Problem 1　True or False (10 points)

1) The pressure drop increases proportionally to the mass flowrate for a turbulent flow in a pipe.
2) The power number N_P is analogous to a friction factor or a drag coefficient.
3) With shear-thinning liquids, a turbine gives a much lower shear rate near the wall, and thus the velocity near the wall is much higher than that with a Newtonian fluid.
4) The settling of nanoparticles does not occur due to brownian movement.
5) The radial velocity decreases with the distance from the tip of a turbine blade, but the volumetric flow rate increases with the distance until the maximum flow rate occurs.
6) The Froude number is a measure of the ratio of the inertial stress to the shear force per unit area acting on the fluid.
7) In a pseudoplastic liquid, blending times at Re < 1,000 are much longer than in newtonian liquids under the same impeller conditions.
8) In the free motion of nonspherical particles through a fluid, the orientation is constantly changing. Thus, the effective drag on the particle is less than for the motion of the fluid past a fixed particle.
9) For an adiabatic process of airflow, the stagnation temperature is constant from the entrance to the exit of the conduit.
10) The drag coefficient of a spherical particle drops suddenly when the corresponding Reynolds number reaches 200,000.

Problem 2　Multiple Choices (10 points)　※ 注意：請於試卷內之「選擇題作答區」依序作答。

1) In chemical dehumidification process
A. wet bulb temperature increases.
B. dry bulb temperature remains constant.
C. dew point temperature increases.
D. dry bulb temperature increases.

2) With increase in compression ratio, the volumetric efficiency of air compressor
A. increases.
B. decreases.
C. remains same.
D. may increase or decrease (depends on the suction pressure).

3) Which of the followings is NOT an assumption of the McCabe-Thiele method?
A. Components have similar ΔH_{vap} values
B. Molar flowrates of vapor and liquid are constant in the rectifying section.
C. Distillation column is well-insulated.
D. There is a significant pressure drop in the column.

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4) Which of the followings is the volume-surface means diameter of a mixture of particles?

A. $\dfrac{1}{\sum_{i=1}^{n}(x_i/\bar{D}_{pi})}$　B. $\dfrac{\sum_{i=1}^{n}(N_i\bar{D}_{pi})}{N_T}$　C. $\sum_{i=1}^{n} x_i\bar{D}_{pi}$　D. $\left[\dfrac{1}{\sum_{i=1}^{n}(x_i/\bar{D}_{pi}^3)}\right]^{1/3}$

x_i: mass fraction in a given increment; N_i: number of particles in a fraction; N_T: total particle number; $\bar{D}_{pi}$: average particle diameter in an increment

5) You are asked to suspend solids in a low viscosity fluid. Which of the following impellers do you choose?

A. six-blade disk turbine

B. 3-blade propeller

C. helical ribbon

D. anchor

6) Two fluids are flowing through two similar pipes of the same diameter. The Reynold's number is same. For the same flow rate if the viscosity of a fluid is reduced to half the value of the first fluid, the pressure drop will

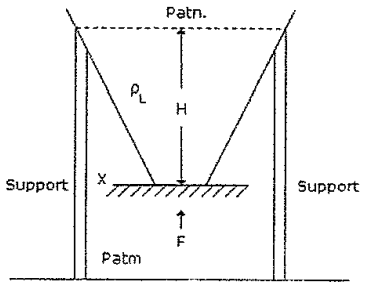
A. Increase

B. Decrease

C. Remain unchanged

D. Data insufficient to predict relative pressure drop

7) A conical tank with a bottom opening of cross-sectional area A is filled with water and is mounted on supports as shown in the figure. What is the force F with which plate X must be pushed up to prevent water from leaking? Assume that the density of air is negligible as compared to the density of water ρ_L.



A. $\rho_L \cdot Vg$

B. $\rho_L \cdot Vg/2$

C. $\rho_L \cdot A \cdot Hg$

D. $\rho_L \cdot A \cdot Hg/2$

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8) In isotropic turbulence, the _____ are equal to each other.
A. Temporal velocity components
B. Mean square of velocity fluctuations in the three co-ordinate directions
C. Root mean square of velocity fluctuations in the three co-ordinate directions
D. None of these

9) Pressure drop in a fluidized bed reactor is _____ that in a similar packed bed reactor.
A. Less than
B. Greater than
C. Same as
D. None of these

10) Which of the following facilitates close control of flow of fluids?
A. Gate valve
B. Check valve
C. Butterfly valve
D. Globe valve

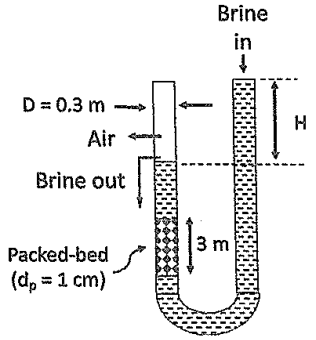
Problem 3 (3 points) What is cavitation? Why cavitation will occur in centrifugal pumps and not in displacement pumps?

Problem 4 (2 points) The x component of velocity is a steady, incompressible flow field in the xy plane is $u = A/x$, where $A = 2$ m^2/s, and x is measured in meters. Find the simplest y component of velocity for this flow field.

Problem 5 (15 points) A 0.3 m-inner-diameter U-glass tube containing a 3-m-long packed bed with 250,000 spherical quartz particles (density $\rho = 7800$ kg/m^3; diameter $D_p = 1$ cm). The particles are held between the two sieves. Brine ($\rho = 1.193$ g/cm^3; $\mu = 1.2$ cp) flows through the U-glass tube at 0.1 m/s.
(a) What is the void fraction (ε) of the packed bed? (3 pts)
(b) What is the pressure drop across the packed bed? (6 pts)
(c) What is the water level of the brine inlet above the top of the brine outlet (H)? (6 pts)

Hint: Eugen Equation $\frac{\Delta p}{L} = \frac{150\bar{V}\mu}{\Phi_s^2 D_p^2}\frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{1.75\rho\bar{V}^2}{\Phi_s D_p}\frac{1-\varepsilon}{\varepsilon^3}$

Φ_s: *sphericity*; L: *the length of the packed bed*; $\bar{V}$: *flow rate*



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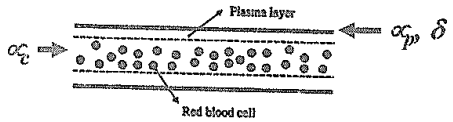
Problem 6 (10 points) Blood is composed of plasma and blood cells. When blood flows through blood vessels with small diameters, the red cells are not uniformly distributed across the vessel lumen, but, instead, they are enriched in the central region of the blood vessel, and a thin cell-free layer is formed along the tube wall. Assuming that in each region the flow is considered to be Newtonian, the viscosities of the core region and the plasma layer are μ_c and μ_p, respectively, the radius of the vessel is R and the thickness of the plasma layer is δ,



(1) Simplify the equations of change in cylindrical coordinates by deleting the zero or neglectable items. **(5 points)**

(2) Write down the boundary conditions. **(5 points)**

Equation of continuity:

$$\frac{\partial \rho}{\partial t}+\frac{1}{r}\frac{\partial(\rho r v_r)}{\partial r}+\frac{1}{r}\frac{\partial(\rho v_\theta)}{\partial \theta}+\frac{\partial(\rho v_z)}{\partial z} = 0$$

Equation of motion:

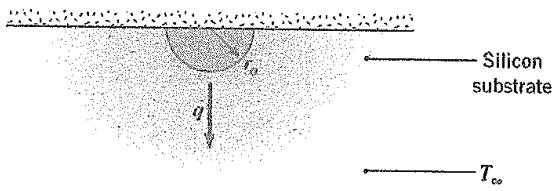
$$\rho\left(\frac{\partial v_r}{\partial t}+v_r\frac{\partial v_r}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_r}{\partial \theta}-\frac{v_\theta^2}{r}+v_z\frac{\partial v_r}{\partial z}\right) = -\frac{\partial P}{\partial r}+\left(\frac{1}{r}\frac{\partial(r\tilde{\tau}_{rr})}{\partial r}+\frac{1}{r}\frac{\partial \tilde{\tau}_{\theta r}}{\partial \theta}-\frac{\tilde{\tau}_{\theta\theta}}{r}+\frac{\partial \tilde{\tau}_{zr}}{\partial z}\right)+\rho g_r$$

$$\rho\left(\frac{\partial v_\theta}{\partial t}+v_r\frac{\partial v_\theta}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_\theta}{\partial \theta}+\frac{v_\theta v_r}{r}+v_z\frac{\partial v_\theta}{\partial z}\right) = -\frac{1}{r}\frac{\partial P}{\partial \theta}+\left(\frac{1}{r^2}\frac{\partial(r^2\tilde{\tau}_{r\theta})}{\partial r}+\frac{1}{r}\frac{\partial \tilde{\tau}_{\theta\theta}}{\partial \theta}+\frac{\partial \tilde{\tau}_{z\theta}}{\partial z}+\frac{\tilde{\tau}_{\theta r}-\tilde{\tau}_{r\theta}}{r}\right)+\rho g_\theta$$

$$\rho\left(\frac{\partial v_z}{\partial t}+v_r\frac{\partial v_z}{\partial r}+\frac{v_\theta}{r}\frac{\partial v_z}{\partial \theta}+v_z\frac{\partial v_z}{\partial z}\right) = -\frac{\partial P}{\partial z}+\left(\frac{1}{r}\frac{\partial(r\tilde{\tau}_{rz})}{\partial r}+\frac{1}{r}\frac{\partial \tilde{\tau}_{\theta z}}{\partial \theta}+\frac{\partial \tilde{\tau}_{zz}}{\partial z}\right)+\rho g_z$$

Problem 7 (15 points)

A transistor, which may be approximated as a hemispherical heat source of radius $r_0 = 0.1\ mm$, is embedded in a large silicon substrate ($k = 125\ W/m \cdot K$) and dissipates heat at a rate q. All boundaries of silicon are maintained at an ambient temperature of $T_\infty = 27°C$, except for the top surface, which is well insulated.



(a) Take the hemisphere transistor as your control volume, and determine the reduced **heat equation.** (5 pt)

(b) Determine the **boundary conditions.** (5 pt)

(c) Solve the equation from (a) and use the boundary conditions to obtain a general expression for the substrate temperature distribution. (3 pt)

(d) Obtain the general expression of **heat rate.** (2 pt)

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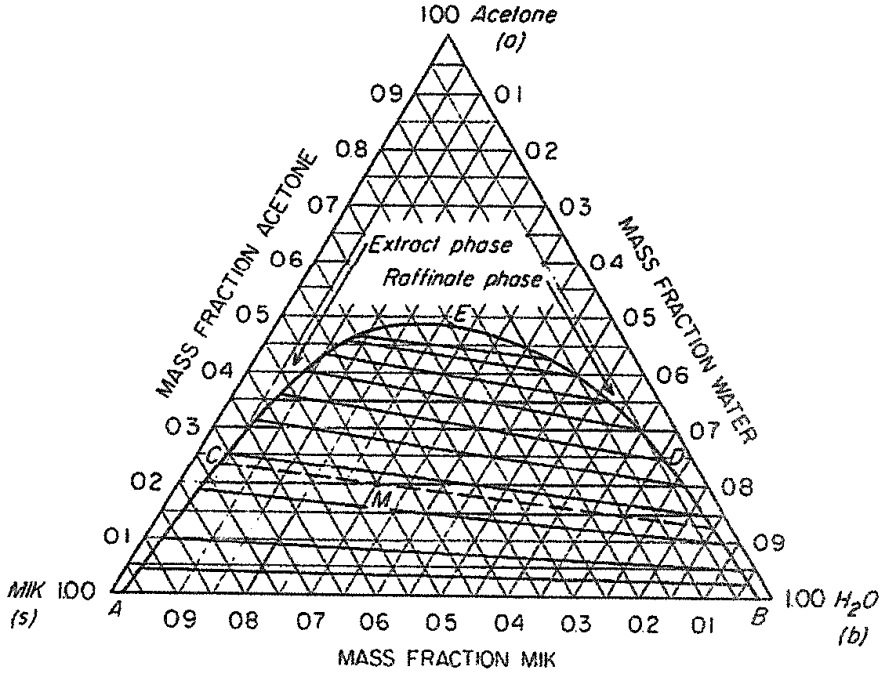
Problem 8　Fill-in-the-Blank (10 points)

A countercurrent extraction plant is used to extract acetone from its mixture with water by means of methyl isobutyl ketone (MIK) at a temperature of 25°C. The feed consists of 40 percent acetone and 60 percent water. Pure solvent equal in mass to the feed is used as the extracting liquid. In such an extraction process, you need __(a) 5pt__ ideal stages to extract 99 percent of the acetone fed, and the extract composition is __(b) 5pt__ after removal of the solvent. (Hint. The following phase diagram can be used)

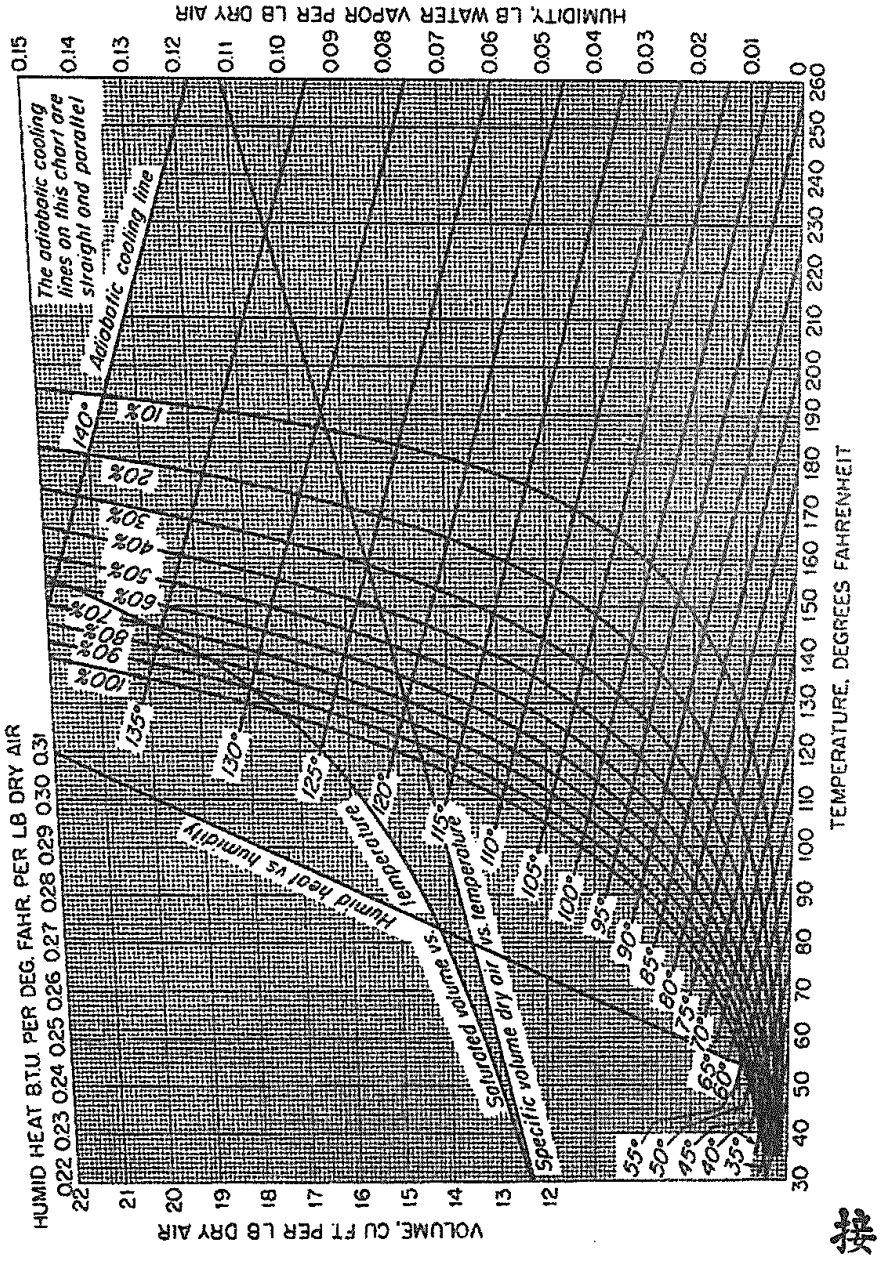


Problem 9　Fill-in-the-Blank (5 points)

Tests are made on the absorption of carbon dioxide from a carbon dioxide–air mixture in a solution containing 100 kg/m^3 of caustic soda, using a 250 mm diameter tower packed to a height of 3 m with 19 mm Raschig rings. The results obtained at atmospheric pressure were: Gas rate, G' = 0.34 kg/m^2·s. Liquid rate, L' = 3.94 kg/m^2·s. The carbon dioxide in the inlet gas was 315 parts per million and the carbon dioxide in the exit gas was 31 parts per million. Therefore the value of the overall gas transfer coefficient KGa is __(a) 5pt__.

Problem 10　Fill-in-the-Blank (10 points)

0.126 kg/s of a solid product containing 4 per cent water is produced in a dryer from a wet feed containing 42 per cent water on a wet basis. Ambient air at 294 K and of 40 per cent relative humidity is heated to 366 K in a preheater before entering the dryer from which it leaves at 60 per cent relative humidity. Assuming that the dryer operates adiabatically, what must be the flowrate of air to the preheater __(a) 2pt__ ? and how much heat must be added to the preheater __(b) 3pt__ ? Conditions change if the air enters the dryer at 340 K and sufficient heat is supplied within the dryer so that the air again leaves at 340 K with a relative humidity of 60 per cent, what must be the flowrate of air to the preheater __(c) 2pt__ ? and how much heat must be added to the preheater __(d) 3pt__ ? (Hint. The following humidity chart can be used)



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Problem 11 Fill-in-the-Blank (10 points)

A continuous rectifying column handles a mixture consisting of 40 per cent of benzene by mass and 60 per cent of toluene at the rate of 4 kg/s, and separates it into a product containing 97 per cent of benzene and a liquid containing 98 percent toluene. The feed is liquid at its boiling-point. In such an operation the mass flow of distillate is __(a) **2pt**__ and the mass flow of waste liquor is __(b) **2pt**__. If a reflux ratio of 3.5 is employed, __(c) **3pt**__ plates are required in the rectifying part of the column. If the plate-efficiency is now requires 60 percent, then __(d) **3pt**__ actual number of plates are needed.

Mole fraction of benzene in liquid	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Mole fraction of benzene in vapor	0.22	0.38	0.51	0.63	0.7	0.78	0.85	0.91	0.96

試題隨卷繳回