NTNU

Department of Civil and Environmental Engineering

Examination paper for TVM4155 Numerical modelling and hydraulics

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Examination date: Monday 27th of May 2019

Examination time (from-to): 15:00-19:00

Permitted examination support material: Code D. No printed or hand-written support material is allowed. A specific basic calculator is allowed:

Casio fx-82ES PLUS and Casio fx-82EX

Citizen SR-270X and Citizen SR-270X College

Hewlett Packard HP30S

Language: English

Number of pages (front page excluded): 4

Number of pages enclosed: 2

Checked by:

Date Signature

Informasjon om trykking av eksamensoppgave

Originalen er:

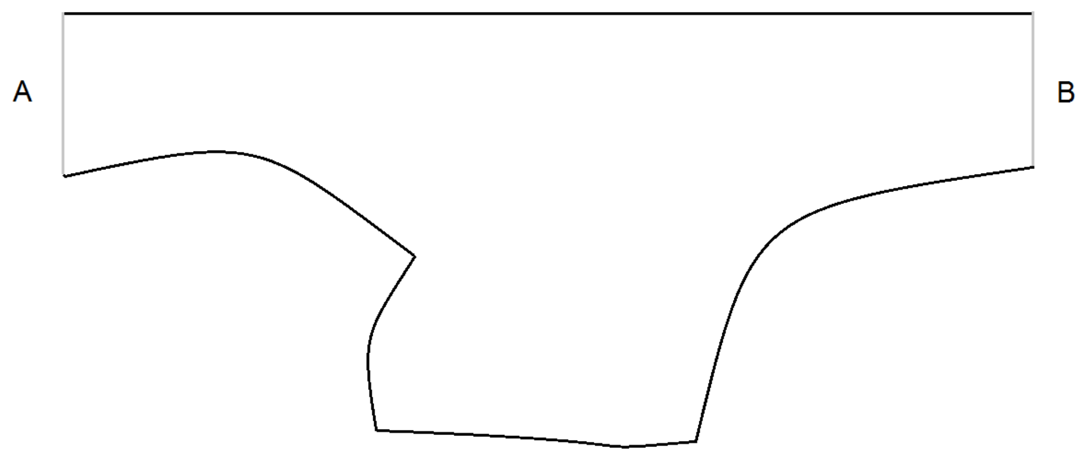
1-sidig ☐ **2-sidig** ☐

sort/hvit ☐ **farger** ☐

skal ha flervalgskjema ☐

Problem 1

Make a structured two-dimensional grid with quadrilateral cells for the geometry given below. Use between 200 and 400 cells. The inflow is along the A side. The outflow side is marked with B. The flow is from left to right. You may use outblocking. You may draw on the exam paper and hand this in.



Problem 2

The article by Almeland, Olsen, Bråtveit and Aryal (2019) is entitled “Multiple solutions of the Navier-Stokes equations computing water flow in sand traps”. The following questions are related to this article:

a) Which equations were solved to compute the water flow field?
b) Which computer programs were used?
c) Looking at the seven types of errors and uncertanties in CFD results given by ERCOFTAC, which were studied in this article?
d) Which parameters and algorithms were tested in the article?
e) What was the main conclusions of the article?
f) If you worked for a consulting company and did a CFD analysis, how would you deal with the problems presented in the article?

Problem 3

We are looking at a wide alluvial channel with uniform sediments of particle size 1 mm. The flow is uniform and the water depth is 1.4 m. The slope is 1:5000, and the width is 100 m.

a) Compute the Manning-Stricklers coefficient
b) Compute the water velocity and water discharge
c) Will the sediments move or not?
d) Compute the sediment discharge with the Engelund-Hansen formula
e) Will there be bedforms in the channel? If so, which type, and what is the estimated length and height?

Problem 4

A physical model study of the channel from Problem 4 is to be done in a geometrical scale of 1:40.

a) Compute the water discharge in the physical model
b) Compute the sediment size in the physical model assuming sand is used and erosion is most important
c) Compute the sediment size in the physical model assuming sand is used and suspended load is most important
d) Explain two problems with the sediment sizes found in question b) and c)
e) If plastic particles are used instead of sand, how will this affect question b) ?
f) If plastic particles are used instead of sand, how will this affect question a) in Problem 3 and the water depth?
g) What is a distorted model, and what is its main advantages and disadvantages for the current case?

Problem 5

a) Describe the nutrient cycle with a figure. Include oxygen, nitrogen, phosphorous and organic material.
b) Give the chemical formulas for Nitrite, Ammonia and Nitrate
c) Compute the stochiometry coefficient for the reaction from Nitrite to Nitrate

Problem 6

Describe the following words from limnology:

a) Aphotic
b) Dimictic
c) Cold Amictic
d) Littoral zone
e) Thermocline
f) Hypolimnion

Problem 7

On the next page, there is a script which is part of the file *blockMeshDict* for an OpenFoam case.

a) Make 2D figure indicating the location of all the patches. The figure should also show the points with indices.
b) What values should replace (X X X X) in the outlet patch? The outlet patch is on the opposite side of the inlet patch.
c) Explain the differences between a grid created by blockMesh and one created by snappyHexMesh. You may include words like multiblocks, block shape, orthogonal, structured/unstructured. What are the advantages of a mesh created with snappyHexMesh? In which cases would you use a blockMesh grid?
d) Describe the procedure to compute the coefficient of discharge for a spillway with OpenFOAM.

blockMeshDict script:

```
vertices
(
   (0 0 0)   // 0
   (5 0 0)   // 1
   (5 2 0)   // 2
   (0 2 0)   // 3
   (0 0 0.5) // 4
   (5 0 0.5) // 5
   (5 2 0.5) // 6
   (0 2 0.5) // 7
);

blocks
(
   hex (0 1 2 3 4 5 6 7) (10 5 1) simpleGrading (1 4 1)
);

boundary
(
   topAndBottom
   {
      type patch;
      faces
      (
         (0 1 5 4)
         (3 7 6 2)
      );
   }
   inlet
   {
      type patch;
      faces
      (
         (0 4 7 3)
      );
   }
   outlet
   {
      type patch;
      faces
      (
         (X X X X)
      );
   }
);
```

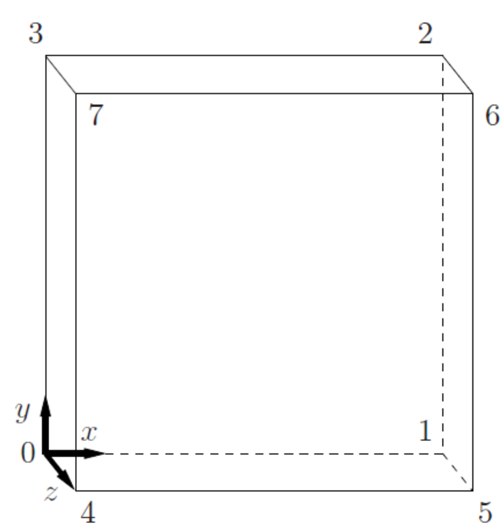


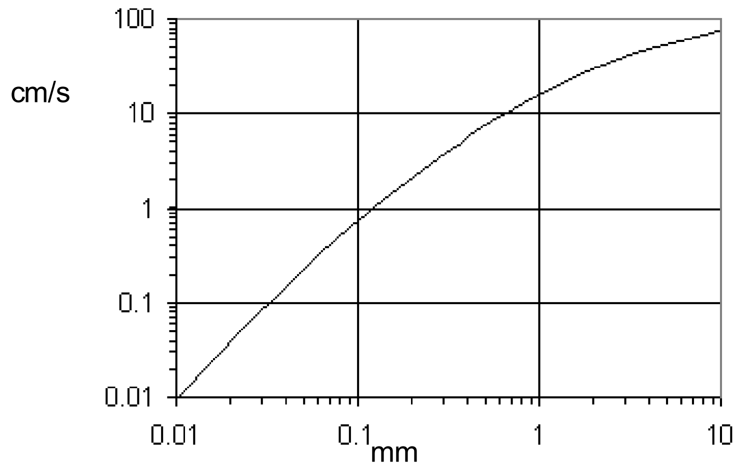
Figure 2.2: Block structure of the mesh for the cavity.

Tables and formulas

$$\frac{u}{u_{max}}=\left(1+\frac{r^2}{0.016}x\right)^{-2} \qquad \frac{u_{max}}{u_0}=6.4\left(\frac{x}{d_0}\right)^{-1} \qquad \frac{u}{u_0}=4.3\,Fr'^{\frac{-2}{3}}\left(\frac{z}{d_0}\right)^{\frac{-1}{3}}e^{\left[-96\frac{r^2}{z^2}\right]}$$

$$\frac{Q}{Q_0}=0.42\,\frac{x}{d_0} \qquad \frac{Q}{Q_0}=0.18\,Fr'^{-2/3}\left(\frac{z}{d_0}\right)^{5/3}$$

Fig. 9.3.1 Fall velocity of quartz spheres in water. The horizontal axis is the diameter of the spheres, and the vertical axis is the fall velocity



$$\Gamma=0.058\frac{Q}{IB} \qquad \Gamma=0.011\frac{(UB)^2}{Hu_*}$$

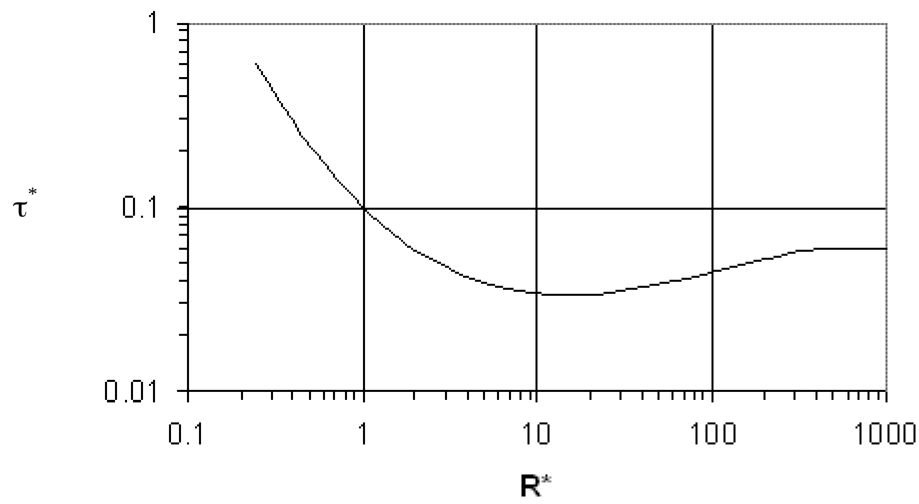
$$c(x,t)=\frac{c_0 L}{2\sqrt{(\pi\Gamma t)}}e^{-\frac{(x-Ut)^2}{4\Gamma t}} \qquad Fr'=\frac{u_0}{\sqrt{\left(\frac{\rho_{res}-\rho_0}{\rho_{res}}\right)g\,d_0}}$$

$$\frac{\rho-\rho_{res}}{\rho_{res}}=9\,Fr'^{-\frac{2}{3}}\left(\frac{z}{d_0}\right)^{-\frac{5}{3}}e^{\left[-71\frac{r^2}{z^2}\right]}$$

$$U=\frac{1}{n}r_h^{2/3}I^{1/2} \qquad U=C\,r_h^{1/2}I^{1/2}$$

$$\rho_s=2650\,kg/m^3 \qquad M=\frac{26}{d_{90}^{1/6}} \qquad \tau=\rho g h I \qquad u_*=\sqrt{\left(\frac{\tau}{\rho}\right)}$$

$$\nu=10^{-6}m^2/s$$



$$R^{*}=u_{*}\frac{d}{\nu} \qquad \tau^{*}=\frac{\tau}{d(\rho_s-\rho_w)g}$$

$$\frac{dy}{dx}=\frac{I_f-I_0}{1-Fr^2} \qquad q_s=\frac{1}{g}\left[\frac{\rho_w g r_h I-0.047g(\rho_s-\rho_w)d_{50}}{0.25\rho_w^{1/3}\left(\frac{\rho_s-\rho_w}{\rho_s}\right)^{\frac{2}{3}}}\right]^{\frac{3}{2}}$$

$$q_s=0.05\rho_s U^2\sqrt{\frac{d_{50}}{g\left(\frac{\rho_s}{\rho_w}-1\right)}}\left[\frac{\tau}{g(\rho_s-\rho_w)d_{50}}\right]^{\frac{3}{2}}$$

$$\frac{c(y)}{c_{bed}}=\left(\frac{h-y}{y}\frac{a}{h-a}\right)^{z} \qquad z=\frac{w}{\kappa u_{*}} \qquad \kappa=0.4$$

$$\frac{\Delta}{h}=0.11\left(\frac{D_{50}}{h}\right)^{0.3}\left(1-e^{-\left[\frac{\tau-\tau_c}{2\tau_c}\right]}\right)\left(25-\left[\frac{\tau-\tau_c}{\tau_c}\right]\right) \qquad \lambda=7.3\,h$$

Atomic weights: Nitrogen: 14 Carbon:12 Hydrogen:1 Oxygen:16