Title

Written Exam with Six Tasks

Instructions

The exam should be completed in the 5 hour assignment period (8-13).
One extra hour until 14.00 is allowed to accommodate late submission due to any technical issues.
All answers should be handwritten and scanned into PDF-format.
Handwritten solutions using tablets are also OK if they are converted into PDF.
The following material is allowed:
Material Properties and Formulas, spring 2020 version
The standard rules and procedures for a written exam apply, see below for full information:

Written Exam
IH1611 Semiconductor Devices
Friday, June 11, 2021, 8.00
Open for submissions in Canvas until Friday, June 11, 14.00

Write clearly and draw figures according to the instructions!
Sign your name on all answer sheets!
Use a new sheet for every task.
Examiner and responsible teacher: Gunnar Malm, 08-790 43 32

The student may use the following items during the exam: Calculator, ruler, and the attached "Material Properties and Formulas"

Structure: *The exam consists of six tasks. To pass the exam you should fulfill the grading criteria to E level. Attempt all problems!*
Carefully read and consider all tasks at the start of the exam.

Students who do not pass the exam, and according to the judgment of the examiner are close to the pass limit, will be offered one chance to complement their exam and thereby receive a passing grade (E). No other grades are achievable in this circumstance.

If nothing else is stated in the tasks: Assume that the material is silicon (Si) and room temperature (T=300 K).

Determine the Fermi level position(s) and draw band diagrams for a pn-junction in silicon at the temperatures 300 K and a lower temperature 77 K.
What is the general trend that you observe for the Fermi level position vs. temperature from these data?
If needed, calculate the Fermi level position at a few additional temperatures, to support your conclusion!

Oxide charge

The flat-band condition is useful to analyze the MOS-system. Draw the energy band-diagram for a MOS-system in flat-band condition using the following information:
• p-type substrate
• a suitable metal gate workfunction, select one metal and motivate why that metal has a suitable workfunction
• a positive charge located at the oxide-substrate interface
Hint: you could start from the normal flat-band condition with no surface charge and then add the influence of the positive charge.

What types of semiconductor devices are used in a **hybrid electric car** like the one showed in the figure?
At least three examples are required!

- name the type of the devices
- explain and motivate the most suitable semiconductor material for each device type
- explain if the devices are used "stand alone" or as part of more complex integrated circuits or memories

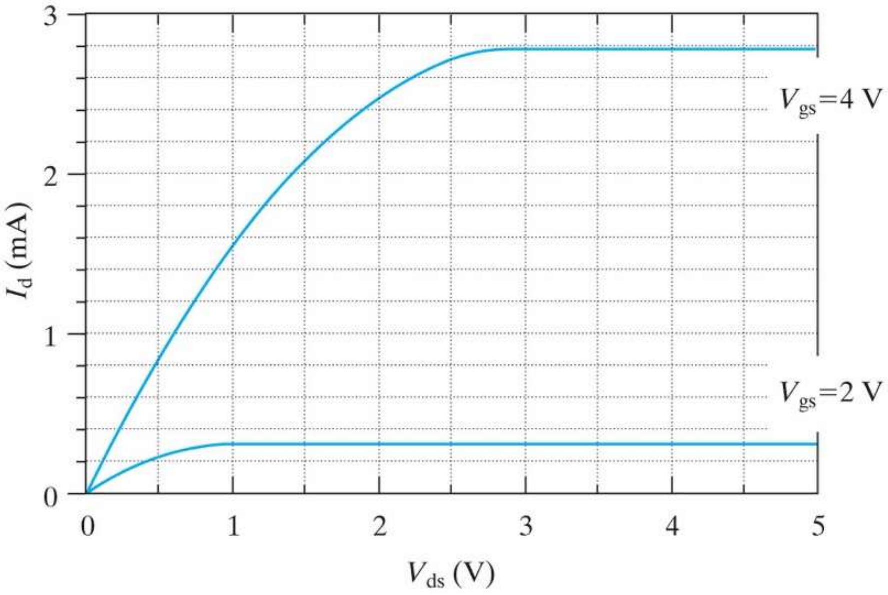
Memory categories
What is your favorite type of semiconductor memory?
Illustrate the basic circuit that is needed for one memory cell!

Explain how this cell performs in terms of categories such as endurance, energy consumption, footprint or area, and ease of fabrication. Additional categories might apply as well. Use at least three categories in your answer.

MOSFET output characteristics
The figure shows the output IV-characteristics of an nMOSFET with gate oxide thickness 10 nm, channel width 5 µm, channel length 1 µm.
The bulk charge factor is 1.2

a) Estimate the threshold voltage, from the curves in the figure

b) Estimate the effective mobility, from the curves in the figures and results from the first task



Hint, you also need to find the **saturation currents** and **saturation voltages** to solve these problems.

Solar cell IV

Draw (in the same diagram) solar cell IV-curves under illumination for two different temperatures. Assume a few degrees (in K) difference.

- Carrier lifetime and mobility can be taken from the tables and formulas sheet.
- Assume an area of 10 cm^2 if needed or just normalize to area.
- Assume a typical doping level if needed.
- Use numeric calculations to estimate the shift in open circuit voltage.
- The relative shift in short circuit current level could be explained by relevant semiconductor physics.