

PROFESSIONAL ENGINEERS ONTARIO
NATIONAL EXAMS – MAY 2002

98-CHEM-A2
Mechanical & Thermal Operations

(3 hours duration)

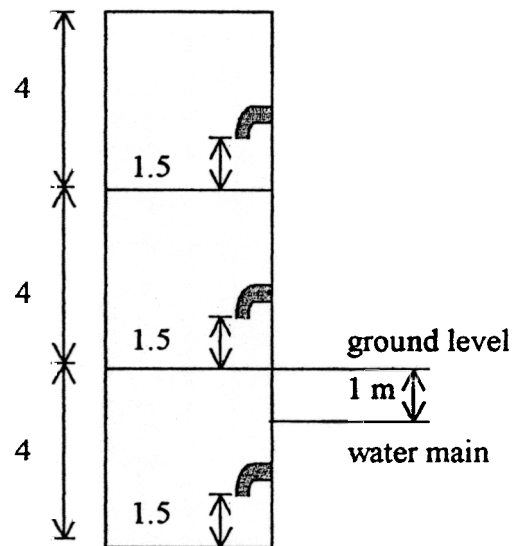
Notes:

1. Whether doubt exists or not as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.
2. Any non-communicating calculator will be permitted. This is an Open Book examination. Candidates should identify the calculator used on the inside left-hand sheet of examination workbook, i.e. name and model designation.
3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. All questions are of equal value.

Q1 (a) A tank of very large surface area contains water that is open to the atmosphere. The water level in the tank is 4 m. A plastic tube with a diameter of 50 mm is inserted into the tank to siphon water from the tank. The bottom of the tube where the water will drain out to the atmosphere is at a level of h m above the bottom of the tank. If the pressure outside the tube is 30 kPa greater than the pressure inside the tube, then the tube will collapse and the siphon will stop functioning.

- Determine the minimum value of h if it can be assumed that the tube is frictionless.
- What would be the effect on the value of h if friction in the tube could not be assumed negligible?

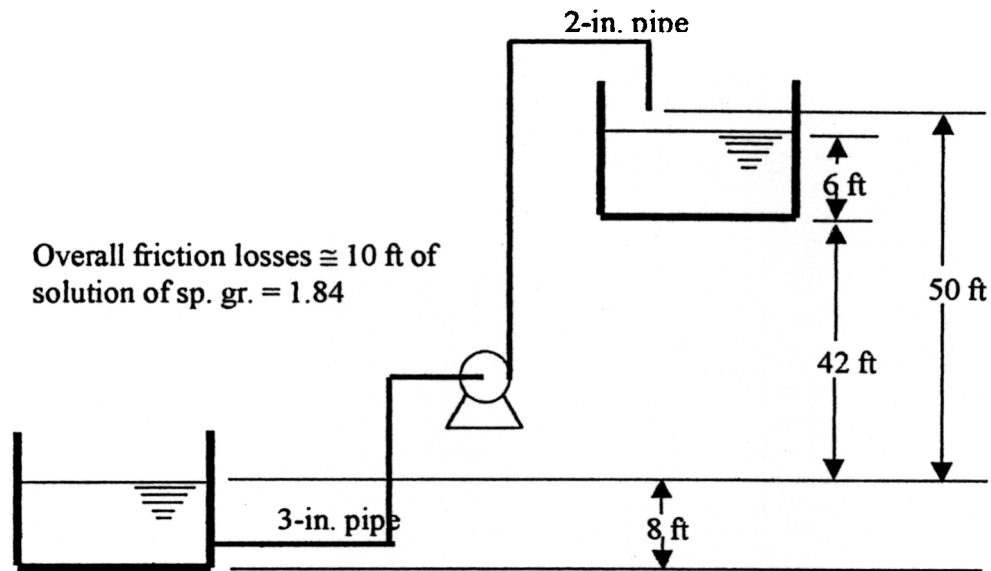
Q1 (b) Water supplying a building comes from a water main that is 1 m below ground and flows to faucets on each floor. Each floor is 4 m in height, and the faucet on each floor is 1.5 m above the floor. If the faucet on the first floor of the building has a maximum velocity of 3 m/s, determine the maximum water velocity from the basement faucet and from the faucet on the second floor.



Q2 A long-tube vertical evaporator is used to concentrate an organic solution from 15 to 50 percent solids. The solution has a negligible elevation in boiling point. The feed entering at 15°C has a specific heat of $0.93 \text{ cal/g }^{\circ}\text{C}$. Steam is available saturated at 0.8 atm absolute, and the pressure of the condenser is 100 mm Hg absolute. The evaporator must evaporate 25,000 kg of water per hour.

- If the overall coefficient of the evaporator is $1700 \text{ W/m}^2 \text{ }^{\circ}\text{C}$, determine the heat transfer surface area required for this operation?
- Calculate the steam consumption in kg/h

Q3. A pump draws a solution, sp. gr. 1.84, from a storage tank of large cross section through a 3-in. pipe as shown below. The velocity in the suction line is 3 fps. The pump discharges through a 2-in. pipe to an overhead tank. Friction losses in the entire system are 10 ft of solution. What pressure must the pump develop in pounds per square inch? What is the theoretical horsepower of the pump?



Schematic diagram of flow in Question Q3

Q4. A flat furnace wall is constructed of a 4.5-in. layer of Sil-o-cel brick, with a thermal conductivity of 0.08 Btu/hr-°F-ft, backed by a 9-in. layer of common brick, of conductivity 0.8 Btu/hr-°F-ft. The temperature of the inner face of the wall is 1400°F, and that of the outer face is 170°F.

- Calculate the heat loss through this wall in Btu/ft² hr.
- What is the temperature of the interface between the refractory brick and the common brick?

Q5. Water is flowing from an elevated reservoir through a conduit to a turbine at a lower level and out of the turbine through a similar conduit. The pressure at a point in the conduit 100 m above the turbine is 200 kPa absolute and 120 kPa absolute at a point in the conduit 3 m below the turbine. The water is flowing at 1000 kg/s, and the output at the shaft of the turbine is 800 kW.

- Calculate the losses by friction in the conduit if the efficiency of the turbine is known to be 90%.
- How much would the water be heated in flowing through the conduit and the turbine if there were no heat transfer to the surroundings.

Q6. Oil of specific gravity 0.9 and viscosity 3 mN s/m² passes vertically upwards through a bed of catalyst consisting of approximately spherical particles of diameter 0.1 mm and specific gravity 2.6. Calculate the following characteristics of the bed:

- (a) At what mass rate of flow per unit area of bed will *fluidisation* occur?
- (b) What mass rate of flow per unit area of bed will transport of particles occur?
- (c) Suppose the weight of the loaded catalyst is 5 lb/ft^2 , what will be the flow rate of the oil when the bed reaches 75% of its maximum height (assuming ideal fluidization)?

Q7. A batch crystalliser is used to prepare sodium carbonate decahydrate crystals, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$. The equipment contains 25000 kg of 30% Na_2CO_3 solution, which is cooled to a temperature of 20°C at which the decahydrate crystals are produced. The solubility of sodium carbonate is 21.5 kg anhydrous Na_2CO_3 per 100 kg of total water.

- (a) What will be the yield of $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ crystals if it is assumed that no water is evaporated?
- (b) If 4% of the total weight of the solution is lost by evaporation of water in cooling, what will be the yield of $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ crystals?

Q8. A plate and frame press, filtering a slurry, gave a total of 8 m^3 of filtrate in 1800 s and 11 m^3 in 3600 s, when filtration was stopped. Estimate the washing time in seconds if 3 m^3 of wash water are used. The resistance of the cloth can be neglected and a constant pressure is used throughout.