MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

III SEMESTER B.TECH. EXTERNAL EXAMINATIONS NOV 2019

SUBJECT:FLUID FLOW OPERATIONS IN BIOPROCESSING [BIO2154]

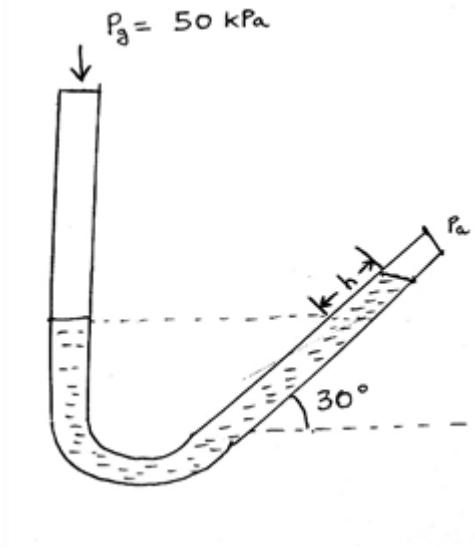
Date of Exam: **28/11/2019** Time of Exam: **9.00 AM – 12.00 PM** Max. Marks: **50**

Instructions to Candidates:

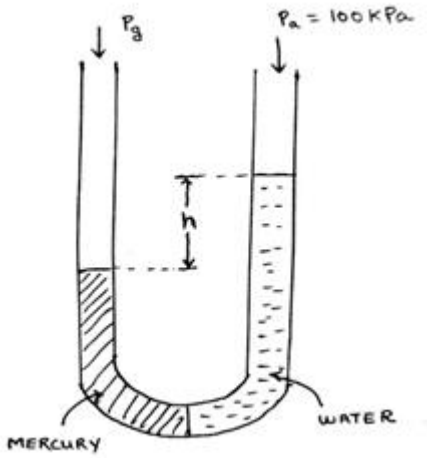
- Answer ALL the questions & missing data may be suitable assumed

Type: DES

1A. The below figure shows an inclined U-tube mercury manometer. The vertical end of the tube is exposed to a gas of gauge pressure 50 kPa and the inclined end is exposed to the atmosphere. The inclined part of the tube is at an angle of 30° with the horizontal. Find the value of h (in cm) (take g = 9.8 m/s^2, $\rho_{mercury}$ = 13600 kg/m^3). Also, develop a mathematical expression for inverted U-tube differential manometer. (4)



1B. In the manometer given below, 2 immiscible fluids mercury (ρ = 13600 kg/m^3) and water (ρ = 1000 kg/m^3) are used as manometric fluids. The water end is exposed to atmosphere (100 kPa) and the mercury end is exposed to a gas. At this position, the interface between the fluids is at the bottom most point of the manometer. Ignore the width of the manometer tube and the radius of curvature. The value of h is found to be 9.45 m. The height of the mercury column is given to be 75 cm. Find the gauge pressure of the gas. (g = 9.8 m/s^2) (3)



1C. The distance between the two parallel plates is 0.00914 m, and the lower plate is being pulled at a relative velocity of 0.366 m/s greater than the top plate. The fluid used is soybean oil with viscosity 4 x 10^{-2} Pa.s at 303 K.

i. Calculate the shear stress and the shear rate.
ii. If glycerol at 293 K having a viscosity of 1.069 kg/m.s is used instead of soybean oil, what relative velocity in m/s is needed using the same distance between plates so that the same shear stress is obtained as in part (i)? (3)

2A. Water is stored in an elevated reservoir to generate power, water flows from this reservoir down through a large conduit to a turbine and then through a similar-sized conduit. At a point in the conduit 89.5 m above the turbine the pressure is 172.4 kPa, and at a level 5 m below the turbine, the pressure is 89.6 kPa. The water flow rate is 0.8 m^3/s. the output of the shaft of the turbine 658 kW. The water density is 1000 kg/m^3. If the efficiency of the turbine in converting the mechanical energy given up by the fluid to the turbine shaft is 89 % (η_t = 0.89), calculate the friction loss in the turbine in J/kg. (5)

2B. A pipe of diameter 400 mm carries water a velocity of 25 m/s. Pressure at point A and B is 29.43 N/cm^2 and 22.563 N/cm^2 respectively. While datum head at A and B are 28 m and 30 m. Find the head loss between A and B. (3)

2C. Elucidate Static pressure, Dynamic pressure and Stagnation pressure with a neat diagram. (2)

3A. Calculate the frictional pressure drop in Pascal for olive oil at 293 K flowing through a commercial pipe having an inside diameter of 0.0525 m and a length of 76.2 m. The velocity of the fluid is 1.22 m/s. Use the friction factor method. Is the flow laminar or turbulent? Density = 919 kg/ m^3 and viscosity = 84 cP. (4)

3B. A smooth pipe of diameter 80 mm and 800 m long carries water at the rate of 0.480 m^3/min. Calculate the loss of head. Take kinematic viscosity of water as 0.015 stokes and coefficient of friction. $C_f = \frac{0.00791}{Re^{\frac{1}{4}}}$. (3)

3C. Water at 25°C is flowing through a 1.0 km long pipe of 200 mm diameter at the rate of 0.07 m^3/s. If the value of Darcy friction factor for this pipe is 0.02 and density of water is 1000 kg/m^3, calculate the pumping power in kw required to maintain the flow. (3)

4A. A cylindrical shell of regenerative heater is packed with a bed of 6 mm spheres to a depth of 3.5 m such that the bed porosity was 0.44. If air flows through this bed entering at 25°C and 7 atm abs. and leaving at 200°C, calculate the pressure drop across the bed when the flow rate is 500 $kg/h.m^2$ of empty bed cross-section. Assume average viscosity as 0.025 cP and density as 6.8 kg/m^3. (5)

4B. A steel sphere of 4 mm diameter falls in glycerin at a terminal velocity of 0.04 m/s. Assuming Stoke's law is applicable, determine:

i. Dynamic viscosity of glycerin
ii. Drag force
iii. Drag coefficient for the sphere

Specific weight of steel and glycerin as 75 kN/m^3 and 12.5 kN/m^3 respectively. (3)

4C. The mass flow rate of water through a cylindrical pipe of cross sectional area A=0.5 m^2 is $\dot{m}$=1500 kg/s. What is the pressure drop over a distance L=10m? Assume flow is laminar. (2)

5A. A venturimeter with an entrance diameter of 0.3 m and a throat diameter of 0.2 m is used to measure the volume of gas flowing through a pipe. The discharge coefficient of the meter is 0.96. Assuming the specific weight of the gas to be constant at 19.62 N/m^3, calculate the volumetric flow rate when the pressure difference between the entrance and the throat is measured as 0.06 m on a water U-tube manometer. (Pipe is not horizontal i.e. $Z_1 \neq Z_2$). (5)

5B. A fermenters (cylindrical) of diameter 3 m has four baffles is used to culture an anaerobic organism. A Rushton turbine mounted in the reactor is operated at a speed of 100 rpm. The density of broth is 1000 kg/m^3. Calculate the power requirements when the viscosity of the broth is approximately that of water. Use the following relationships for different flow conditions: (3)

Type of flow	**Power number correlation**
Laminar	$N_P = 6000 / Re_i$
Transition	$N_P = 600 / Re_i$
Turbulent	$N_P = 6 + (1/Re_i)$

5C. A rotameter with a stainless steel float has a maximum capacity of 3.0 L/s of water at 28°C. What will be the maximum capacity for kerosene in L/s for the same rotameter and the same float? Specific gravity of stainless steel and kerosene are 7.92 and 0.82 respectively. (2)