Name: BITS ID:

BITS Pilani, Pilani campus

Comprehensive examination, First semester 2022-2023

MF F218 Transport Phenomena in Manufacturing

Total marks: 40, Weightage: 40%, and Date & Time: 21/12/2022 and 9:00 am to 12:00 noon.

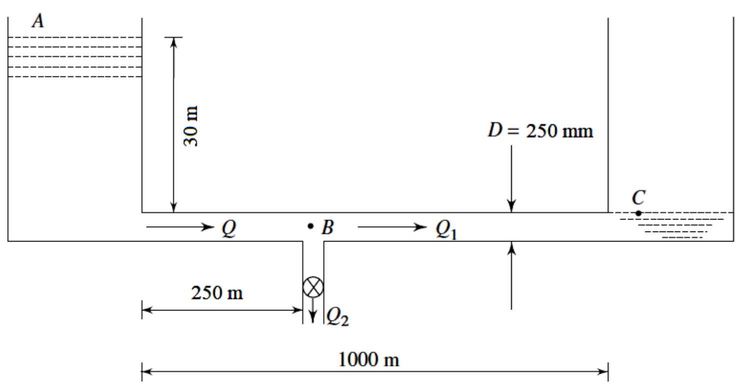
Assume any missing data and state the assumptions if any.

<u>Questions</u>

1. When a thermocouple is moved from one medium to another medium at a different temperature, the thermocouple must be given sufficient time to come to thermal equilibrium with the new conditions before a reading is taken. Consider a 2 mm diameter thermocouple bead originally at 15 ^oC. Determine the time taken for the bead to reach 59.5 ^oC, if the thermocouple bead is suddenly immersed in (a) water at 60 ^oC (h= 80 W/m^2K) and (b) air at 60 ^oC (h= 10 W/m^2K). For thermocouple bead material, take density, ρ = 8900 kg/m^3, specific heat, c = 380 J/kgK and thermal conductivity, k = 390 W/mK. Also, comment on the heating rate, i.e., dT/dt. [5 marks]

2. A venturimeter is inserted in an inclined pipe line on the vertical wall (say, at an angle θ with respect to the horizontal floor) to measure the flow rate through the pipe. Assume that the flow through this venturimeter is steady, non-viscous and one dimensional along the axis of venturimeter. Draw a neat schematic diagram of this arrangement with salient features. Further, show that the actual discharge through the venturimeter meter is: $Q_{act} = C_d \frac{A_1 A_2}{\sqrt{{A_1}^2 - {A_2}^2}} \sqrt{2g(h_1 - h_2)}$; where, subscripts 1 and 2 represent the inlet and throat conditions, C_d is the coefficient of discharge, A is cross sectional area, g is acceleration due to gravity and h is piezometric pressure head. [5 marks]

3. Two open reservoirs are connected through a 250 mm diameter pipe line, 1000 m long as shown in the figure below. At a point B, 250 m from the reservoir A, a valve is inserted on a short branch line which discharges to atmosphere. The valve may be regarded as a rounded orifice 50 mm diameter, C_d= 0.65. If Darcy's friction factor (f_D) for all the pipes is 0.01, calculate the rate of discharge to the reservoir C when the valve at B is fully opened. Estimate the leakage through the short pipe line at B. [6 marks]



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4. Consider air flow through a thin-walled tube of 10 mm diameter and 2 m-long at 1 m/s, 30 ^oC, and 200 kPa. Steam at atmospheric pressure condenses on the outer surface of this thin tube. (a) Determine the outlet temperature and pressure drop of the air, as well as the rate of heat transfer to the air. (b) Calculate the parameters of part (a) if the inlet pressure of the air is doubled, keeping other inlet parameters the same. [6 marks]

5. A plate made of aluminum alloy, heated to a uniform temperature of 100 ^oC, is allowed to cool while vertically suspended in a room where the ambient air is at 30 ^oC. The plate is 0.5 m square with a thickness of 2 mm. For the given alloy, take density, ρ = 2700 kg/m^3, specific heat, c = 900 J/kgK and thermal conductivity, k = 200 W/mK.
   (a) Estimate the steady state heat transfer coefficient due to natural convection as per the initial conditions.
   (b) Assuming the temperature to be uniform at any time, determine the initial rate of cooling, i.e., dT/dt (in K/s), when the plate temperature is 100 ^oC. Use the heat transfer coefficient obtained in part (a) for calculating the cooling rate.
   (c) Is the assumption of uniform plate temperature assumption correct here? Justify your answer.
   (d) Assume the plate has an emissivity of 0.25 and the temperature of the surrounding is 30 ^oC. Considering the radiation effects also, determine the initial rate of cooling-dT/dt (in K/s) when the plate temperature is 100 ^oC. Use the heat transfer coefficient obtained in part (a) for calculating the cooling rate. Compare the results with that obtained in part (b). [8 marks]

6. Liquid oxygen is stored in a thin-walled, spherical container 0.8 m in diameter, which is enclosed within a second thin-walled, spherical container 1.2 m in diameter. There is a tiny hole given at the topmost point of the container for safety purposes. The opaque, diffuse, gray container surfaces have an emissivity of 0.5 and are separated by an evacuated space. The outer surface is at 300 K and the inner surface is at 90 K. Take the latent heat of vaporization of oxygen (h_{lg}) is 2.13×10^5 J/kg.
   (a) What is the steady mass rate of oxygen lost due to evaporation?
   (b) To reduce the mass rate obtained in part (a), it is proposed to reduce the emissivity of container surfaces by polishing or coating. If the emissivity is reduced to 0.1, re-calculate the steady mass rate of oxygen lost due to evaporation. Does the proposal serve the purpose?
   (c) To reduce the mass rate obtained in part (a), it is also proposed that a thin radiation shield of 1 m diameter and ε_3= 0.05 (both sides) can be inserted midway between the inner and outer surfaces. Calculate the steady mass rate of oxygen lost due to evaporation for this case. Does the proposal also serve the purpose?

   (Hint: mass rate$\times$ h_{lg} = heat rate.) [10 marks]