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III SEMESTER B.TECH (BIOTECHNOLOGY)

END SEMESTER EXAMINATIONS, NOV/DEC 2015

SUBJECT: FLUID FLOW OPERATIONS IN BIOPROCESSING [BIO 209]

Time: 3 Hours MAX. MARKS: 50

Instructions to Candidates:

- Answer any **five** questions.
- Missing data may be suitable assumed.

1A.	State the SI-dimensions of dynamic and kinematic viscosity, respectively. Also provide approximate values (with two significant digits) for water and air at standard room conditions (20°C, 1 atm). At around standard room conditions, what are the separate effects of changing the pressure and temperature, respectively?	**3**
1B.	Select a device which is required to measure the pressure difference between two different pipes. Justify your selection with its principle of working.	**3**
1C.	A hydrocarbon liquid enters a simple flow system at an average velocity of 1.282 m/s, over an area 43.3 cm^2 with density 902 kg/m^3. The liquid is heated in the process and exit density is 875 kg/m^3 and flowing over an area 52.6 cm^2. The process is at steady state, calculate the mass flow rate at entrance and exit and calculate the average velocity at point 2.	**4**
2A.	Calculate the volumetric flow rate of water (viscosity 0.85 cP) at the critical velocity flowing through 25 mm i.d pipe.	**3**
2B.	A fluid is flowing through a 5 cm diameter pipe at a velocity of 2 m/s. Suddenly it enters into a large cross sectional part of the pipe having a diameter of 10 cm. Calculate the frictional loss due to sudden expansion.	**2**
2C.	60 % Sulphuric acid is to be pumped through a 25 mm i.d lead pipe (k = 0.002) at a rate of 4000 cm^3/s. It is desired to raise it to a height of 25 m. The pipe is 30 m long and includes two right angled bends. Calculate the theoretical power required. Specific gravity of acid 1.531, kinematic viscosity of acid 0.425 cm^2/s. Assume that 0.8 velocity heads are lost through each bend.	**5**
3A.	A regenerative heater is packed with a bed of 6 mm spheres. The cubes are poured into the cylindrical shell of the regenerator to a depth of 3.5 m such that the bed porosity was 0.44. If air flows through this bed entering at 25ºC and 7 atm abs and leaving at 200ºC, calculate the pressure drop across the bed when the flow rate is 500 kg/h per square meter of empty bed cross section. Assume average viscosity as 0.025 cP and density as 6.8 kg/m^3.	**5**
3B.	Calculate the settling velocity of dust particles of 60 mm diameter in air at 21°C and 100 kPa pressure. Assume that the particles are spherical of density 1280 kg m^{-3}, and the viscosity and density of air are 1.8 x 10^{-5} N s m^{-2} and 1.2 kg m^{-3}. If the diameter of dust particle is 10 mm, then what is the terminal velocity at same settling condition?	**3**

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3C.	A tower having a diameter of 0.1524 m is being fluidized with water at 20.2ºC. The uniform spherical beads in the tower bed have a diameter of 4.42 mm and a density of 1603 kg/m^3. Estimate the minimum fluidization velocity and compare with the experimental value of 0.02307 m/s of Wilhelm and Kwauk.	**2**
4A.	Identify a mechanical device which delivers the liquid at several thousands of kPa pressure. Explain the working principle of that with a neat schematic diagram.	**3**
4B.	A 5 stage compressor is to compress $7.5x10^{-3}$ kmol/s of nitrogen gas (γ = 1.4) at 27°C and 135.5 kPa abs to 55.56 Mpa abs. Calculate the power required if the efficiency is 75 % and the compression is adiabatic. Also calculate the outlet temperature.	**3**
4C.	An orifice meter is used to measure the flow rate of water flowing in a pipe line of 78 mm I.D. The orifice diameter is 15 mm. Mercury manometer reads 18 cm. The volumetric flow rate in this case is 719 cm^3/s. Calculate the coefficient of discharge of the meter. If the pressure drop is decreased to 9 cm of Hg, what will be the flow rate?	**4**
5A.	A tank 1.2 m in diameter and 2 m high is filled to a depth of 1.2 m with a latex having a viscosity of 10 P and a density of 800 kg/m^3. The tank is not baffled. A three-blade 360 mm diameter propeller is installed in the tank 360 mm from the bottom. The motor available develops 8 kW. Is the motor adequate to drive this agitator at a speed of 800 r/min? What power is required for the mixing operation, if a propeller 400 mm in diameter turning at 15 r/s is used and if four baffles, each 120 mm wide, are installed?	**6**
5B.	Describe the agitation of fermentation broth in a reactor vessel with different impellers used for it. And also the flow patterns during agitation in vessel. How do you calculate the power required for an aerobic and anaerobic process?	**4**
6A.	High speed is not desirable in reciprocating pump. Give reasons for it.	**3**
6B.	State different types of pipe fittings and mention its usage in the fluid transportation.	**3**
6C.	A centrifugal pump with an efficiency of 65 % is driven by an electric motor having an efficiency of 90 %. The pump delivers water at a rate of 4 kg/s against total head of 25 m. What is the power required by the motor and what is the power delivered by the motor?	**4**

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List of formulae

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

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

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

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

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

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

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

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

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

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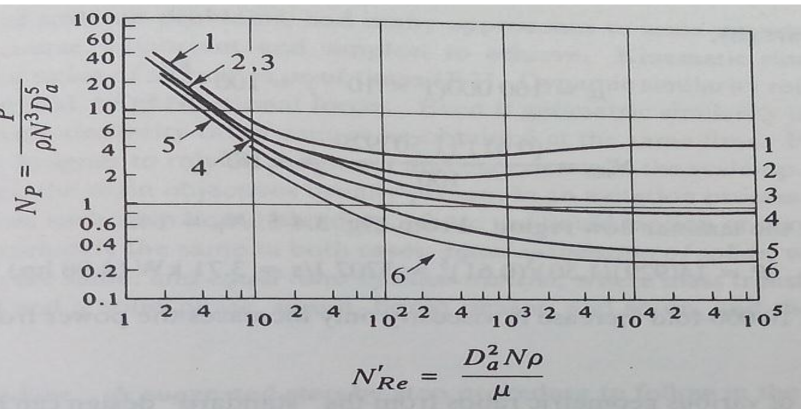

FIGURE 3.4-5. *Power correlations for various impellers and baffles (see Fig. 3.4-3c for dimension D_a, D_t, J, and W).*

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 (pitched-blade) 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.*

Curve 5. *Propeller; pitch $= D_a$; four baffles each $D_t/J = 10$; also holds for same propeller in angular off-center position with no baffles.*

Curve 6. *High-efficiency impeller (like Fig. 3-4-4a); four baffles each $D_t/J = 12$.*