Reg. No.

MANIPAL UNIVERSITY

THIRD SEMESTER B.S. (ENGG.) DEGREE EXAMINATION –DECEMBER 2015

SUBJECT: FLUID FLOW OPERATIONS IN BIOPROCESSING (BT 231)
(BRANCH: INDUSTRIAL BIOTECH.)
(NEW SCHEME)

Friday, December 11, 2015

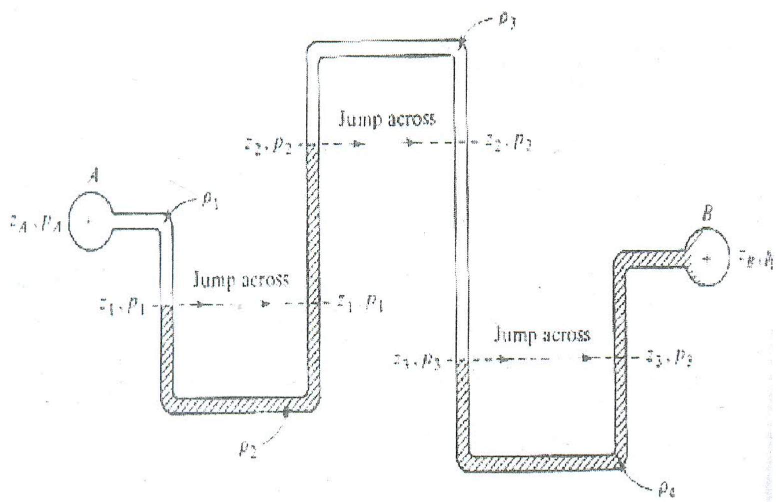
Time: 10:00-13:00 Hrs. Max. Marks: 100

✍ **Answer any FIVE full questions out of EIGHT questions.**

1A. A cylindrical open topped tank that serves as a reservoir for octane before it is piped to another location is 140ft in diameter. Determine the pressure difference between the top and bottom of the walls due to the octane when the tank is filled to a depth of 30ft and also explain the principle behind the equation used. Given ρ=1.35 slug/ft^3. Also explain the equation used.

1B. Describe the various types of manometers used for measuring pressure.

1C. Find the pressure difference between p_A - p_B in the figure. If z_A =1.6m, z_1=0.7m, z_2=2.1m, z_3=0.9m, z_B=1.8m, fluids 1 and 3 are water and fluids 2 and 4 are mercury. The specific weights of water and mercury are 9790 and 133100N/m^2.

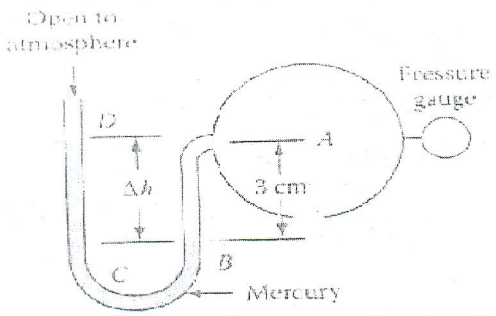


1D. With a graphical representation explain the variation of viscosity of gases and liquids with temperature.

1E. i) Figure shows a portion of pipeline that conveys benzene. A guage attached to the line reads 150Kpa. It is desired to check the guage reading with a benzene-over mercury U-tube manometer.

Determine the expected reading Δh on the manometer. Given ρ (benzene) = 876 kg/m^3, ρ (mercury)= 13000 kg/m^3.

ii) What is relative density?



(5+5+3+2+5 = 20 marks)

2A Explain the rheological diagram for Newtonian and non Newtonian time independent fluids

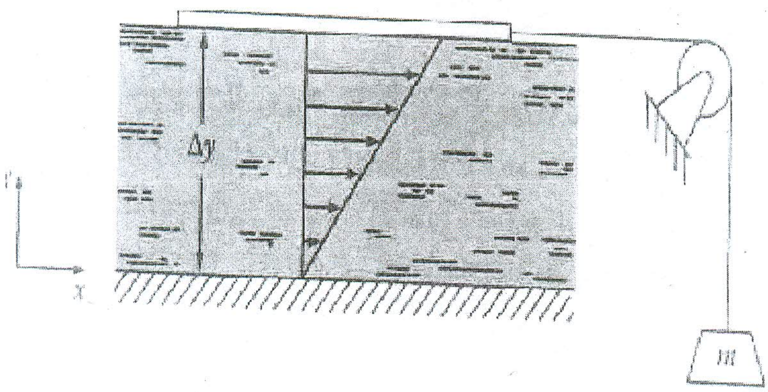
2B. A fluid is placed in the area between two plates. The upper plate is movable and is connected to a weight by a cable. Calculate the velocity of the plate for three cases

i) Assume the fluid to be linseed oil (Newtonian)

ii) Assume the fluid to be water

iii) Assume the fluid to be grease having $\tau_0 = 4N/m^2$, and $\mu_0=0.004Ns/m^2$.

In all cases take m=0.001kg, Δy=5mm, and area of contact $A=0.5m^2$. Given μ for linseed oil is $0.0331Ns/m^2$, μ for water = $0.89*10^{-3}$ Ns/m^2, and shear stress is $\tau=0.02N/m^2$.



2C. A small capillary with an ID of 2.22×10^{-3} m and a length 0.317m is being used to continuously measure the flow rate of a liquid having a density of 875 kg/m^3 and viscosity $1.3x10^{-3}$ Pa-s. The velocity is given as 0.275m/s. Predict the pressure drop. List the assumptions

2D. A nozzle of cross sectional area A_2 is discharging to the atmosphere and is located in the side of a large tank, in which the open surface of the liquid in the tank is H m above the center line of the nozzle. Calculate the velocity v_2 in the nozzle and the volumetric rate of discharge if no friction losses are assumed.

(5+5+4+6 = 20 marks)

3A. The fluid flowing in a typical piping system experiences different types of losses. Explain

3B. Briefly explain the drag force acting on a flat plate placed parallel to the flow and normal to the flow.

3C. Explain the following terms: stagnation point, stagnation pressure and equivalent length.

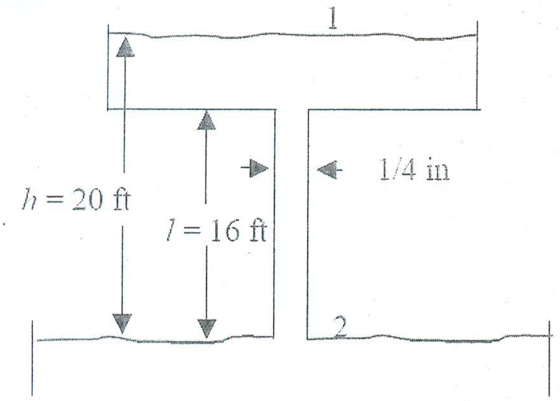
3D. Compute the loss of head and pressure drop in 200ft of horizontal 6inch diameter asphalted cast iron pipe carrying water with a mean velocity of 6ft/s. Given ϵ=0.0004ft for cast iron, $\rho=998kg/m^3$, dynamic viscosity of water is about 0.001 Pa.s

3E. Two tanks containing an oil of ρ=950kg/m^3 and μ=8*10^{-2} Pa.s are connected by a 15cm diameter pipeline of length 200m. Calculate the maximum difference in the elevation in the oil surfaces that can exist while maintaining laminar flow in the pipe.

(4+5+3+5+3 = 20 marks)

4A. Discuss the Bernoulli's equation in two cases: i) horizontal flow ii) static fluid and state the assumptions made.

4B. Assuming laminar flow and steady state conditions, calculate the discharge of the system shown below in ft^3/s, assuming that there is no pressure drop inside the large tanks. For the fluid, dynamic viscosity is 0.1 poise and SG=0.88. Was the assumption of laminar flow correct?



4C. Oil of relative density 0.9 and dynamic viscosity 2.5poise is pumped through a 100mm diameter pipe 500m long at a rate of 2L/s

i) Find the Reynolds number of the flow

ii) Calculate the pressure required at the pump if the outlet end which is free, is at 20m above the pump level

iii) What should be the power input if the overall efficiency of the pump set is 65%.

4D. How are creeping flow, Reynolds number and Stoke's law related to the drag force of a spherical object.

(5+5+7+3 = 20 marks)

5A. Particles having a size of 0.1 mm, a shape factor of 0.86, and a density of 1200kg/m^3 are to be fluidized using air at 25°C and 202.65 kPa abs pressure. The void fraction at min fluidizing conditions is 0.43. The bed diameter is 0.6m and the bed contains 350 kg of solids.

i) Calculate the min height of the fluidized bed.

ii) Calculate the pressure drop at min fluidizing conditions.

iii) Calculate the min velocity for fluidization.

5B. Air flows through a packed bed of powdery material of 1 cm depth at a superficial gas velocity of 1 cm/s. A manometer connected to the unit registers a pressure drop of 1cm of water. The bed has a porosity of 0.4. Assuming that Kozney-Carmann equation is valid for the range of study, estimate the particle size of the powder? Density of air = 1.23 kg/m^3 and Viscosity of air = 1.8x10^{-5} kg/m.s.

5C. Find the sphericity of a solid particle of a cubical shape.

(8+6+6 = 20 marks)

6A. List the advantages and disadvantages of fluidization.

6B. Define the following:

i) Potential flow ii) Entry length iii) Boundary layer iv) Drag

v) Drag coefficient

6C. Estimate the minimum fluidization velocity for a bed of particles fluidized by water. Given that Dp = 120mm; $\Phi_s=1$; $\rho_p = 2500$ kg/m^3; $e_{mf} = 0.45$; $\rho_w = 1000$kg/m^3 and $\mu = 0.9$ mPa-sec.

(5+5+10 = 20 marks)

7A. Brine of specific gravity 1.2 is flowing through a 10 cm I.D. pipeline at a maximum flow rate of 1200 liters/min. A sharp edged orifice connected to a simple U-tube mercury manometer is to be installed for the purpose of measurements. The maximum reading of the manometer is limited to 40 cm. Assuming the orifice coefficient to be 0.62, calculate the size of the orifice required.

7B. A rotameter calibrated for metering has a scale ranging from 0.014 m^3/min to 0.14 m^3/min. It is intended to use this meter for metering a gas of density 1.3 kg/m^3 with in a flow range of 0.028 m^3/min to 0.28 m^3/min. What should be the density of the new float if the original one has a density of 1900 kg/m^3? Both the floats can be assumed to have the same volume and shape.

7C. i) Why and how circular flow pattern of fluids could be prevented in an agitated tank?

ii) Radial-flow impellers have blades which are parallel to the vertical axis of the stirrer shaft and tank. Why?

(7+7+(3+3) = 20 marks)

8A. Why environmental protection legislation considers flanged and screw joints to be sources of emission of volatile materials when compared to welded joints? Elaborate.

8B. A horizontal venturimeter having a throat diameter of 4 cm is set in a 10 cm I.D. pipeline. Water flows through the system and the pressure differential across the venturimeter is measured by means of a simple U-tube manometer filled with mercury. Estimate the flow rate when the manometer reading is 30 cm. Assume $C_v = 0.98$. If 10% of the pressure differential is permanently lost, calculate the power consumption of the meter.

8C. A flat blade turbine agitator with disk having six blades is installed in a tank. The tank diameter Dt is 1.83m, the turbine diameter Da is 0.61m. The tank contains four baffles. The turbine is operated at 90rpm and the liquid in the tank has a viscosity of 10cP and a density of 929kg/m^3.

i) Calculate the required kW of the mixer.

ii) For the same conditions, except for the solution having a viscosity of 100 000cP, cal the required kW.

(5+10+5 = 20 marks)

List of Formulae

$$\Rightarrow \frac{\Delta P}{L_{mf}} = (1-\varepsilon_{mf})(\rho_p - \rho)g$$

$$v_{mf} \approx \frac{g(\rho_p-\rho)}{150\mu} \frac{\varepsilon_{mf}^3}{1-\varepsilon_{mf}} \phi_s^2 D_p^2$$

$$v_{mf} \approx \left[\frac{\phi_s D_P g(\rho_p-\rho)\varepsilon_{mf}^3}{1.75\rho}\right]^{1/2}$$

$$N_{\mathrm{Re},mf} = \left[33.7^2 + 0.0408\left(\rho D_P^3 / \mu^2\right) g(\rho_p-\rho)\right]^{1/2} - 33.7$$

$$\frac{150\ (1-\varepsilon_{mf})}{\phi_s^2\ \varepsilon_{mf}^3} N_{\mathrm{Re},mf} + \frac{1.75}{\phi_s\ \varepsilon_{mf}^3}\left(N_{\mathrm{Re},mf}\right)^2 = \left(\rho D_P^3 / \mu^2\right) g(\rho_p-\rho)$$

$$\Rightarrow v_t = \frac{g D_p^2(\rho_p-\rho)}{18\mu}$$

$$\Rightarrow v_t = 1.75\sqrt{\frac{g D_p(\rho_p-\rho)}{\rho}}$$

$$\therefore N_{\mathrm{Re},p} = \left|\frac{1}{1-\varepsilon}\right| D_p v_s \frac{\rho}{\mu}$$

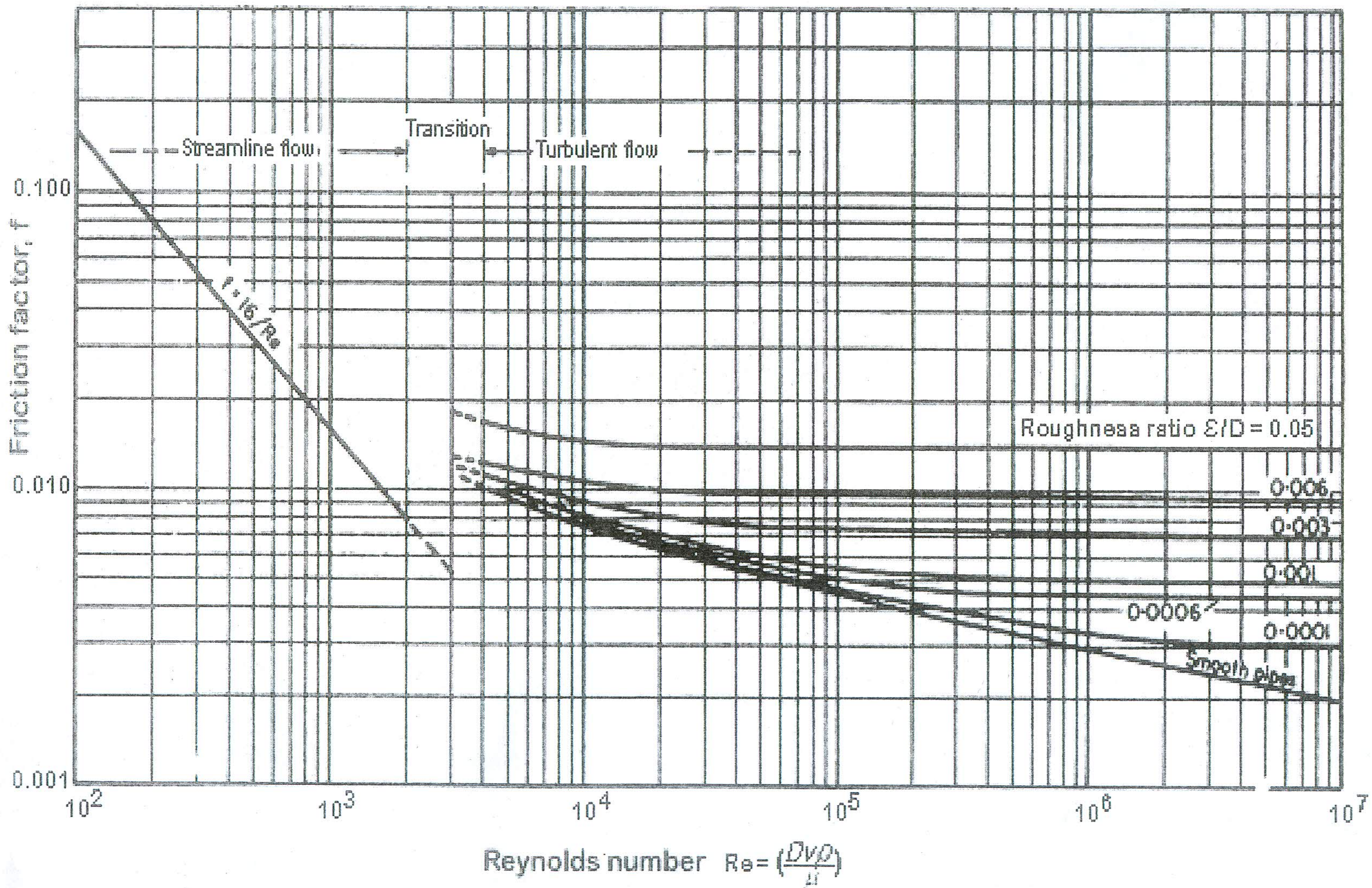
$$\therefore \frac{\Delta P}{L} = 150 \frac{\mu v_s}{D_p^2} \frac{(1-\varepsilon)^2}{\varepsilon^3}$$

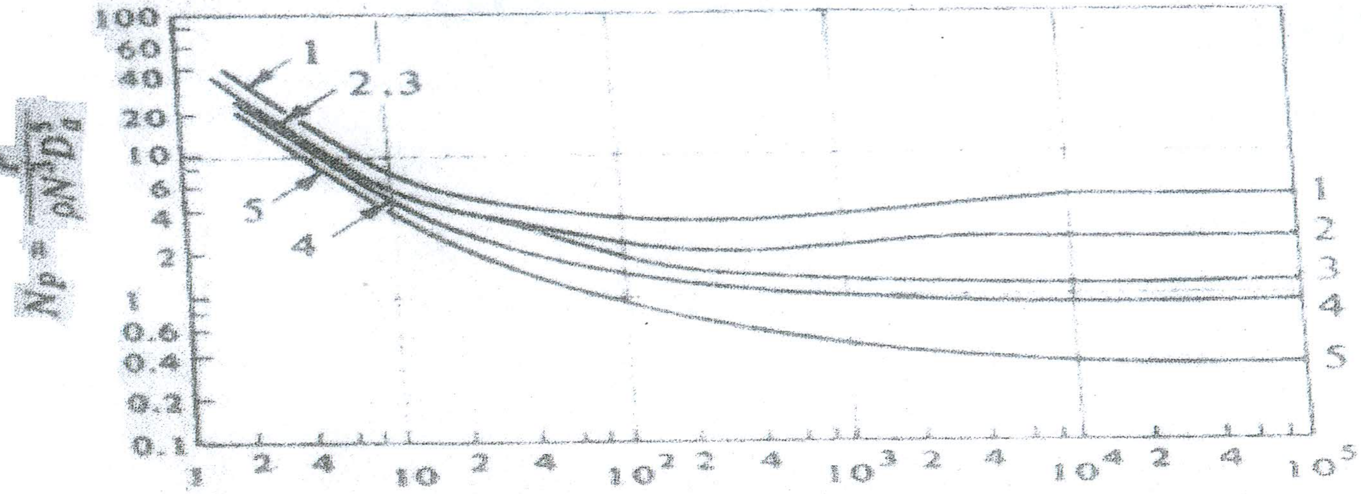
$$\frac{\Delta P}{L} = \frac{1.75\ \rho v_s^2}{D_p} \frac{(1-\varepsilon)}{\varepsilon^3}$$

$$\frac{\Delta P}{L} = \frac{150\mu v_s}{D_p^2} \frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{1.75\ \rho v_s^2}{D_p} \frac{(1-\varepsilon)}{\varepsilon^3}$$

Impeller type	K_L ($Re_i = 1$)	K_T ($Re_i = 10^5$)
Rushton turbine	70	5–6
Paddle	35	2
Marine propeller	40	0.35
Anchor	420	0.35
Helical ribbon	1000	0.35

Friction factor chart (MOODY chart)





$$N'_{Re} = \frac{D_a^2 N \rho}{\mu}$$

FIGURE 3.4-4. *Power correlations for various impellers and baffles (see Fig. 3.4-3c for dimensions D_a, D_t, J, and W).*

Curve 1. *Flat six-blade turbine with disk (like Fig. 3.4-3 but six blades); $D_a/W = 5$; four baffles each $D_t/J = 12$.*

Curve 2. *Flat six-blade open turbine (like Fig. 3.4-2c); $D_a/W = 8$; four baffles each $D_t/J = 12$.*

Curve 3. *Six-blade open turbine but blades at 45° (like Fig. 3.4-2d); $D_a/W = 8$; four baffles each $D_t/J = 12$.*

Curve 4. *Propeller (like Fig. 3.4-1); pitch = $2D_a$; four baffles each $D_t/J = 10$; also holds for same propeller in angular off-center position with no baffles.*

eller; pitch = D_a; four baffles each $D_t/J = 10$; also holds for same propeller in angular off-center position with no baffles.

and R. R.