UNIVERSITI SAINS MALAYSIA

First Semester Examination
2009/2010 Academic Session

November 2009

EKC 212 – Fluid Flow For Chemical Engineering
[Aliran Bendalir Kejuruteraan Kimia]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of SIX pages of printed material and THREE pages of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM muka surat yang bercetak dan TIGA muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

Instructions: Answer **SIX** (6) questions. Section A is **COMPULSORY.** Answer **THREE** (3) questions from Section B. All questions carry the same marks.

*[**Arahan:** Jawab **ENAM** (6) soalan. Bahagian A **WAJIB** dijawab. Bahagian B pilih **TIGA** (3) soalan sahaja. Semua soalan membawa jumlah markah yang sama.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai].

Section A : Answer ALL questions.
Bahagian A : Jawab SEMUA soalan.

1. The pressure drop, ΔP along a tubular membrane of diameter D has been experimentally studied (Figure Q.1.). It is observed that for laminar flow of a given fluid and tube, the ΔP drop varies directly with the distance l, between pressure taps. Assume that ΔP is a function of D, l, the velocity, v, and the fluid dynamic viscosity, μ.

Kejatuhan tekanan, ΔP sepanjang membran tiub berdiameter D telah diujikaji (Rajah S.1.). Diperhatikan bahawa untuk aliran lamina bendalir dalam tiub, ΔP susut secara lelurus dengan jarak antara tap tekanan. Anggapkan ΔP adalah fungsi D, l, halaju v, dan kelikatan dinamik bendalir, μ.

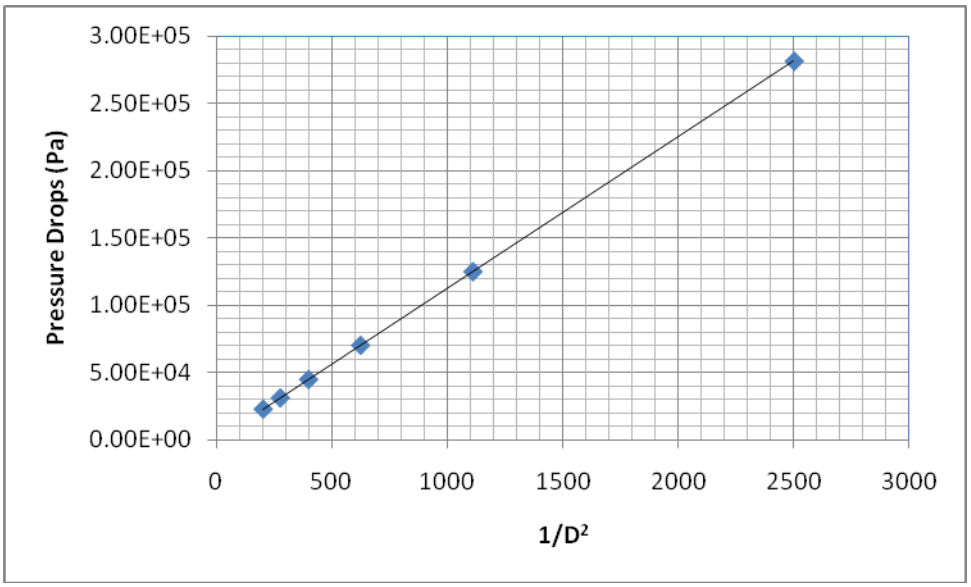

Figure Q.1. : Laboratory result of pressure drop under different tube diameters for gas mixture under constant viscosity (0.015 cP) and velocity (10 m/s)

Rajah S.1. Keputusan makmal kejatuhan tekanan campuran gas untuk tiub yang berlainan diameter tetapi berkelikatan (0.015 cP) dan halaju (10 m/s) yang sama.

[i] Based on Figure Q.1., write a full expression on how ΔP is affected by tube dimensions and flow parameters.

Berdasarkan Rajah S.1., tuliskan ungkapan penuh bagaimana ΔP dipengaruhi oleh dimensi tiub dan parameter pengaliran.

[10 marks/markah]

[ii] What is the ratio of pressure drop in a 1:10 (scaled up) prototype tubular membrane under the same gas temperature and properties, but 10 times higher in the flow velocity?

Apakah nisbah kejatuhan tekanan bagi contoh sulung tiub membran 1:10 di bawah suhu dan ciri-ciri gas yang sama tetapi 10 kali lebih tinggi dalam halaju pengaliran.

[5 marks/markah]

2. A spherical particle is settling in still air at 20°C and 1 atm. The particle has a density of 1600 kg/m^3 and a diameter of 25 μm. Take air density and viscosity as 1.2 kg/m^3 and 1.8 x 10^{-5} kg/ms, respectively, calculate:

Satu zarah berbentuk sfera jatuh di dalam persekitaran udara tenang 20°C dan 1 atm. Zarah tersebut mempunyai ketumpatan 1600 kg/m^3 dan berdiameter 25 μm. Dengan mengambil ketumpatan dan kelikatan udara masing-masing 1.2 kg/m^3 and 1.8 x 10^{-5} kg/ms, kirakan:

[i] Particle terminal velocity
Halaju terminal zarah

[ii] Drag force
Daya hela

[iii] Buoyancy force
Daya apungan

[iv] Drag coefficient
Pekali hela

[10 marks/markah]

3. [a] Based on the velocity of a streamline in a pipe, derive a relationship between the average velocity in the pipe ($\bar{v}$) and the maximum velocity in the pipe (U_{max}).

Berdasarkan halaju garis aliran di dalam sebatang paip, terbitkan hubungkait antara purata halaju ($\bar{v}$) dan halaju maksima dalam paip tersebut (U_{max}).

[6 marks/markah]

[b] When a fluid is flowing in a pipe passing two (2) locations (entering point and exit point), derive the following equation.

Apabila sesuatu bendalir melepasi dua (2) kedudukan (titik masukan dan titik keluaran), terbitkan persamaan berikut :

$$\frac{\Delta P_s}{L} = \frac{2f\rho \bar{v}}{D}$$

where : ΔP_s = Pressure drop
L = Length of the pipe
f = Friction factor
ρ = Density of fluid
D = Diameter of the pipe
$\bar{v}$ = Average velocity of the fluid

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dimana : ΔP_s = *Kejatuhan tekanan*
L = *Panjang paip*
f = *Faktor geseran*
ρ = *Ketumpatan bendalir*
D = *Garis pusat paip*
$\bar{v}$ = *Halaju purata bendalir*

[9 marks/markah]

Section B : Answer any THREE questions
Bahagian B: Jawab mana-mana TIGA soalan

4. [a] Solid particles having a size of 0.12 mm, a shape factor ϕ_s of 0.88, and a density of 1000 kg/m^3 are to be fluidized using air at 2.0 atm and 25°C. The bed diameter is 0.62 m and the bed contains 300 kg of solids. The minimum height of the fluidized bed is 1.724 m. Take air density as 2.374 kg/m^3,

Zarah-zarah pepejal bersaiz 0.12 mm, faktor bentuk ϕ_s 0.88 dan berketumpatan 1200 kg/m^3 akan diterbendalirkan dengan menggunakan udara pada tekanan 2.0 atm dan suhu 25°C. Garis pusat lapisan tersebut ialah 0.62 m dan ianya mengandungi 300 kg pepejal. Ketinggian minimum lapisan terbendalir ialah 1.724 m. Anggap ketumpatan udara sebagai 2.374 kg/m^3,

[i] Calculate the voidage at minimum fluidizing condition.
Kirakan lompangan pada keadaan terbendaliran minimum.

[ii] Calculate the pressure drop at minimum fluidizing condition.
Kirakan kejatuhan tekanan pada keadaan terbendaliran minimum.

[5 marks/markah]

[b] Hydrogen flows from a reservoir where the temperature is 20°C and the pressure is 500kPa absolute to a section 2 cm in diameter where the velocity is 250 m/s. Assuming isentropic flow, calculate the temperature, pressure, Mach number, and mass flow rate at the 2-cm section. Given specific heat ratio, k for hydrogen is 1.41 and gas constant for hydrogen, R is 4127 J/kg.K.

Hidrogen mengalir dari suatu takungan di mana suhunya adalah 20°C dan tekanan mutlak adalah 500kPa ke suatu keratan berdiameter 2 cm di mana halajunya ialah 250 m/s. Andaikan aliran isentropik, kirakan suhu, tekanan, nombor Mach dan kadar aliran jisim dikeratan 2-cm tersebut. Diberi nisbah haba tentu, k untuk hidrogen ialah 1.41 dan pemalar gas untuk hidrogen, R ialah 4127 J/kg.K.

[15 marks/markah]

5. [a] A layer of water flows down an inclined fixed surface with the velocity profile shown in Figure Q.5.[a]. Determine the magnitude of the shear stress that the water exerts on the fixed surface for U = 2 m/s and h = 0.1 m. Take water viscosity as 1.12 x 10^{-3} N.s/m^2.

Selapisan air mengalir turun pada permukaan tetap condong dengan susuk halaju seperti ditunjukkan dalam Rajah S.5.[a]. Tentukan magnitud tegasan ricih yang dikenakan oleh air pada permukaan tetap dengan halaju, U = 2 m/s dan h = 0.1 m. Ambil kelikatan air sebagai 1.12 x 10^{-3} N.s/m^2.

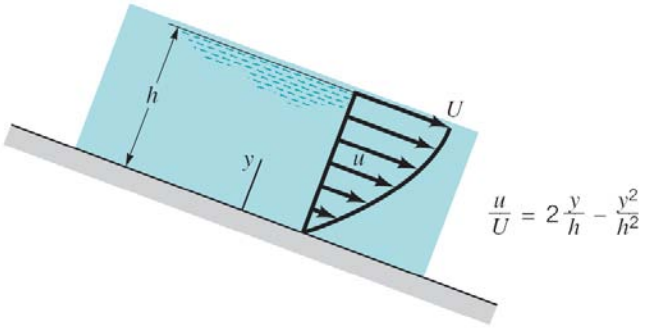

Figure Q.5.[a]
Rajah S.5.[a].

[10 marks/markah]

[b] A flat-blade turbine with six blades is installed centrally in a vertical tank. The tank is 1.83 m in diameter, the turbine is 0.61 m in diameter and is positioned 0.61 m from the bottom of the tank. The turbine blades are 127 mm wide. The tank is filled to a depth of 1.83 m with a solution of 50% caustic soda at 65.6^{o}C, which has a viscosity of 12 cP and a density of 1498 kg/m^3. The turbine is operated at 90 rpm. The tank was unbaffled. What power is required to operate the turbine?

Sebuah turbin berbilah rata dengan enam bilah dipasang ditengah-tengah sebuah tangki menegak. Tangki berdiameter 1.83 m serta turbin berdiameter 0.61 m berkedudukan 0.61 m dari dasar tangki. Bilah turbin ini berkelebaran 127 mm. Tangki diisi sedalam 1.83 m dengan larutan 50% soda kaustik bersuhu 65.6^{o}C, berkelikatan 12 cP dan berketumpatan 1498 kg/m^3. Turbin beroperasi pada kadar 90 rpm. Tangki ini dibina tanpa sesekat. Berapa kuasa yang diperlukan oleh turbin ini untuk beroperasi?

[10 marks/markah]

6. [a] Show that the fluid passes over the orifice meter (pressure drop is measured by U manometer) can be expressed as:

Tunjukkan bahawa bendalir yang melalui meter orifis (kejatuhan tekanan diukur dengan menggunakan manometer U) dapat diterbitkan seperti persamaan di bawah:

$$G = C_D A_2 \rho \sqrt{2gh_v}$$

where, G = mass flowrate
A_2 = cross sectional area of orifice meter
C_D = discharge coefficient
ρ = fluid density
h_v = pressure drop

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di mana, G = *kadar aliran jisim*
A_2 = *luas keratan rentas meter orifis*
C_D = *pekali nyahcas*
ρ = *ketumpatan bendalir*
h_v = *kejatuhan tekanan*

[12 marks/markah]

[b] Air at a density of 1.6 kg/m^3 is flowing through a pitot tube. The gauge indicates a pressure difference of 24 kg/ms^2. What is the air velocity?

Udara berketumpatan 1.6 kg/m^3 melalui sebuah tiub pitot. Tolok tekanan menunjukkan perbezaan tekanan sebanyak 24 kg/ms^2. Berapakah halaju udara?

[4 marks/markah]

[c] A venturi meter of 150 mm diameter at inlet and 50 mm diameter at the throat is used for measuring the flow of water. If the pressure drop at convergence is 121 mmH_2O and water mass flowrate is 3 kg/s, what is the discharge coefficient (C_D) at convergence part of venturi meter?

Sebuah meter venturi dengan diameter masuk 150 mm dan diameter kerongkongan 50 mm diguna bagi mengukur kadar aliran air. Jika kejatuhan tekanan pada penumpuan ialah 121 mmH_2O dan kadar aliran air ialah 3 kg/s, berapakah pekali nyahcas (C_D) pada bahagian penumpuan meter venturi.

[4 marks/markah]

7. A reverse-osmosis unit for purifying brackish water has about 800,000 hollow fibres that permit the diffusion of water but reject most of the salt. The fibres are 80 μm in outside diameter, 40 μm in inside diameter, and 3 ft. long. The average flow through the tubes is 1,500 gallon of water every 24 hr. When the feed pressure is 400 psig, calculate the pressure drop within an individual fibre from the feed end to the discharge end.

Sebuah unit osmosis berbalik untuk menulenkan air separa masin mempunyai 800,000 gentian geronggang yang membenarkan resapan air dan menyekat hampir kesemua garam yang terdapat dalam air berkenaan. Gentian tersebut mempunyai 80 µm garispusat luaran, 40 µm garispusat dalaman dan panjangnya adalah 3 kaki. Purata halaju melalui tiub adalah 1,500 gelen air bagi setiap 24 jam. Apabila tekanan masukan adalah 400 psig, kira kejatuhan dalam tekanan gentian individu dari hujung masukan hingga ke hujung luahan.

[20 marks/markah]

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Appendix

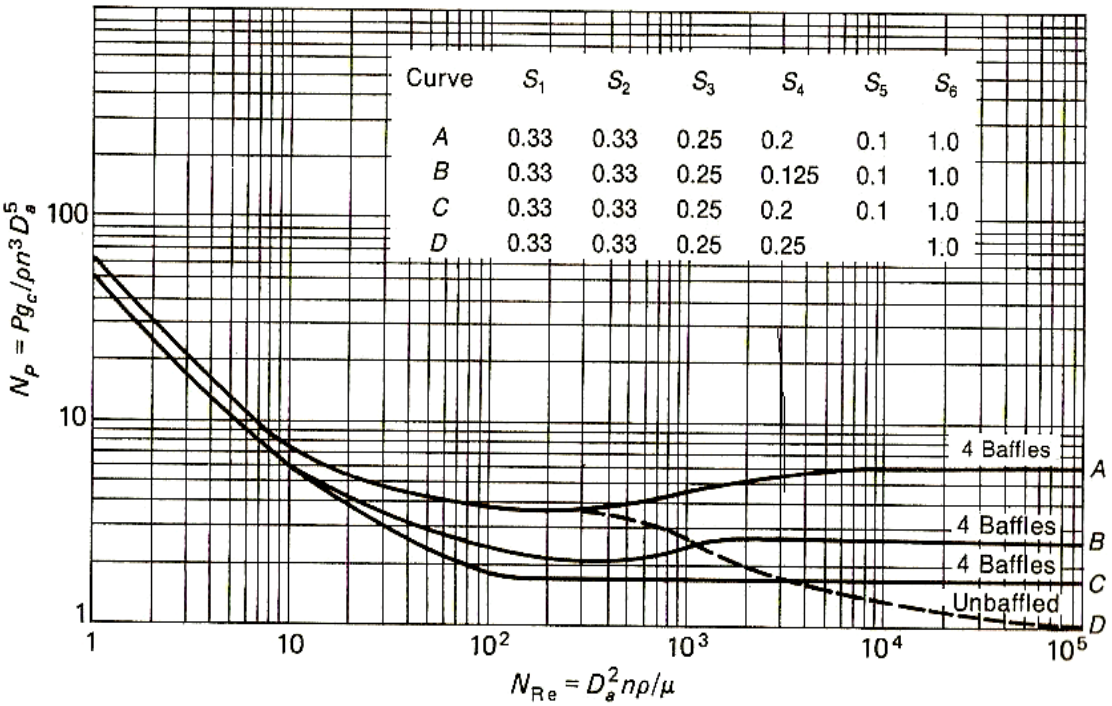

Figure A1.
Power number N_P versus N_{Re} for six-blade turbines. With the dashed portion of curve D, the value of N_P read from the figure must be multiplied by N_{Fr}^m.

$$N_{Fr} = \frac{n^2 D_a}{g}$$

For six blades ; $m = \frac{1 - \log_{10} N_{\mathrm{Re}}}{40}$

$$N_{P(Corr)} = N_P \text{ X } N_{Fr}^m$$

$$P = \frac{N_P n^3 D_a^5 \rho}{g_c}$$

For venturi meter; $G = \frac{C_D \rho A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gh_v}$

Immersed body, $u_t = \frac{g\, d_p{}^2 \left[\frac{\rho_s}{\rho_f} - 1 \right]}{18 \nu_f}$; $F_k = 3\pi \mu_f d_p u_t$; $F_B = \pi (\frac{d_p{}^3}{6}) \rho_f . g$; $f = \frac{24 \mu_f}{\rho_f u_t d_p}$

$\Delta P_{mf} = L_{mf} (1-\varepsilon_{mf}) (\rho_s - \rho_f) g$

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$$\frac{T}{T_0} = \frac{1}{1+\left[(k-1)/2\right]Ma^2}$$

$$\frac{\mathrm{P}}{\mathrm{P}_0} = \left\{\frac{1}{1+\left[(\mathrm{k}-1)/2\right]\mathrm{Ma}^2}\right\}^{\mathrm{k}/\mathrm{k}-1}$$

$$\frac{\rho}{\rho_0} = \left\{\frac{1}{1+\left[(\mathrm{k}-1)/2\right]\mathrm{Ma}^2}\right\}^{\mathrm{k}/\mathrm{k}-1}$$