Questionnaire on

Subject of Examination (legible if possible ;))
Solar Energy

☐ Oral	☐ Oral Re-examination	Date:	**08.03.2022**	Examiner:	**Prof. Dr. Bryce Sydney Richards** **Jun.-Prof. Dr. Ulrich W. Paetzold**
☑ Written		Duration:	**2 hours**	Programme of Study	**ETIT Master**

Preparation

a) Continuous attendance at lectures? ☑ Yes ☐ No

b) Effects of a): ☑ Positive ☐ None ☐ Negative

c) Amount of time spent on preparation: **2 weeks (not full time)** ☑ by yourself ☐ group work

d) Prior knowledge from other lectures/practical experiences?
"Halbleiterbauelemente" (Bachelor) for semiconductor basics
"Thermische Solarenergie"

e) What resources did you use? *(literature, websites etc.)*
Lecture slides
"Solar Energy" by Arno Smets

f) Can you give any advice on the preparation of this exam?
- **Tutorial and Mock Exam are a good training for the exam (almost the same questions are in the real exam) but no solutions will be uploaded! → Ask the students from last year / go in the tutorials.**
- **Quick Tests at the end of each lecture are mandatory.**
- **Last lecture (Q&A) is very important, the important question for the exam will be shown.**
- **They test if you understood the basic concepts (like in the quick tests) and don't annoy you with detailed questions about a specific technology.**

Exam

a) Had there been any agreements in form or contents of the exam? Were they met?
Exam was oriented on Mock Exam, Tutorials & Quick Tests

b) Advice on behaviour during the exam:
Be fast…

c) Examination style: *(atmosphere, questions: clear or unclear, in-depth knowledge or general questions, specific interposed questions, specific questions in case of knowledge gaps, …?)*
The exam consists of 6 Tasks with a) - f), you should know the required basics by heart since you will have a lot of time pressure exam but with fair questions!

Other questions

a) How were you graded? (*optional of course*) **You find the statistics at the end.**

b) Do you think this grade is appropriate? ☑ Yes ☐ No *(why not?)*

c) Would you recommend this exam? ☑ Yes *(to whom especially?)* ☐ No *(why not?)*
Very interesting subject with great professors (one is from Australia) & fair exam with a lot of topics.

d) Do you have any other advice or remarks about this exam?
Don't underestimate the time to prepare.

Contents of the Exam: Please try to reproduce as many questions as possible. At which points did the examiner ask for derivations, at which analytic proof? *(If the space here is not sufficient do not hesitate to add additional sheets. But please staple the pages and number them.)*

Task 1: Radiation

- Draw a Black Body spectrum at $T = 5\,000\,\mathrm{K}$ and $T = 2\,000\,\mathrm{K}$.
- At $T = 6\,000\,\mathrm{K}$: Draw the spectrum for Black Body, AM0, AM1.5. Explain the differences and where they come from.
- Draw the absorption curve and label the regions with "thermalization losses" and "transparency losses".
- Given P_{Sun}, distance from Earth to Mars, calculate the Power at AM0 on Mars.
- A PV-panel will produce $400\,\mathrm{Wp}$ on Earth, how much would it produce on Mars?
- What does the SQ limit say? What are the assumptions?

Task 2: Semiconductor basics

Important: Check out the Diagrams for DoS, Fermi Levels and charge carrier concentrations!

- Explain DoS and Fermi Level.
- Draw the band diagrams for an insulator, semiconductor and metal. Annotate valence, conduction bands and the Fermi level.
- What's is the difference between a direct and indirect semiconductor?
- In a table, the DoS for an intrinsic, n-type and p-type semiconductor are given. Sketch the corresponding graphs for the Fermi level as well as $n(E)$ and $p(E)$.
- Draw the energy levels for a pn-junction in open-circuit condition in the dark and under light (2 graphs).
- Explain in detail what happens under illuminated condition and how you get power out of the cell. (This gave 6 marks, so write a bit more.)
- Advantage of small / large bandgap.
- Explain the tree bulk recombination mechanisms. Which one is unavoidable? Which one can be reduced by a reducing the impurities?
- Calculate the required absorption coefficients for 3 different given wavelengths so that a fixed percentage of light is absorbed. The thickness is given and always the same.

Task 3: J-V Curves

- Draw J-V Curves, mark important points (J_{SC}, V_{OC}, FF, P_{max}).
- Draw the curves for a small, medium and large bandgap in a single graph.
- State the efficiency formula.
- The influence of concentrated suns on J_{SC} and V_{OC} is important. This was done in the lecture and the mock exam.

Task 4: PV Modules

Module calculation, consists of 60 cells. Datasheet of the module was given.

- Draw the J-V curve
- Determine the J_{SC} and V_{OC} of the 60 cells.
- Draw the curve if one cell is shaded.
- Calculate the efficiency.

Task 5: Tandem cells

- Diagramm of solar spectrum given with 2 different band gaps, explain what happens in the different band gaps.
- Which losses will occur in the two different band gaps?
- How to overcome the SQ limit, name 3 options.

Task 6: 3rd Gen (up-conversion layer)

Almost exactly the same exercise like the tutorial task "Solar cell configurations (adapted from: exercise 16.4 of textbook 'Solar Energy')"! (same graphs and same numbers)

Differences:

- Last part with spectral range C (task f) and g) in the tutorial) is not part of the exam.
- Up-conversion only has 80% efficiency (in the tutorial it was 100%)

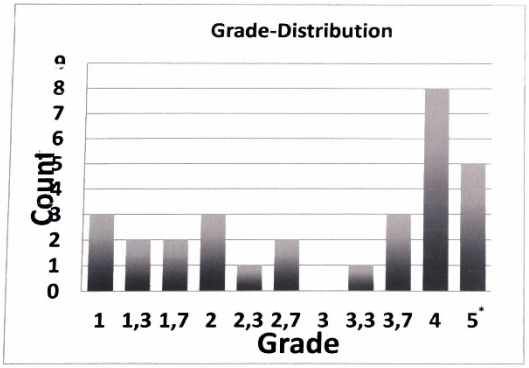
Here's the statistics of the exam

(after the review and oral re-examinations)

Total Points:			**78**	Points	100,0%
Points for 1		1	**62,5**	Points	**80,1%**
Points for 4		4	**29**	Points	**37,2%**

Mark	min. points
1	62,5
1,3	58,5
1,7	55
2	51,5
2,3	47,5
2,7	44
3	40
3,3	36,5
3,7	32,5
4	29
5	0

			in %
Participants*:		**30**	100,0
Passed:		**25**	83,3
Failed*:		5	16,7
Mean of points*:			37,9
Mean:			**3,1* (2,9**)**



* incl. non-attendees
** excl. non-attendees

Good luck for the exam and your further studies!

Thank you for your help! **Your fellow students.**