École polytechnique fédérale de Lausanne
School of Architecture, Civil and Environmental Engineering
Civil Engineering & Environmental Science and Engineering Sections
CIVIL-312: Hydraulic Engineering and Infrastructures

Mock Exam

Professor: Mirko Musa
Duration: 3 hours
Date: Wednesday, January 21, 2026, from 9:15 to 12:15
Location: Rooms CE 1 1 and CE 1 3

General Instructions

- **Allowed material:** only **two double-sided A4 sheet** with handwritten or printed notes is permitted, as well as a **scientific calculator** (see next page). No other material or electronic device is allowed.
- Read carefully all data provided. Everything needed to solve the exercises is included in the exam statement.
- Write your **name and surname in capital letters on every sheet** you submit, including this document.
- The exam consists of **two parts**. The first part is a short, **theory-focused section** lasting **45 minutes**. After a **15-minute break**, the exam continues with **two hours of problem solving**. One problem concerns **flow in closed conduits**, while the other deals with **open-channel flow and hydraulic structures**.

  The total score for the exam is **X points**. The **final grade** is computed as:

$$\text{Final Grade} = 1.0\ (\text{attendance point}) + 5 \times \frac{\text{points obtained}}{\text{total points}}.$$

- All numerical results must be **clearly boxed** and written in a **very legible manner**. Calculations may be presented on clean, well-organized sheets. Illegible work or work written in pencil will be considered drafts and will **not be graded**. Submissions that do not meet these formatting requirements will receive a **maximum grade of 5.0**. Always include **units** in numerical applications.
- Unless otherwise stated, take the following default values:

$$g = 9.81\ \mathrm{m \cdot s^{-2}}, \quad p_{\text{atm}} = 0, \quad \rho_{\text{water}} = 1000\ \mathrm{kg \cdot m^{-3}}, \quad \mu_{\text{water}} = 1.00\ \mathrm{mPa \cdot s}.$$

- Final numerical results may be rounded to **two decimal places**. Use the most appropriate units. For instance, write 10.8 kN instead of 10 823.237 N.

Calculators allowed

Only **basic** and **scientific** calculators are permitted during this examination.

- Basic calculators with arithmetic operations.
- Scientific calculators with numeric functions such as trigonometric, logarithmic, exponential, and statistical operations.

Programmable, graphing, and CAS-enabled calculators are strictly forbidden. This includes calculators with graphing capabilities, symbolic computation, stored programs, communication ports, or equation libraries.

Examples of **allowed calculator models** include (non-exhaustive list):

- Casio FX-82 series (e.g. FX-82MS, FX-82ES)
- Casio FX-991 series (e.g. FX-991ES, FX-991EX)
- Texas Instruments TI-30 series (e.g. TI-30XS, TI-30X Pro)

The use of any calculator not meeting the above criteria may result in disqualification from the examination.

Figure 1: Examples of permitted scientific calculators (Casio FX-82 series, Casio FX-991 series, and Texas Instruments TI-30 series).

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Part I

Question 1

In open channel flow, the Froude number is defined as the ratio of inertial forces to gravitational forces. Which of the following statements best explains why the hydraulic depth appears in the definition of the Froude number for noncircular channels?

- ○ Because hydraulic depth directly represents the wetted perimeter controlling viscous dissipation.
- ○ Because hydraulic depth provides a characteristic length scale that governs the propagation speed of gravity waves in shallow water.
- ○ Because hydraulic depth ensures that the Froude number remains independent of flow velocity for geometrically similar channels.

Questions 2 & 3

An open tank has a vertical partition and on one side contains gasoline with a density $\rho_g = 700\ \mathrm{kg/m^3}$ at a depth of $4\ \mathrm{m}$. A rectangular gate that is $4\ \mathrm{m}$ high and $2\ \mathrm{m}$ wide and hinged at one end is located in the partition. Water ($\rho_w = 1000\ \mathrm{kg/m^3}$) is slowly added to the empty side of the tank.

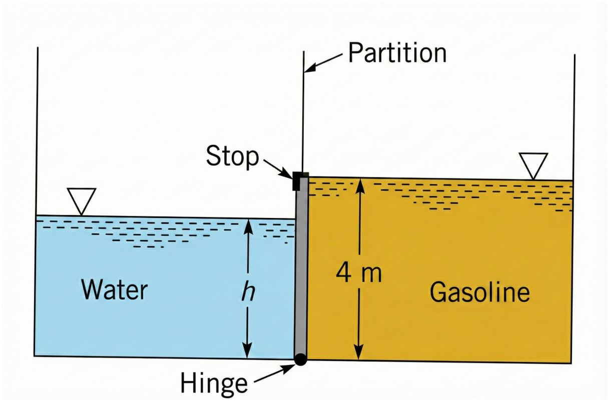

Figure 2: Open tank filled with water (left) and galosine (right).

(Q2) The magnitude of the resultant hydrostatic force exerted by the gasoline on the gate is:

- ○ $F = 2.20 \times 10^5\ \mathrm{N}$
- ○ $F = 1.10 \times 10^5\ \mathrm{N}$
- ○ $F = 5.50 \times 10^4\ \mathrm{N}$

(Q3) At what depth, h, will the gate start to open?

- ○ $h = 2.80\ \mathrm{m}$
- ○ $h = 3.17\ \mathrm{m}$
- ○ $h = 3.55\ \mathrm{m}$

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Question 4

A culvert is designed to convey a given discharge. Two headwater depths are computed: one assuming inlet control, one assuming outlet control. The headwater depth required under inlet control is larger than that required under outlet control. Which statement is correct?

○ The culvert operates under inlet control because the inlet requires a higher headwater to pass the flow.

○ The culvert operates under outlet control because barrel friction losses always affect the flow.

○ The culvert operates under outlet control unless the culvert is submerged.

These exercises are representative of the type of questions that will appear in this first part of the exam. The total number of exercises will be defined such that they can be reasonably solved **within 45 minutes**.

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Part II

Problem 1

Consider a hydraulic system connecting three open reservoirs (A, B, and C) meeting at a common Junction J. Town C (supplied by Reservoir C) requires a strict water demand of 0.6 m^3/s to be delivered from the junction. The system layout is shown in Figure 3. Consider the pump in the Figure only for Question 3.

The elevations of the components are as follows:

- **Reservoir A**: 60 m
- **Reservoir B**: 65 m
- **Reservoir C**: 50 m
- **Junction J**: 40 m

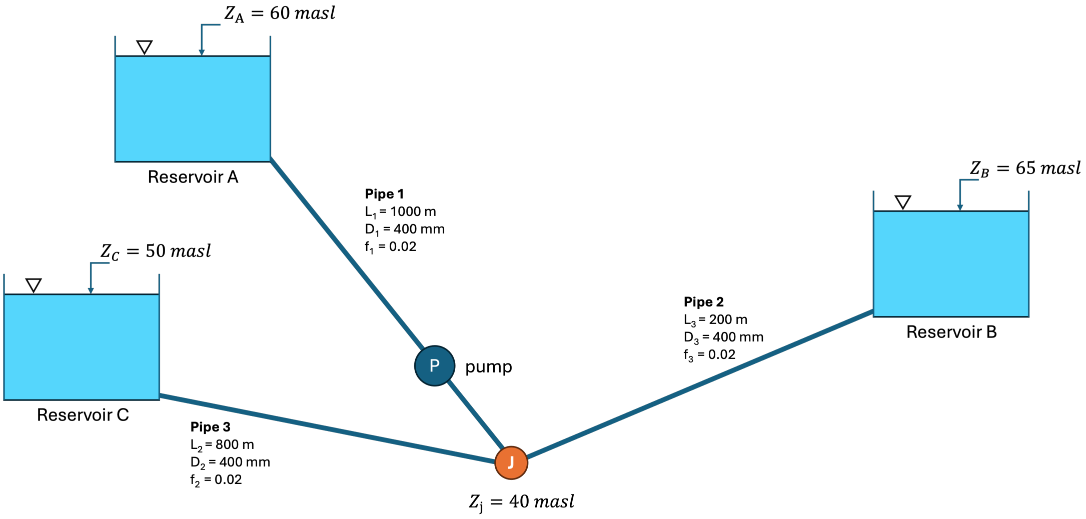

Figure 3: Schematic of the three-reservoir system with demand at C.

The physical properties of the pipes are given in Table 1. Assume a constant friction factor f for all pipes.

Table 1: Pipe Characteristics

Pipe	From/To	Length (L)	Diameter (D)	Friction Factor (f)
1	A – J	1000 m	0.4 m	0.02
2	B – J	200 m	0.4 m	0.02
3	C – J	800 m	0.4 m	0.02

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Questions

1. **Required Junction Head:**
   Calculate the Hydraulic Head (H_J) required at the Junction to drive exactly $0.6\ \mathrm{m}^3/\mathrm{s}$ through Pipe 3 into Reservoir C.

2. **Status of Reservoir B:**
   Using the Junction Head calculated in Question 1, determine the flow rate in **Pipe 2** (Q_B). Is Reservoir B acting as a source (feeding the junction) or a sink (receiving water)?

3. **Pump Sizing:**
   The level of Reservoir A is located now at a low elevation (60 m) and requires a pump on **Pipe 1** to contribute to the system.

   (a) Using mass balance at the junction, determine the required flow rate from Reservoir A (Q_A).

   (b) Calculate the **Hydraulic Power (kW)** the pump must deliver to the water to achieve this flow. (Assume $\rho = 1000\ \mathrm{kg/m}^3$).

Problem 2

A rectangular concrete canal conveys water to a hydroelectric power plant. The longitudinal profile and plan view are shown in Fig. 4. The discharge is $Q = 36$ m^3/s and the flow is steady throughout the system. From section (1) to section (5) the bed slope is constant with $S_0 = 0.005$. The Manning coefficients are $n_1 = 0.02$ in the 5-meter reach and $n_2 = 0.032$ in the 6-meter reach.

Between sections (1) and (3) the canal is prismatic with width 5 m. Between sections (3) and (4) the canal expands gradually to a width of 6 m at section (4) that stays constant until section (5). The flow is treated as one dimensional in all prismatic reaches and throughout the gradual expansion. Local two dimensional effects may occur only at the sluice gate and at a possible hydraulic jump.

A vertical sluice gate is located just upstream of section (2), which corresponds to the location of the *vena contracta*. The reach upstream from section (1) is assumed to have steady uniform flow The water depth upstream is y_1 at section (1). Immediately downstream of the gate the flow forms a supercritical jet. The jet thickness at the *vena contracta* (section (2)) is $y_2 = 1.36$ m. The distance from section (2) to section (3) is assumed to be very long. Section (4) is located right downstream of the mild expansion (i.e., where the expansion ends). The distance from section (4) to section (5) is assumed to be very long.

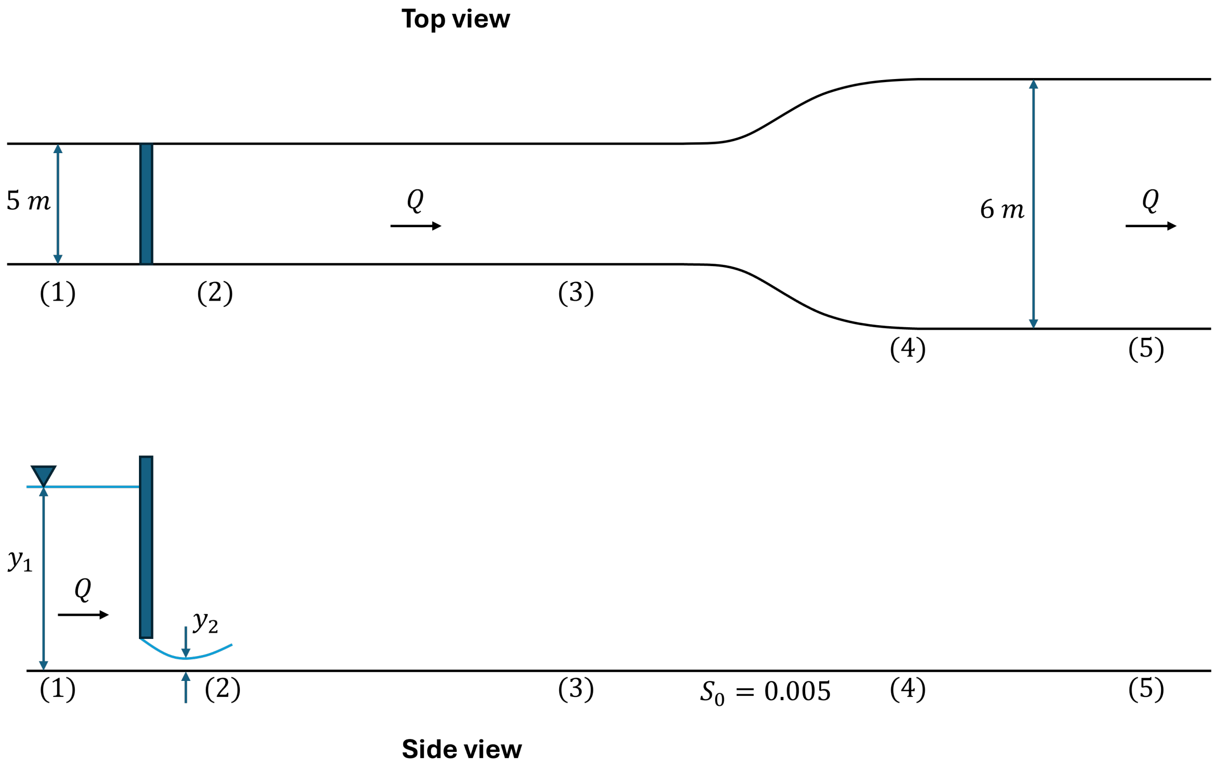

Figure 4: Longitudinal profile and plan view of the canal system supplying the power plant. The figure shows the upstream prismatic reach, the sluice gate, the long adjustment reach, and the gradual expansion to the downstream prismatic reach. The scale is not exact.

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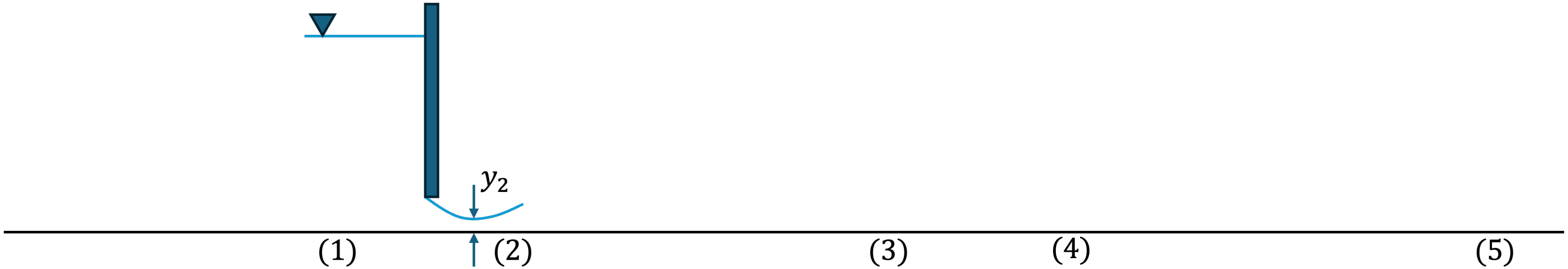
Questions

1. Compute the normal depth and the critical depth in each prismatic reach.
2. Determine whether a free hydraulic jump forms between sections (2) and (3). Explain your answer. Compute the conjugate depths and the associated energy loss.
3. Compute the water depths at sections (1) through (5). **State clearly all assumptions used for each calculation**.
4. Using the drawing provided in the solution, sketch the water surface profile from section (1) to section (5). Label all normal and critical depths, control points, the computation direction in each reach, and the flow profile types. Include the conjugate depths of the hydraulic jump in the drawing.
5. On the provided graph, draw the specific energy diagram for the flow configurations analyzed above. Complete the diagram including the axis labels, the computed values to plot the points corresponding to the four sections, and the critical flow condition(s).

Remember:

$$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right) \qquad \& \qquad \frac{y_1}{y_2} = \frac{1}{2}\left(\sqrt{1 + 8Fr_2^2} - 1\right)$$

Question 4. Water surface profile



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Question 5. Specific Energy Diagram