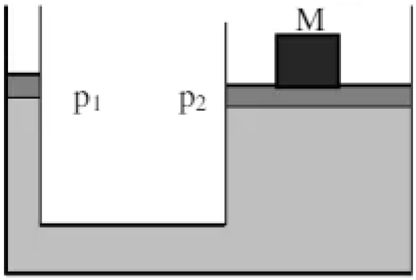
الجمهوريــة الجزائـريــة الديمقراطيــة الشعبيــة
Democratic and Popular Algerian Republic
وزارة التعليــم العالــي والبحــث العلمــي
Ministry of Higher Education and Scientific Research
University Center Abdelhafidh Boussouf Mila
المركــز الجامعي عبد الحفيظ بوالصوف ميلـة

Supervised Work Fluid Mechanics **2nd Year Science and Technology**

Part II: Pressure and Fluid Statics Chapter I

SW - Pressure and Fluid Statics

Exercise 01:



A hydraulic press shown opposite consists of two pistons **P1**and **P2** located in the same horizontal plane. The liquid is incompressible. **S1**=10 cm^2 and **S2**=1000 cm^2

1. What force **F** must be applied to p1to lift a mass **M**=1000 kg placed on **P2**?
2. What force F is required if piston P1 is located 1 m below piston **P2** (with liquid density **ρ**=1000 kg/m3)?

Exercise 02: (*Calculation of Submerged Volume)*

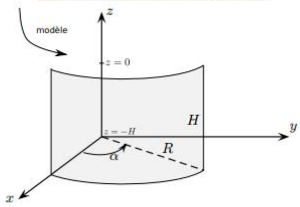
We consider an iceberg floating on the ocean (or an ice cube floating in a glass of water). Let **V$_1$** represent the volume of the submerged part (underwater), and **V$_2$** the volume of the emerged part (in the air).

1. Calculate the ratio **V$_1$/V$_2$**.
2. Can we (roughly) say that the artist's drawing opposite is realistic?

Density of water $\rho_e=1.0\times10^3$ kg/m^3, of ice Density glass $\rho_g=0.9\times10^3$ kg/m^3 and of air $\rho_{air}=1.2$ kg/m^3.

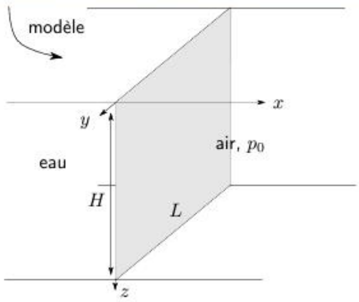
Exercise 03:

A hemi cylindrical dam with radius **R** is filled with water to a height **h**. Determine the resultant force exerted by the water (and the air) on the dam.



Exercise 04:

We consider the Serre-Ponçon Dam (in the Hautes-Alpes), which forms the largest water reservoir in Europe. We model it as a vertical rectangle with a height of 115 m and a width of 630 m (as shown in the diagram below).



1. The pressure in the water is given by $\mathbf{P(z)=P_0+\rho_0 \times g \times z}$. Recall the assumptions that lead to this expression.
2. (Question addressed in class; redo for practice) Express the force exerted by the water on the dam.
3. On the other side of the dam, there is air at a uniform pressure $\mathbf{P_0}$.
4. Provide the expression for the force exerted by the air on the dam.
5. Finally, give the expression for the total force exerted on the dam. Perform the numerical application.

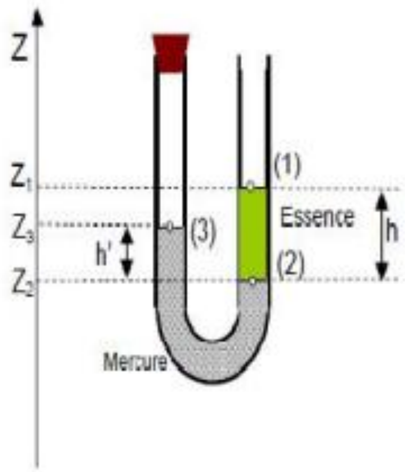
Fluid Statics | Chapter I

SW - Fluid Statics

Exercise 01

Consider a U-tube closed at one end that contains two immiscible liquids.

- Between surfaces (1) and (2), there is gasoline with a density of $\rho_{gasoline}$=700 kg/m^3=700kg/m3.
- Between surfaces (2) and (3), there is mercury with a density of $\rho_{mercury}$=13,600 kg/m3.



The pressure above the free surface (1) is P_1=Patm=1 bar. The acceleration due to gravity is g=9.8 m/s^2. The closed branch traps a gas at a pressure P_3, which we need to calculate.

1. Applying the Fundamental Relation of Hydrostatics (RFH) for the gasoline, calculate the pressure P_2 (in mbar) at the interface (2), knowing that h=(Z1−Z2) =728 mm.
2. Similarly, for the mercury, calculate the pressure P_3 (in mbar) at the surface (3), knowing that h′=(Z3−Z2) =15 mm.

Exercise 02

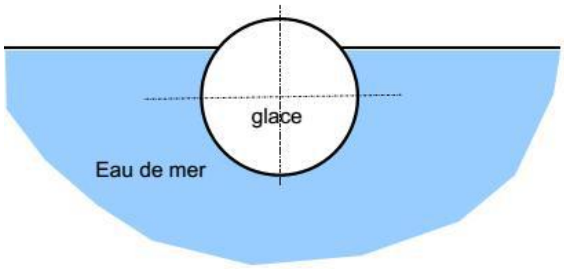
Let's consider, as a first approximation, that the blood is in static equilibrium.

1. Calculate the hydrostatic pressure of the blood in mm Hg:
   - a) At the level of the foot, located 1.2 m below the heart.
   - b) At the level of a cerebral artery, located 0.6 m above the heart.
2. What happens to these pressures when the subject is lying down?
3. What happens to these pressures if the subject is subjected to an acceleration of 2g directed from the head towards the feet?
4. Same question with an acceleration of g directed from the feet towards the head.

Given:

- Hydrostatic pressure of blood in the aorta at the level of the heart = 100 mm Hg.
- g=9.81 m/s^2 and ρ_{blood}=1050 kg/m3 at 37°C.
- 1 atm=1.05×10^5 Pa=760 mm Hg.

Exercise 03



The ice at -10°C has a density of ρ_{glace}=995 kg/m3. A spherical iceberg of 1000 tonnes is floating on the surface of the water. Seawater has a density of ρ_{eau}=1025 kg/m3.

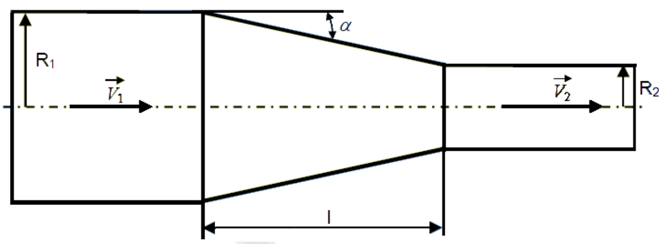
1. Determine the fraction F of the iceberg's volume that is submerged.
2. What would FFF be if the iceberg were cubic in shape?

Fluid Statics — Chapter II

SW - Fluid Dynamic

Exercise 01

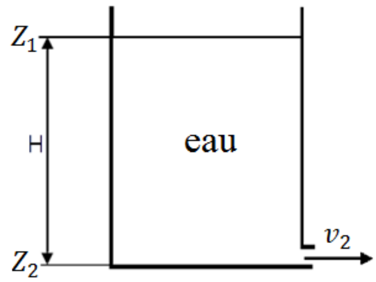
We want to accelerate the flow of a perfect fluid in a pipe so that its velocity is multiplied by 4. For this purpose, the pipe includes a converging section characterized by the angle α (see accompanying diagram).



1. Calculate the ratio of the radi $(\frac{R_1}{R_2})$.
2. Calculate $(R_1 - R_2)$ as a function of L and α. Deduce the length L. Given: R_1 = 50 mm and α = 15°.

Exercise 02

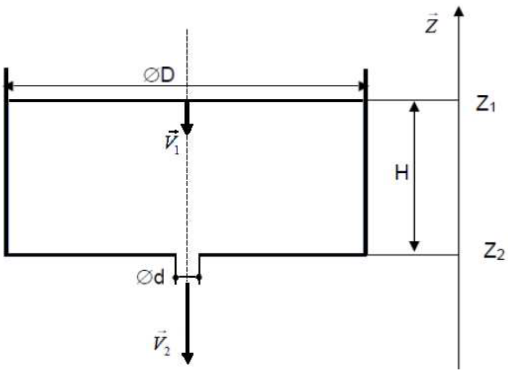
We consider a tank filled with water at a height H=3m equipped with a small orifice at its base with a diameter d=10 mm.



1. By specifying the assumptions taken into account, apply Bernoulli's theorem to calculate the outflow velocity v_2 of the water.
2. Deduce the volumetric flow rate Q in (l/s) at the outlet of the orifice. Assume that g=9.81 m/s^2.

Exercise 03

We consider a cylindrical tank with an internal diameter D=2 m filled with water up to a height H=3 m. The bottom of the tank has an orifice with a diameter d=10 mm allowing the water to flow out. If a very small time interval dt passes, the level H of the tank decreases by an amount dH. We denote $v_1 = \frac{dH}{dt}$ as the rate at which the water level descends, and v_2 as the flow velocity through the orifice. The acceleration due to gravity is given as g=9.81 m/s^2.

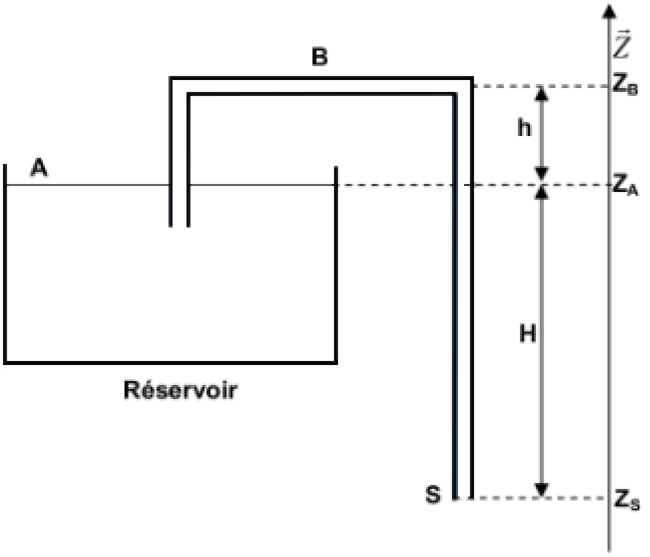


1. Write the continuity equation and derive the expression for v_1a function of v_2, D and d,
2. Write Bernoulli's equation, assuming the fluid is ideal and incompressible.
3. From the answers to questions 1) and 2), derive the expression for the flow velocity v_2 as a function of g, H, D, and d.
4. Calculate the velocity v_2.Assume that the diameter d is negligible compared to D, i.e., $\frac{d}{D} \ll 1$.
5. Deduce the volumetric flow rate Q_V.

Exercise 04

We consider a siphon with a diameter d=10 mm supplied by a fuel tank of large dimensions relative to d and open to the atmosphere. We assume that:

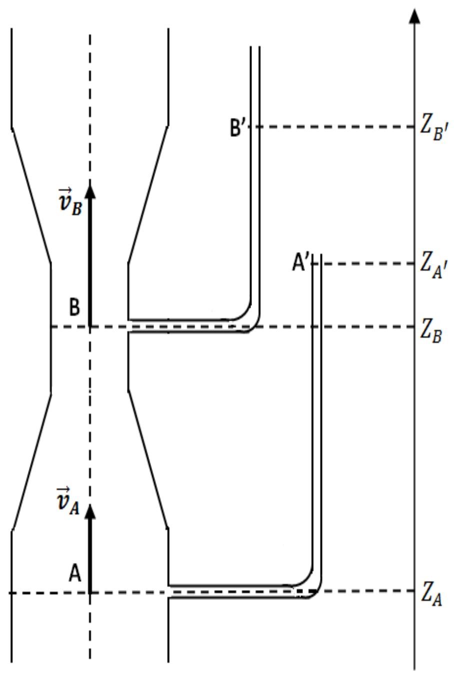
- The fluid is ideal;
- The fluid level in the tank varies slowly;
- The acceleration due to gravity $g=9.81\ m/s^2$;
- The specific weight of the fuel $\omega=6896\ N/m^3$;
- $H=Z_A-Z_S=2.5$ m.



1. By applying Bernoulli's theorem between points A and S, calculate the flow velocity v_s in the siphon.
2. Deduce the volumetric flow rate Q_V.
3. Give the expression for the pressure P_B at point B as a function of h, H, ω, and Patm. Provide a numerical application for h=0.4 m.
4. Can h take any value? Justify your answer.

Exercise 05

In the Venturi tube shown in the diagram below, water flows from bottom to top. The diameter of the tube at A is d_A=30 cm, and at B it is d_B= 15cm. To measure the pressure P_A at point A and the pressure P_B at point B, two water column manometers are connected to the Venturi. These piezometric tubes are graduated and allow measurement of the free surface levels Z_A'=3.061 m and Z_B'=2.541 m at points A′ and B′ respectively.



Given:

- The altitude of section A: Z_A=0 m,
- The altitude of section B: Z_B=50 m,
- Acceleration due to gravity $g=9.81\ m/s^2$,
- Pressure at the free surfaces $P_A'=P_B'$=Patm=1 atm,
- The density of water $\rho=1000\ kg/m^3$.

Assume the fluid is ideal.

1. Apply the fundamental hydrostatic relation between B and B′and calculate the pressure P_B at point B.
2. Similarly, calculate the pressure P_A at point A.
3. Write the continuity equation between points A and B. Deduce the flow velocity $v_A$as a function of v_B.
4. Write the Bernoulli equation between points A and B. Deduce the flow velocityv_b

Fluid Statics Chapter III

SW - LOAD FLOW

Exercise 01

Determine the critical velocity:
a) For medium fuel at 15°C flowing through a pipe with a diameter of 15 cm;
b) For water at 15°C flowing through the same pipe.

The kinematic viscosity at 15°C is:

- $\vartheta_{fuel} = 4.47.10^{-6} m/s$ for fuel,
- $\vartheta_{water} = 1.142\ 10^{-6}$ for water.

Exercise 02

Oil with an absolute viscosity of 0.101 Pa·s and a density of 0.850 flows through 3000 m of cast iron pipe with a diameter of 300 mm and 30 mm at a rate of 44.4 l/s.
- What is the pressure drop (head loss) in the pipe d=300mm and 30mm ?

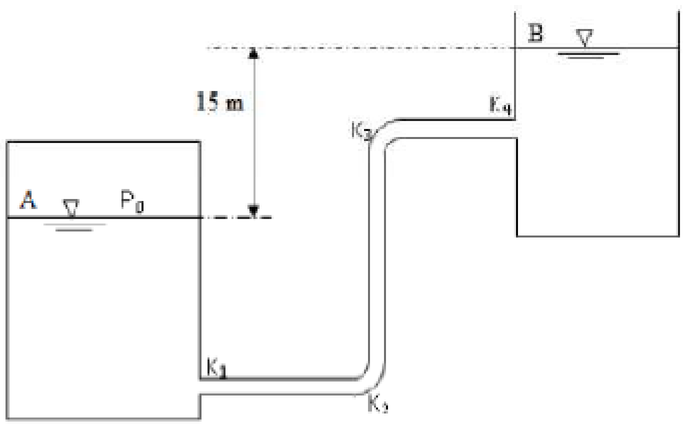
Exercise 03

Calculate the pressure drop for 305 m of new cast iron pipe (unlined), with an inner diameter of 305 mm, when:
a) Water at 15.6°C flows through it at 1.525 m/s.
b) Medium fuel oil at 15.6°C flows at the same velocity.

The roughness of the cast iron is ε=0.244 mm, the kinematic viscosity of water at 15.6°C is $\vartheta_{water} = 1.13\ 10^{-6} m^2/s$ and the kinematic viscosity of fuel oil at 15.6°C is $\vartheta_{fuel-oil} = 4.41 m^2/s$

Exercise 04

Due to an overpressure P_0, water flows from reservoir A to reservoir B through a pipe with a diameter d=300mm, roughness ε=0.3 mm, and length l=170 m.



The coefficients of localized head losses are:

- K_1=0.5 at the outlet of reservoir A,
- K_2=K_3=0.15 for the two bends,

- K_4=1 at the inlet of reservoir B.

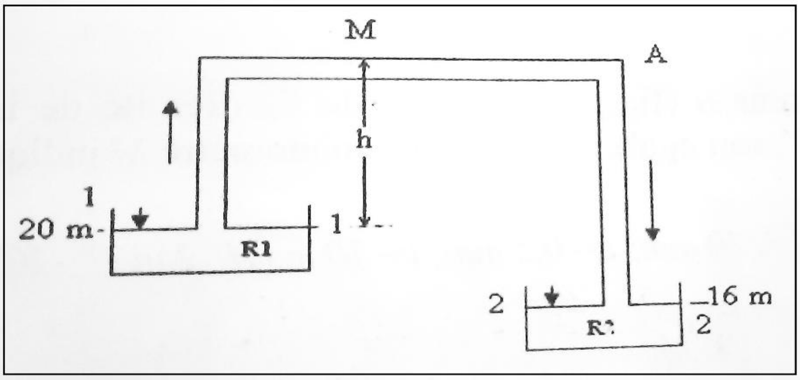
Determine the gauge pressure P_0 required to achieve a flow rate of Q_v=200 l/s.

Given:

- ρ=1000 kg/m^3,
- g=9.81 m/s^2,
- ϑ=1.005×10^{-6} m2/s.

Exercise 05

Determine the flow rate through the siphon (figure) connecting two reservoirs R_1 and R_2, where the water surface levels are at 20 m and 16 m, respectively.



Data :

- d=50 mm,
- L=24 m,
- Ke=1, Kc=0.3, Ks=0.5K_s = 0.5Ks=0.5.

Evaluate the relative pressure at point M, P_M , as well as the vacuum pressure Pv and the vacuum height hv, knowing that h=2 m, l = 10 m, and λ=0.025. Determine the point where the vacuum pressure is highest.

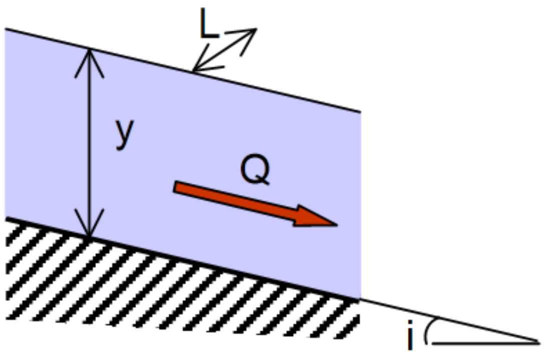
Chapter IV

SW - FREE SURFACE FLOWS AND HYDROLOGY

Exercise 01

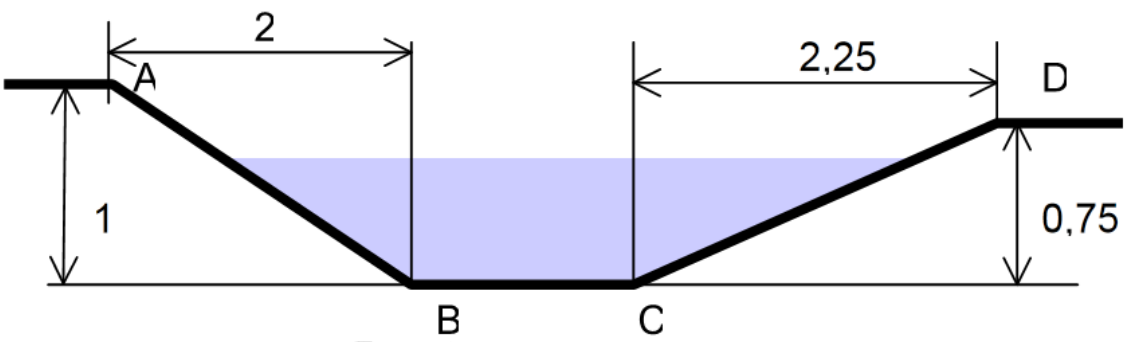
Problem Statement (Translated):

1. **Consideration:**
   A uniform rectangular irrigation channel with a given slope (i) and flow rate (Q). Determine the water depth (y) and the width (L) such that L is minimized.
2. **Steps:**
   - Using Chezy and Manning's formulas, derive the expression for the flow rate Q in a uniform flow.
   - Translate the condition into one based on the wetted perimeter.
   - Derive a relationship between y (depth) and L (width).
   - Express the length L as a function of Q, K, and iii.



3. **Numerical Application (NA):**
   Given:
   - i=?(slope),
   - Q=100 m^3(flow rate),
   - K=60 $m^{1/3}$/s (Manning's coefficient),
   Solve for the required parameters.

Exercise 02



Problem Statement (Translated):

Consider the rectangular cross-section ABCD of a canal:

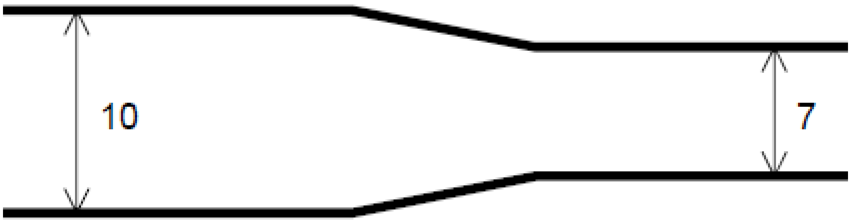
- The bottom of the canal is at an altitude $Z_B=Z_C=115.25$ m.
- The width of the canal BC=1.5 m.

- On the right bank, there is a horizontal embankment at an altitude Z_D=116 m.
- On the left bank, there is a horizontal embankment at an altitude Z_A=116.5 m.
- The canal slope is 50 cm/km (i.e., i=0.0005).
- The slope of bank AB is 50% (1 vertical:2 horizontal), and the slope of bank CD is 33.3% (1 vertical:3 horizontal).
- The water depth in the canal is h=0.5m.
- The flow rate is Q=0.875 m3/s.

Questions :

1. What is the value of the Strickler coefficient (K) of the canal?
2. What is the maximum flow rate that the canal can carry in uniform flow without flooding the embankments?

Exercise 03



Problem Statement (Translated):

Consider a straight rectangular canal:

- Width L=10 m,
- Slope $i=5\times10^{-4}$,
- Strickler coefficient K=60 (SI units).

Questions :

1. What is the flow rate Q for a uniform flow in the canal when the water depth is h=2 m?
2. For this flow rate, calculate the critical depth h_c. Deduce the nature of the flow (supercritical/torrential or subcritical/fluvial).
3. The canal has a constriction where the width narrows to L′=7 m. How does the water surface profile change through this gradual narrowing?
4. Neglecting head losses caused by the narrowing (constant specific energy assumption), calculate the downstream depth h′ of the flow after the constriction for the previously calculated Q.