UNIVERSITI SAINS MALAYSIA

First Semester Examination
2012/2013 Academic Session

January 2013

EKC 212 – Fluids 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 **ALL** (4) questions.

*[**Arahan:** Jawab **SEMUA** (4) soalan.]*

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.]

Answer ALL questions.
Jawab SEMUA soalan.

1. [a] Assume the temperature of 20 ^{o}C, find the pressure at the center of pipe A as shown in Figure Q.1.[a]. Suggest a method to reduce the total length of the manometer required.

Andaikan suhu 20^{o}C, carikan tekanan di pusat paip A seperti yang ditunjukkan dalam Rajah S.1.[a]. Cadangkan satu kaedah untuk mengurangkan jumlah panjang manometer yang diperlukan.

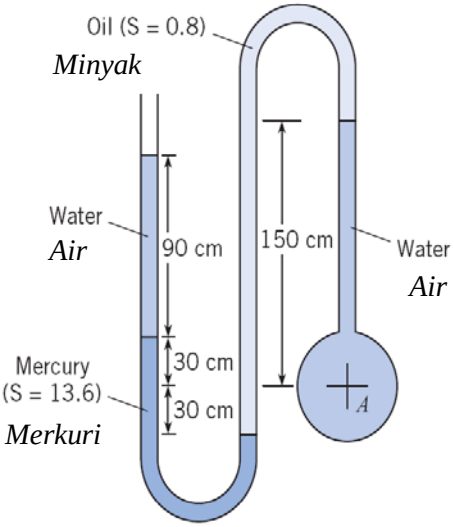

Figure Q.1.[a].
Rajah S.1.[a].

[8 marks/markah]

[b] As a plant engineer, you are required to determine the pressure drop of a pipe with diameter of 2 ft, which carry water at a velocity of 5 ft/s. It is required to estimate the pressure drop for one particular section of the pipe of length 20 ft without disrupting the plant production. Thus you decide to do experiments using a model similar to this system. Assuming that you have a piece of pipe made of the same material, with a diameter of 0.2 ft, which you can use for constructing the model;

Sebagai jurutera loji, anda dikehendaki untuk menentukan susutan tekanan paip berdiameter 2 kaki, yang membawa air pada halaju 5 kaki/s. Adanya keperluan untuk menganggarkan susutan tekanan satu bahagian tertentu paip sepanjang 20 kaki tanpa mengganggu operasi pengeluaran. Oleh sebab itu, anda membuat keputusan untuk melakukan eksperimen dengan menggunakan model yang serupa dengan sistem ini. Andaikan bahawa anda mempunyai sebatang paip yang diperbuat daripada bahan yang sama seperti paip asal, dengan diameter 0.2 kaki, yang mana anda boleh gunakan untuk membina model tersebut.

[i] Perform the dimensional analysis on the important variables and determine the governing dimensionless group for the pipe flow.

Lakukan analisa dimensi terhadap pembolehubah penting dan tentukan kumpulan tak berdimensi yang mengawal aliran paip tersebut.

[10 marks/markah]

[ii] Determine the water velocity and length of the model pipe so that you can make sure that your model adequately represents the real flow situation.

Tentukan halaju air dan panjang paip model supaya anda boleh pastikan bahawa model anda dapat mewakili keadaan aliran sebenar.

[4 marks/markah]

[iii] With a pressure drop of 1000 Pa in the model system obtained, what will be the real pressure drop over the 20 ft length pipe?

Dengan susutan tekanan sebanyak 1000 Pa dalam sistem model yang diperolehi, apakah susutan tekanan sebenar untuk paip sepanjang 20 kaki tersebut?

[3 marks/markah]

2. [a] Oil flows in a new smooth pipe of 80 mm bore diameter with a mean velocity of 0.4 m/s. The density of the oil is 890 kg/m^3 and the viscosity is 75 cP. Show that the flow is laminar and hence deduce the pressure loss per meter length. By increasing the flow, it was found that the Reynold number become 6000. How much is the pressure drop under this new flow rate?

Minyak mengalir di dalam paip baru dan licin dengan diameter jarak 80 mm dan halaju purata 0.4 m/s. Ketumpatan minyak adalah 890 kg/m^3 dan kelikatannya adalah 75 cP. Tunjukkan bahawa aliran ini adalah lamina dan seterusnya jangkakan susutan tekanan per meter panjang. Dengan meningkatkan aliran, didapati bahawa nombor Reynold menjadi 6000. Berapakah susutan tekanan di bawah kadar aliran baru ini?

[10 marks/markah]

[b] A large reservoir containing nitrogen at 20 atm and 600 K discharges the gas through a choked convergent-divergent nozzle to a test section of constant cross-sectional area. The cross-sectional area of the throat of the nozzle is 400 mm^2 and the Mach number in the test section is 3.5. Assumed that specific heat ratio, k=1.4 and the flow is adiabatic and frictionless. Calculate:

Satu takungan besar yang mengandungi nitrogen pada 20 atm dan 600 K melepaskan gas melalui muncung tercekik tumpu-capah ke seksyen ujian dengan luas keratan rentas malar. Luas keratan rentas tekak muncung tersebut ialah 400 mm^2 dan nombor Mach di seksyen ujian adalah 3.5. Andaikan bahawa nisbah haba tentu, k = 1.4. Anggapkan bahawa aliran adalah adiabatik dan tanpa geseran. Kirakan:

[i] The cross-sectional area of the test section.
Luas keratan rentas seksyen ujian.

[3 marks/markah]

[ii] The temperature and pressure of the gas at the throat of the nozzle.
Suhu dan tekanan gas di tekak muncung

[6 marks/markah]

[iii] The changes (in percentage) of gas density between the compressed tank and the test section?
Perubahan (dalam peratusan) ketumpatan gas antara tangki termampat dan seksyen ujian?

[6 marks/markah]

3. [a] Initially, two spherical particles (S1 and S2) with same position fall into water. Both particles have same final terminal velocity. What is the distance between them when both of the particles achieve terminal velocity of 99%? Assume that Stoke law is valid for this case.

Dua zarah sfera (S1 dan S2) yang pada mulanya berada pada kedudukan yang sama telah jatuh ke dalam air. Kedua-dua zarah tersebut mempunyai halaju tamatan akhir yang sama. Apakah jarak antara zarah-zarah tersebut jika kedua-duanya mencapai 99% halaju tamatan? Anggap hukum Stoke dapat digunapakai bagi kes ini.

Given: ρ_{S1} = 1940 kg/m^3, ρ_{S2} = 2750 kg/m^3, μ_{water} = 1.0 x 10^{-3} kg/ms.
Diberi: ρ_{S1} = 1940 kg/m^3, ρ_{S2} = 2750 kg/m^3, μ_{air} = 1.0 x 10^{-3} kg/ms.

[12 marks/markah]

[b] Catalyst pellets (shape factor ϕ_s = 0.86, ρ = 960 kg/m^3, diameter = 5 mm) are to be fluidized with 45,000 kg/h of air at 1 atm and 80^{o}C in a vertical vessel. What is the vessel diameter, if the quantity of air is just sufficient to fluidize the pellets?

Pelet-pelet mangkin (faktor bentuk ϕ_s = 0.86, ρ = 960 kg/m^3, diameter = 5 mm) akan diterbendalirkan dengan 45,000 kg/j udara pada 1 atm dan 80^{o}C di dalam sebuah bekas menegak. Berapakah diameter bekas sekiranya kuantiti udara ini hanya mencukupi untuk terbendalirkan pelet-pelet tersebut?

Given ε_{mf} = 0.45, ρ_{air} = 1 kg/m^3, μ_{air} = 2.0 x 10^{-5} kg/ms.
Diberi ε_{mf} = 0.45, ρ_{udara} = 1 kg/m^3, μ_{udara} = 2.0 x 10^{-5} kg/ms.

[8 marks/markah]

[c] A cylindrical bridge pier 0.9 meter in diameter is submerged to a depth of 17 meter in a river at 25°C. Water is flowing past at a velocity of 1.05 m/s. Calculate the force on the pier.

Sebatang tiang jambatan berbentuk silinder berdiameter 0.9 meter direndam sedalam 17 meter di dalam sungai yang bersuhu 25°C. Air mengalir pada kelajuan 1.05 m/s. Kirakan daya yang dikenakan kepada tiang tersebut.

Given $\rho_{water} = 990.2\ kg/m^3$; $\mu_{water} = 1.1x10^{-3} kg/m \cdot s$

Diberi $\rho_{air} = 990.2\ kg/m^3$; $\mu_{air} = 1.1 \times x10^{-3}\ kg/m \cdot s$

[5 marks/markah]

4. [a] Explain with the aid of a sketch the working principles of reciprocating pump and centrifugal pump.
Terangkan dengan bantuan lakaran prinsip kerja bagi pam salingan dan pam emparan.

[6 marks/markah]

[b] From continuity equation, show that the fluid passes over the orifice meter (pressure drop is measured by U manometer) can be expressed as:

Bermula daripada persamaan keterusan, tunjukkan bahawa aliran bendalir yang melalui meter orifis (kejatuhan tekanan diukur dengan menggunakan manometer U) boleh diterbitkan sebagai:

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

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

dimana, G = kadar aliran jisim
A_2 = luas keratan rentas meter orifis
C_D = pekali luahan
ρ = ketumpatan bendalir
h_v = susutan tekanan

[7 marks/markah]

[c] A tank with 1.2 m in diameter and 2 m height is filled to a depth of 1.2 m with a latex (μ_{latex} = 10 P, ρ_{latex} = 800 kg/m^3). A three-blade 360-mm-diameter propeller is installed in the tank located 360 mm from the bottom. The motor available develops 9 kW. Is the motor adequate to drive this propeller at a speed of 800 r/min if;

Sebuah tangki berdiameter 1.2 m dan berketinggian 2 m diisi dengan lateks (μ_{lateks} = 10 P, ρ_{lateks} = 800 kg/m^3) berkedalaman 1.2 m. Sebuah kipas 3 bilah berdiameter 360 mm dipasang pada kedudukan 360 mm dari dasar tangki. Motor sedia ada menghasilkan 9 kW. Adakah motor tersebut mampu untuk menggerakkan kipas pada kelajuan 800 putaran/min jika;

[i] The tank was baffled?
Tangki ini dibina dengan sesekat?

[ii] The tank was unbaffled?
Tangki ini dibina tanpa sesekat?

[iii] Compare and discuss the results.
Banding serta bincangkan keputusannya.

[12 marks/markah]

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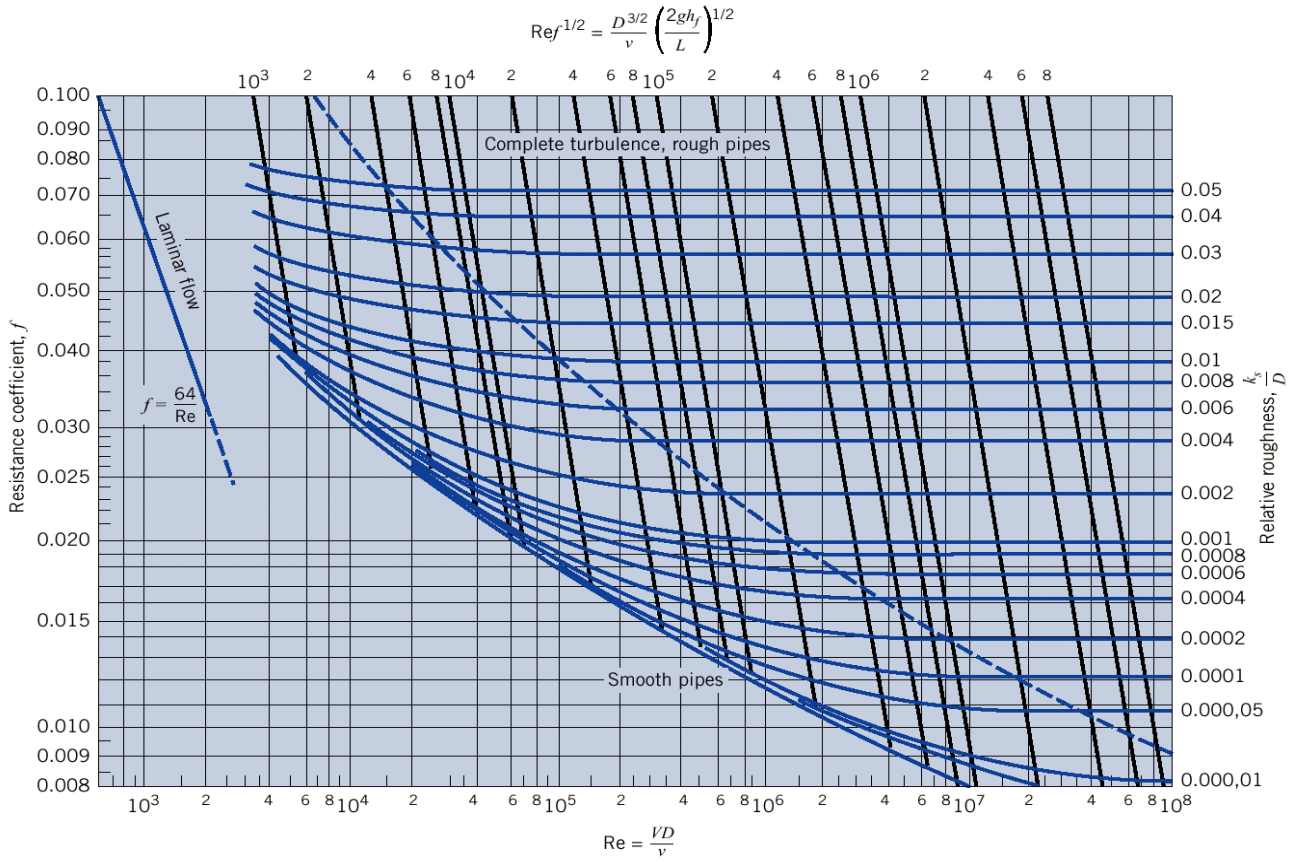
Appendix

Properties of Water

Temperature	Density	Specific Weight	Dynamic Viscosity	Kinematic Viscosity	Vapor Pressure
	kg/m^3	N/m^3	$N \cdot s/m^2$	m^2/s	N/m^2 abs.
0°C	1000	9810	1.79×10^{-3}	1.79×10^{-6}	611
5°C	1000	9810	1.51×10^{-3}	1.51×10^{-6}	872
10°C	1000	9810	1.31×10^{-3}	1.31×10^{-6}	1230
15°C	999	9800	1.14×10^{-3}	1.14×10^{-6}	1700
20°C	998	9790	1.00×10^{-3}	1.00×10^{-6}	2340
25°C	997	9781	8.91×10^{-4}	8.94×10^{-7}	3170
30°C	996	9771	7.97×10^{-4}	8.00×10^{-7}	4250
35°C	994	9751	7.20×10^{-4}	7.24×10^{-7}	5630
40°C	992	9732	6.53×10^{-4}	6.58×10^{-7}	7380
50°C	988	9693	5.47×10^{-4}	5.53×10^{-7}	12,300
60°C	983	9643	4.66×10^{-4}	4.74×10^{-7}	20,000
70°C	978	9594	4.04×10^{-4}	4.13×10^{-7}	31,200
80°C	972	9535	3.54×10^{-4}	3.64×10^{-7}	47,400
90°C	965	9467	3.15×10^{-4}	3.26×10^{-7}	70,100
100°C	958	9398	2.82×10^{-4}	2.94×10^{-7}	101,300

Moody Chart

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$



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Isothermal flow

$$\frac{f(X_T - X_M)}{D} = \ln\left(DMa^2\right) + \frac{(1-kMa^2)}{kMa^2} \quad ; \quad \frac{P}{P_T} = \frac{1}{\sqrt{k}Ma}$$

Fanno Flow

$$\frac{1}{k}\frac{(1-Ma^2)}{Ma^2} + \frac{k+1}{2k}\ln\left\{\frac{[(k+1)/2]Ma^2}{1+[(k-1)/2]Ma^2}\right\} = \frac{f\left(\ell^* - \ell\right)}{D} \quad ; \quad \frac{T}{T^*} = \frac{(k+1)/2}{1+[(k-1)/2]Ma^2} \quad ;$$

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

Isentropic Flow

$$\left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}} = \left(\frac{\rho_2}{\rho_1}\right)^k = \left(\frac{P_2}{P_1}\right) \quad ; \quad \frac{T}{T_o} = \frac{1}{1+[(k-1)/2]Ma^2} \quad \frac{P}{P_o} = \left\{\frac{1}{1+[(k-1)/2]Ma^2}\right\}^{k/k-1} \quad ;$$

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

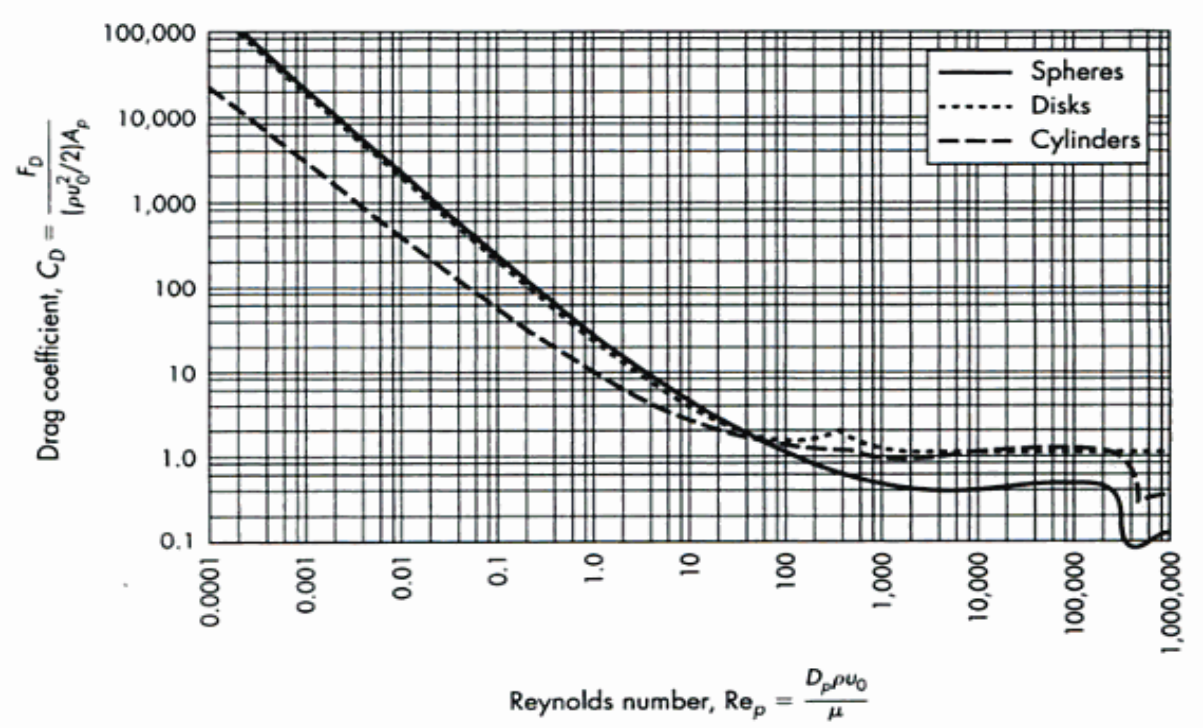
$$u_t = \frac{g\,D_p{}^2\left[\frac{\rho_p}{\rho_f} - 1\right]}{18\nu_f} = \frac{gD_p^2\left[\rho_p - \rho_f\right]}{18\mu_f};\ a_1 = \frac{18\mu}{D_1^2\rho_1};\ b_1 = \left(1 - \frac{\rho_f}{\rho_1}\right)g\ ;\ y = \frac{bt}{a} - \frac{b}{a^2} + \frac{b}{a^2}e^{-at}$$

$$g(\rho_p - \rho) = \frac{150\mu V_{mf}}{\phi_S^2 D_P^2}x\frac{(1-\varepsilon)^2}{\varepsilon^3} + \frac{1.75\rho_f (V_{mf})^2}{\phi_S D_P}x\frac{1}{\varepsilon^3}$$

$$N_{\mathrm{Re}} = \frac{DV\rho}{\mu};\ F_d = \frac{C_d V_o^2 \rho_f A_p}{2}$$

$$N_{RE} = \frac{D_a^2 n\rho}{\mu};\ N_{Fr} = \frac{n^2 D_a}{g};\ m = \frac{1.7 - \log_{10}\ N_{\mathrm{Re}}}{18};\ P = N_P n^3 D_a^5 \rho$$

…3/-



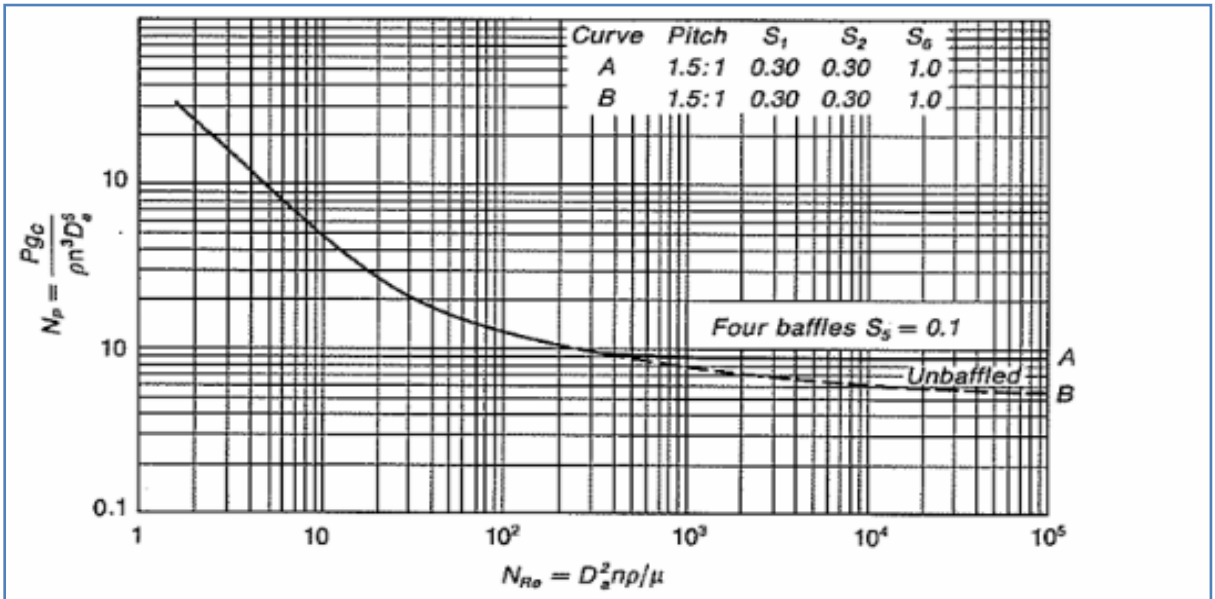


FIGURE 9.13
Power number N_p versus N_{Re} for three-blade propellers. (*After Oldshue.*[35]) With the dashed portion of curve *B*, the value of N_p read from the figure must be multiplied by N_{Fr}^m.