

Ordre des Ingénieurs du Québec

SPRING 2026

Notice regarding the intellectual property of the Ordre des ingénieurs du Québec's exam models the exam models available on the Ordre des ingénieurs du Québec website are the exclusive property of the Ordre, and their use is strictly limited to academic and personal purposes. Any unauthorized reproduction, distribution, or commercial use of these models constitutes an infringement of intellectual property and is strictly prohibited. The OIQ reserves the right to take all appropriate legal action against any unauthorized use of its exam models.

All documentation permitted Calculators: authorized models only Exam duration: 3 hours

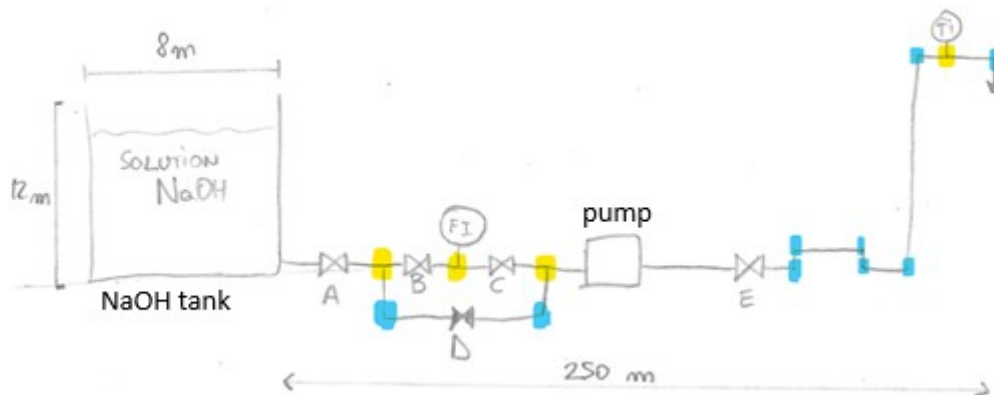
23-CH-A2 Mechanical and Thermal Operations

Problem 1 (total of 30 pts/100)

At a production site, an open cylindrical tank with an inner diameter of 8 m and a height of 12 m is filled to 90% of its total volume and contains an aqueous NaOH solution at 25 wt%.

The NaOH solution is at ambient temperature and it has a density (ρ) of 1268.4 kg/m^3 and a viscosity (μ) of 0.0075 Pas .

A pump sends the solution to a reactor, located 250 m linearly from the tank, through the circuit shown in the following figure:



The description of each piece of equipment on the line is provided below:

- A: gate valve, half open
- B: gate valve, fully open
- C: gate valve, half open
- D: gate valve, completely closed
- E: globe valve, half open
- Yellow color: T-connections (tee fittings)
- Blue color: L-connections (90°), "elbows"

The point of discharge of the NaOH line is situated at an elevation of 6 m above ground level.

All pipes between the tank and the reactor are in steel, with an internal diameter of $D = 0.025 \text{ m}$ and an average roughness of $k = 0.00005 \text{ m}$.

Calculate the absolute pressure at the bottom of the tank (**5 pts**) and calculate the power required by a pump that delivers 100,000 ton per year of a 25 wt% aqueous NaOH solution to the reactor (efficiency of the pump $\eta = 70\%$). Assume that the process operates 330 days per year. (**25 pts**)

Problem 2 (total of 20 pts/100)

A column filled with ion-exchange resin is used for water pretreatment prior to its introduction into a proton exchange membrane (PEM) electrolyzer. The objective is to analyze operation in fixed-bed and fluidized-bed modes

Given data:

- Inner diameter of the column: 0.60 m
- Density of water: 997 kg/m³
- Viscosity of water: 0.89 cP
- Mean ion-exchange resin diameter (D_p): 0.30 mm
- Sphericity of ion-exchange resin: 1
- Density of particles (solid): 1200 kg/m³
- Fixed-bed porosity (ϵ): 40%

What will be the superficial velocity in the ion-exchange column if the inlet flow rate is 0.1 m³/min? **(5 pts).**

If the height of the ion exchange bed is 1.5 m, what is the associated pressure drop for the fixed bed? **(7.5 pts).**

You want to analyze the operation of the ion exchanger in a fluidized-bed mode. If the porosity at the minimum fluidization velocity is estimated to be $\epsilon_{mf} = 0.50$, what will be the pressure drop per unit height ($\Delta p/L$) for the fluidized bed? **(7.5 pts)**

Problem 3 (total of 20 pts/100)

In a refinery located in a cold region, a vertical cylindrical tank contains water. This tank is exposed to the outdoor air during winter.

- Tank height: $H = 6 \text{ m}$
- External diameter: $D = 6 \text{ m}$
- Tank wall thickness: $x_w = 0.1 \text{ m}$
- Tank material: stainless steel ($k_w = 20 \text{ W/m/K}$)

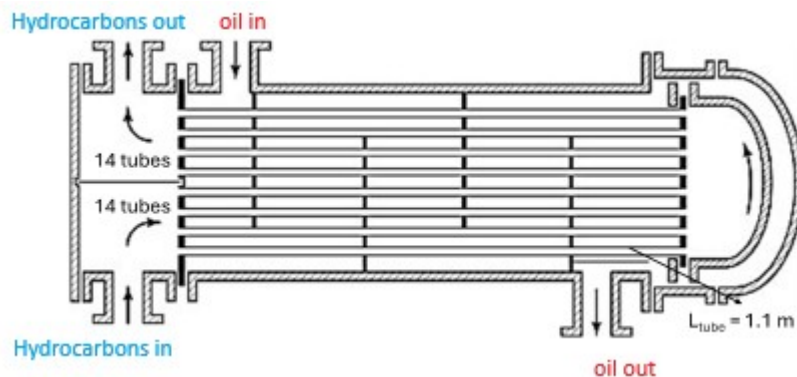
The temperature of the water inside the tank is maintained constant at $T_{in} = 75 \text{ }^\circ\text{C}$, while the outside winter temperature is $T_{out} = -15 \text{ }^\circ\text{C}$.

It is planned to insulate the lateral wall of the tank using a material with a thermal conductivity of $k_i = 0.02 \text{ W/m/K}$.

Determine the energy loss in watts (W) through the lateral wall of the tank for an insulation thickness of 0.2 m . Assume steady-state conditions and one-dimensional radial heat conduction. Neglect internal and external convection resistances. **(20 pts)**

Problem 4 (total of 30 pts/100)

Your supervisor asks you to analyze a 1-2 heat exchanger that can be used to heat 350 kg/h of hydrocarbons, which enter at 30 °C and must be heated to 65 °C, using an oil. The oil enters the exchanger at 120 °C and exits at a temperature of 95 °C.



Here are the characteristics of the available heat exchanger:

- Type: 1-2
- Number of tubes: 28 (14 + 14 forward and return passes, see figure)
- Tube length: 1.1 m
- Tube diameter: 0.05 m

Characteristics of the diathermic oil

- Inlet temperature: $T_{\text{in}} = 120 \text{ }^{\circ}\text{C}$
- Outlet temperature: $T_{\text{out}} = 95 \text{ }^{\circ}\text{C}$
- Specific heat capacity: $c_p = 2000 \text{ J/kg/K}$

Characteristics of the hydrocarbons

- Inlet temperature: $T_{\text{in}} = 30 \text{ }^{\circ}\text{C}$
- Outlet temperature: $T_{\text{out}} = 65 \text{ }^{\circ}\text{C}$
- Mass flow rate: 350 kg/h
- Specific heat capacity: $c_p = 3500 \text{ J/kg/K}$

What is the minimum diathermic oil flow rate that can be used? (5 pts).

Estimate the correction factor (F_g) and the value of the logarithmic mean temperature difference (LMTD) for the operation of this heat exchanger (15 pts).

Calculate the overall heat-transfer coefficient U_i for this heat exchanger (10 pts).