PROFESSIONAL ENGINEERS ONTARIO

NATIONAL EXAMS – DECEMBER 2009

04-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 work book, 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.

(MARKING SCHEME)

Q1.	(a)	3	(b)	2	(c)	15.
Q2.	20					
Q3.	(a)	5	(b)	5	(c)	10
Q4.	20					
Q5.	(a)	16	(b)	4		
Q6.	(a)	10,	(b)	10		
Q7.	20.					
Q8.	20.					

Q1 In a calibration exercise of a thermocouple probe, the probe is used to measure the temperature of hot air flowing in a pipe whose walls are at $T_W = 400$ K. The true gas temperature $T_G = 465$ K.

a. Sketch a PFD (Process Flow Diagram) showing heat transfers (source to sink),

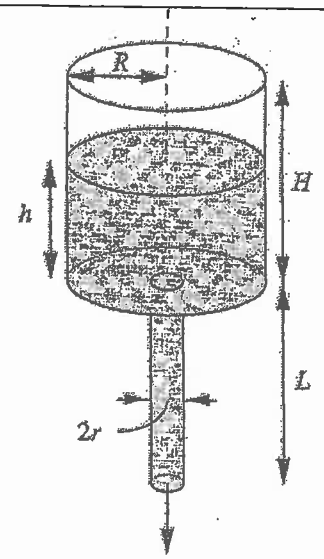
b. Discuss the role of radiation in the calibration.

c. Determine the temperature of the probe.

Q2 *The* tank and pipe shown Fig **Q2** is initially filled with liquid of viscosity, μ and density, ρ. Assuming laminar flow and taking friction to be the only resistance and ignoring exit kinetic-energy effects. Show that the efflux time is? Where

$$T_{efflux} = (8\mu LR^2)/(\rho g r^4).\ \ln(1 + H/L)$$

Fig.Q2: Tank draining in laminar flow



Q3 A hydrocarbon oil with specific heat $c_p = 2.09$ kJ/kg. K° and flowing at a rate of 5.04 kg/s is cooled in a 1-2 shell-and-tube heat exchanger from 366.5 K to 344.3 K by 2.02 kg/s of water entering at 283.2 °K. The overall heat transfer coefficient U_o is 340 W/m^2. K.

a. Determine the outlet water temperature. *5 marks*

b. What is the value of F_T, the correction factor for LMTD, the log mean temperature difference? *5 marks*

c. Calculate heat transfer area required. *10 marks*

Q4 Water stored in large, well-insulated storage tank at 21.0 C and the atmosphereic presure is being pumped at steadt state from this tank by a pump at the rate of 8.5 kW. The water is used as a cooling medium and passes through a heat exchanger where 255 kW of heat is added to the water. The heated water then flows to a second, large vented tank, which is 25 m above the first tank. Determine the final temperature of the water delivered to the second tank.

Q5 Figure Q5 shows a centrifugal pump installation that is used for pumping high performance lubricating oil with specific gravity, s = 0.92, from one tank into a process under a pressure p_3 through to another tank at an elevation of 25 m.of 4-in I.D.. The installation consists of another 20 m of equivalent of pipe length (including for fittings, etc.) of nominal 4-in I.D. pipeline. is it to another tank at that height, or into a pressurized tank, or a pressurized process? Is p3 the pressure at what point on the diagram? As it is the problem is under ddefined

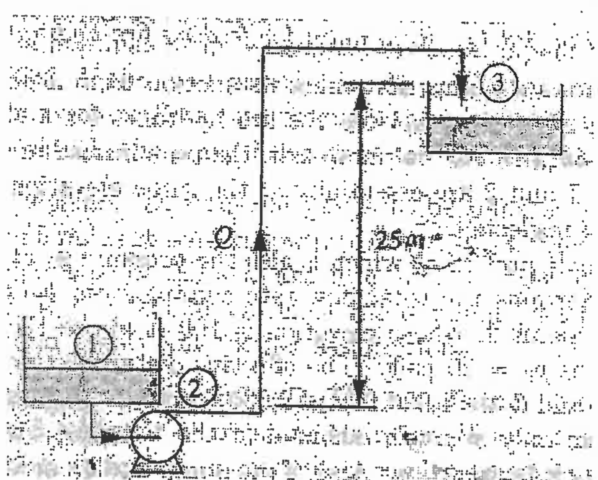


Figure Q5: Pumping Installation

a) Show that by doing an energy balance for the pumping installation, the pressure drop in the pipeline between points 2 and 3 is given closely in terms of the volumetric flow rate Q m^3/s by:

$$\Delta p = p_2 - p_3 = C_1 + C_2 . f . Q^2$$

Where C_1 and C_2 are constants and f is the Fanning friction factor. What are the values of C_1 and C_2?

b) Calculate the Reynolds number Re in the pipeline.

Q6. A single-effect evaporator is used in concentrating an aqueous feed solution of organic colloids and water from 5 to 50 wt %. The mean heat capacity of the feed is C_{pm} = 4.06kJ/kg.K and the feed enters at 15.6°C. Saturated steam at 101.32 kPa is available for heating, and the pressure in the vapour space of the evaporator is 15.3 kPa. A total of 4536 kg/hr of water is to be evaporated. Assuming that no colloid gets evaporated in the process,

a) Calculate the feed rate of the organic solution;

b) What is the required heat transfer surface area if the overall heat transfer coefficient is 1988 W/m^2.K?

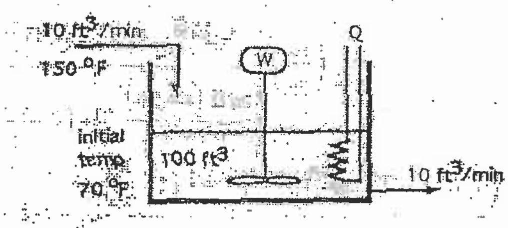


Figure Q7

Q7 An insulated and perfectly mixed tank contains a heating coil. Water flows in and out of the tank at 0.283 m^3/min. The volume of in the tank is 2.83 m^3 with initial temperature of 21°C. The temperature of the water flowing out is 66°C. The heater adds 88 kW and the horsepower added by the mixer is 5 hp. Using mass and energy balances, derive an expression for determining the tank temperature as a function of time. *20 marks)*

Q8 A food cold storage room is to be constucted of an inner layer of 19.1 mm pine wood, a middle layer of cork board and an outer layer 50.8 mm of concrete. The inside wall is at -17.8°C and the outside suface temperature at the outer concrete surface 29.4°C.. The mean coductivities for pine –wood = 0.151, for cork board = 0.0433, and for concrete = 0762 W/m.°K. The total inside surface area is approximately 40 m^2 (neglecting corners and end effects). Determine the thickness of the cork board needed to keep the heat loss to 586 W. *(20 marks)*