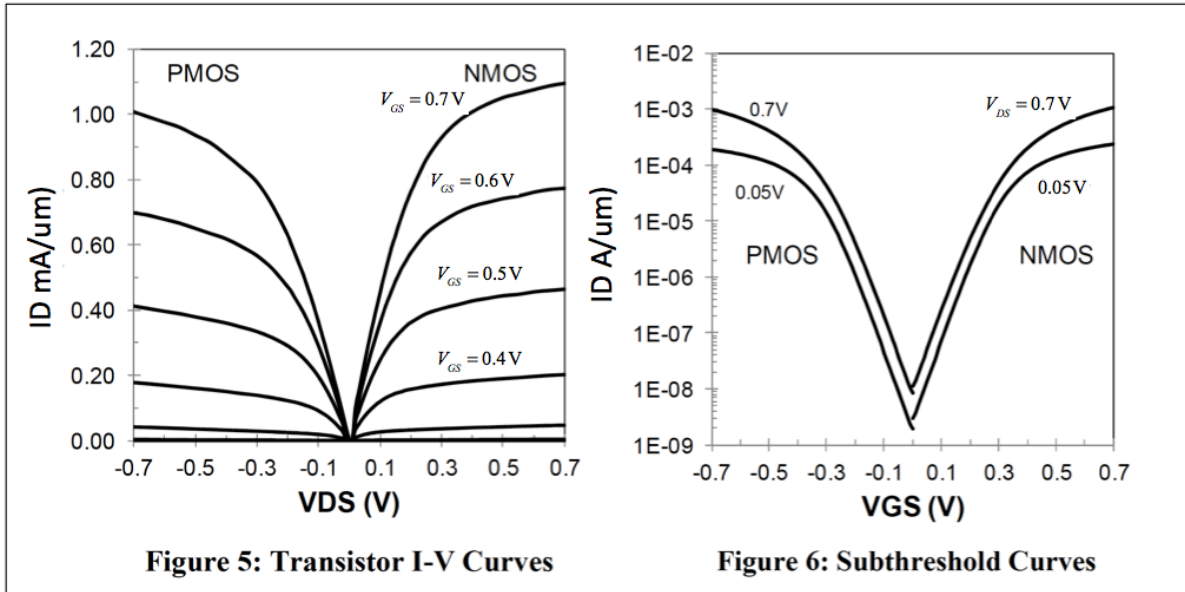


Answer the following questions about this MOS capacitor.

- 2a) Is the semiconductor in accumulation, flat-band, depletion, or inversion? Explain your answer.
- 2b) What is the numerical value of the surface potential? (Be sure to include a sign.)

- 2c) What is the electrostatic potential voltage of the gate electrode with respect to the semiconductor? Include the proper sign. (Hint: The answer is not zero)?
- 2d) What is the numerical value of the electric field in the silicon right at the oxide-silicon interface? Be sure to include a sign in your answer.
- 2e) What is the value of the charge in the semiconductor in C/cm^2 ? Be sure to include the sign.

- 3) The figures below show transistor IV characteristics for Intel’s 14 nm technology. Assume that the transistor has a 1 micrometer width. Also assume that $C_{ox} = 3.0 \times 10^{-6} \text{ F/cm}^2$ and that the source and drain series resistances are 100 Ohms each.



- 3a) What is the ON-current in Amperes of the NMOS device? Explain how you find it.

- 3b) What is the OFF-current of the NMOS device? Explain how you find it.

3c) Approximately what is the threshold voltage of the NMOS transistor? Explain how you find it.

3d) Approximately what is the DIBL of the NMOS device?

3e) Approximately what is the inversion layer charge density, $n_s = |Q_n|/q$ in the ON-state?