☐ **Department of Civil and Environmental Engineering**

Examination paper for TVM4155 Numerical modelling and hydraulics

Examination date: 21. May 2021

Examination time (from-to): 09 am to 1 pm

Permitted examination support material: A / All support material is allowed

Academic contact during examination: Nils Reidar B. Olsen
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Technical support during examination: Orakel support services
Phone: 73 59 16 00

If you experience technical problems during the exam, contact Orakel support services as soon as possible before the examination time expires. If you don't get through immediately, hold the line until your call is answered.

OTHER INFORMATION

Make your own assumptions: If a question is unclear/vague, make your own assumptions and specify them in your answer. Only contact academic contact in case of errors or insufficiencies in the question set.

Cheating/Plagiarism: The exam is an individual, independent work. Examination aids are permitted, but make sure you follow any instructions regarding citations. During the exam it is not permitted to communicate with others about the exam questions, or distribute drafts for solutions. Such communication is regarded as cheating. All submitted answers will be subject to plagiarism control. *Read more about cheating and plagiarism here.*

Citations: Please state in your answer if you quote text directly

Notifications: If there is a need to send a message to the candidates during the exam (e.g. if there is an error in the question set), this will be done by sending a notification in Inspera. A dialogue box will appear. You can re-read the notification by clicking the bell icon in the top right-hand corner of the screen. All candidates will also receive an SMS to ensure that nobody misses out on important information. Please keep your phone available during the exam.

Weighting: The weight for each problem is given on the exam question.

ABOUT SUBMISSION

Many of the exam problems requires uploading of files. Please use Excel or LibreOffice Calc files if uploading results from a spreadsheet. Files made by hand-drawing may be in the formats PDF, PNG, GIF or TIF.

How to answer questions: All question types other than Upload assignment must be answered directly in Inspera. In Inspera, your answers are saved automatically every 15 seconds. **NB!** We advise against pasting content from other programs, as this may cause loss of formatting and/or entire elements (e.g. images, tables).

File upload: When working in other programs because parts of/the entire answer should be uploaded as a file attachment – make sure to save your work regularly.

All files must be uploaded <u>before</u> the examination time expires.

The file types allowed are specified in the upload assignment(s).

30 minutes are added to the examination time to manage the sketches/calculations/files. The additional time is included in the remaining examination time shown in the top left-hand corner.

NB! You are responsible to ensure that the file(s) are correct and not corrupt/damaged. Check the file(s) you have uploaded by clicking "Download" when viewing the question. All files can be removed or replaced as long as the test is open.

How to digitize your sketches/calculations
How to create PDF documents
Remove personal information from the file(s) you want to upload

Automatic submission: Your answer will be submitted automatically when the examination time expires and the test closes, if you have answered at least one question. This will happen even if you do not click "Submit and return to dashboard" on the last page of the question set. You can reopen and edit your answer as long as the test is open. If no questions are answered by the time the examination time expires, your answer will not be submitted. This is considered as "did not attend the exam".

Withdrawing from the exam: If you become ill, or wish to submit a blank test/withdraw from the exam for another reason, go to the menu in the top right-hand corner and click "Submit blank". This cannot be undone, even if the test is still open.

Accessing your answer post-submission: You will find your answer in Archive when the examination time has expired.

1 Problem 1

A hydraulic jump is located downstream of a dam. The upstream Froude number is 7 and the upstream water depth is 0.4 m. The width of the channel is 12 meters. Compute the downstream water depth. Assume a rectangular cross-section and a horizontal bed.

Downstream water depth: [   ] meters.

Maximum marks: 2

2 Problem 2

A physical model test is to be done to see if erosion will occur in a river. The river has a width of 200 meters, a depth of 2 meters, a slope of 1/350 and a discharge of 1400 m³/s. The physical model is made in a scale 1:20. The prototype gravel on the river bed has a diameter of 6 cm. The physical model sediments has the same density as the prototype. The physical model is made in a non-distorted scale.

Compute the following numbers and indicate if the two last statements are correct.

Bed shear stress for prototype [ ] Pa

Bed shear stress for physical model [ ] Pa

Critical bed shear stress for the prototype particles [ ] Pa

Critical bed shear stress for the physical model particles [ ] Pa

The particles will be eroded in the prototype
Select an alternative

○ True

○ False

The particles will be eroded in the physical model
Select an alternative

○ True

○ False

Maximum marks: 6

3 Problem 3

Compute the vertical diffusion [m^2/s] in a wide river with a water depth of 2.5 meters and a discharge of 2 m^2/s. Assume a Manning-Strickler number of 46 and a *K* value of 0.11. Do not use formulas for the longitudinal or transverse diffusion. Use at least three digits in the answer.

Answer: ⬚ m2/s.

Maximum marks: 3

4 Problem 4

We are looking at the currents in two lakes: Lake A and Lake B. Both lakes are deep, long and narrow, and have stratified density distribution. Lake A is located in Norway and Lake B is located in the south part of Chile. Lake A has inflow from the North and outflow to the South side. The longest axis of the lake is in the North-South direction. Lake B has inflow from the East and outflow to the West. The longest axis of the lake is in the East-West direction. The temperature of the inflowing water is 20 degrees.

On which side of the lakes will the surface water current be located?
Select one or more alternatives:

☐ West side on Lake A and north side on Lake B.

☐ East side on Lake A and south side on Lake B.

☐ East side on Lake A and north side on Lake B.

☐ West side on Lake A and south side on Lake B.

Maximum marks: 1

5 Problem 5

How much artificial diffusion is needed to get the central scheme stable if the grid cell sizes are 10x10x10 cm, the velocity is 2 m/s and the turbulent diffusion is 0.02 m^2/s? The scheme is applied to a convection-diffusion equation without the transient term.

Answer: ⬚ m^2/s.

Maximum marks: 4

6 Problem 6

Compute the Grid Convergence Index (GCI) for the following case: The trap efficiency of a long sand trap is computed to be 88.4 % for a grid with 300x15x15 cells, and 90.1 % for a grid with 700x30*30 cells. The length of the sand trap is 200 meters, and the depth is 3.5 meters. The water velocity in the sand trap is 0.25 m/s and the fall velocity of the particles is 0.05 m/s.

The CGI is: [   ] %.

Maximum marks: 4

7 Problem 7

Compute the trap efficiency in a 200 m long desilting basin. The water depth is 4 meters and the discharge pr. width is 1.2 m^2/s. Use a spreadsheet with 10 cells in the vertical direction and 20 cells in the longitudinal direction. Use the first-order upwind scheme. The fall velocity of the silt is set to 8 mm/s. Assume a zero gradient boundary condition at the bed, a uniform concentration of particles over the entire inflow cross-section, a uniform velocity field, a free surface and a very wide geometry. Assume a turbulent diffusion coefficient of 0.01 m^2/s in the vertical direction and zero in the horizontal direction.

Upload a spreadsheet with the computation. In the spreadsheet, indicate clearly what the trap efficiency is in %.

Upload your file here. Maximum one file.

All file types are allowed. Maximum file size is **50 GB**

☐ Select file to upload

Maximum marks: 6

8 Problem 8

Use the Streeter-Phelps model to compute the BOD and the oxygen saturation deficit in a 100 km long reach of a river downstream City A. There is a sewer outlet at City A with a BOD of 20 kg/s. 50 km downstream of City A, there is another city, City B. There is a sewer outlet from CityB of 15 kg/s. The oxygen saturation deficit and BOD in the river water is 0 % upstream City A. Upload a graph showing the longitudinal profile of BOD and the oxygen saturation deficit in the 100 km river reach.

The river has a width of 200 meters, and a water depth of 6 meters. The dishcarge is 200 m^3/s. The reaction rate, k_d, is 0.9/day and the aeration coefficient k_a is 0.4/day. The stochiometry coefficient between BOD and oxygen saturation deficit is set to 1.0.

Upload a spreadsheet file with the result, including a figure showing the longitudinal profiles of BOD and oxygen saturation deficit.

<table>
<tr><td>

□

Upload your file here. Maximum one file.

All file types are allowed. Maximum file size is **50 GB**

□ Select file to upload

</td></tr>
</table>

Maximum marks: 8

9 A shallow lake contains two types of algae: Flagellates and diatoms. The wind direction is from West to East. In which side will the concentration of diatoms be highest? And were will the concentration of flagellates be highest? Explain why in a figure with a longitudinal profile of the lake in the East-West direction.

☐

Upload your file here. Maximum one file.

All file types are allowed. Maximum file size is **50 GB**

☐ Select file to upload

Maximum marks: 4

10 What is the difference between modelling errors and errors in numerical approximations for CFD computations? How can the two errors be assessed when looking at the results from a CFD computation?

Fill in your answer here

Format ▾ | **B** *I* <u>U</u> x₂ x² | I× | ⧉ ⧉ | ↰ ↱ | ▢ | ≔ ≔ | Ω ⊞ | ▢ |

Σ | ▢

Words: 0

Maximum marks: 3

11 Describe how you would use an STL file to generate the geometry of a spillway when using OpenFOAM. Which other files are involved? What can you say about the resulting grid? Make a hand drawing of a profile with the STL file and the grid.

☐

Upload your file here. Maximum one file.

All file types are allowed. Maximum file size is **50 GB**

☐   Select file to upload

Maximum marks: 3

12 Give the names and locations (directory) of the files used to specify the inflow boundary conditions in OpenFOAM.

Fill in your answer here

Words: 0

Maximum marks: 4