PART A / *BAHAGIAN A*

(1). (a). Interpret Pascal's Law. Prove the pressure decreases linearly with an increase in height for fluid under gravity by considering a vertical cylindrical element of fluid. Use a schematic diagram to support your answer.

Tafsirkan Hukum Pascal. Buktikan tekanan menurun secara linear dengan peningkatan ketinggian untuk bendalir di bawah graviti dengan mempertimbangkan elemen bendalir silinder tegak. Gunakan gambar rajah skema untuk menyokong jawapan anda.

(10 marks/*markah*)

(b). Explain Newton law of cooling and why convective heat transfer coefficient is not a material property

Terangkan hukum penyejukan Newton dan mengapa pekali pemindahan haba perolakan bukan sifat bahan.

(10 marks/*markah)*

PART B / *BAHAGIAN B*

(2). (a). The top part of a water tank is divided into two compartments, as shown in Figure 1. Now a fluid with an unknown density is poured into one side, and the water level rises a certain amount on the other side to compensate for this effect. Based on the final fluid heights shown in figure 1, determine the density of the fluid added. Assume the liquid does not mix with water.

Bahagian atas tangki air dibahagikan kepada dua bahagian, seperti yang ditunjukkan dalam Rajah 1. Sekarang bendalir dengan ketumpatan yang tidak diketahui dituangkan ke satu bahagian, dan paras air meningkat dengan jumlah tertentu di sisi lain untuk mengimbangi kesan ini. Berdasarkan ketinggian bendalir terakhir yang ditunjukkan dalam Rajah 1, tentukan ketumpatan bendalir yang ditambah. Andaikan bendalir tersebut tidak bercampur dengan air.

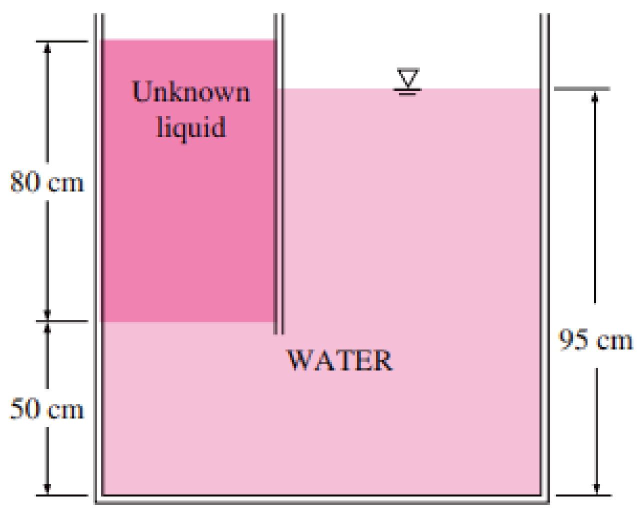

Figure 1 / *Rajah 1*

(7 marks/*markah*)

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(b). Explain why the friction factor is independent of the Reynolds number at very large Reynolds number.

Terangkan mengapa faktor geseran adalah tidak bergantung kepada nombor Reynolds pada nombor Reynolds yang sangat besar.

(5 marks/*markah*)

(c). A layer with viscous liquid of constant thickness (no velocity perpendicular to the plate) flows steadily down an infinite, inclined plane. Determine, by means of the Navier-Stokes equations, the relationship between the thickness of the layer and the discharge per unit width. The flow is laminar, and assume air resistance is negligible so that the shear stress at the free surface is zero

Satu lapisan cecair likat dengan ketebalan tetap (tidak ada halaju serenjang dengan plat) mengalir secara tetap ke bawah satah condong yang tidak terbatas. Tentukan melalui persamaan Navier-Stokes, hubungan antara ketebalan lapisan dan kadar aliran per unit lebar. Aliran adalah lamina dan anggaplah rintangan udara diabaikan supaya tegasan ricih pada permukaan bebas adalah sifar.

(8 marks/*markah*)

…5/-

(3). (a). What are the characteristics of a fully-developed flow? Briefly discuss the development of a fully-developed flow using an appropriate diagram.

Apakah ciri-ciri aliran dihasilkan sepenuhnya? Bincangkan secara ringkas perkembangan aliran dihasilkan sepenuhnya dengan menggunakan gambar rajah yang bersesuaian.

(8 marks/*markah*)

(b). The velocity profile in fully-developed laminar flow in a circular pipe is given by $u(r) = u_{max}(1 - r^2/R^2)$. Determine (i) maximum velocity, (ii) average velocity, and (iii) volume flow rate in a pipe with inner radius, R = 2 cm as shown in Figure 2.

Profil halaju dalam aliran lamina yang dihasilkan sepenuhnya dalam paip bulat diberikan oleh $u(r) = u_{max}(1 - r^2/R^2)$. Tentukan (i) halaju maksimum, (ii) halaju purata, dan (iii) kadar aliran isipadu dalam paip dengan jejari dalam, R = 2 cm seperti ditunjukkan dalam Rajah 2.

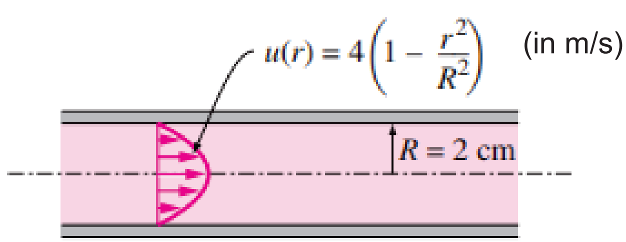

Figure 2 / *Rajah 2*

(6 marks/*markah*)

…6/-

(c). Briefly discuss the real-life example of boundary layer separation. Suggest the methods to avoid this phenomenon. Support your answer using an appropriate diagram.

Bincangkan secara ringkas contoh sebenar pemisahan lapisan sempadan. Cadangkan kaedah untuk mengelakkan fenomena ini. Sokong jawapan anda menggunakan rajah yang sesuai.

(6 marks/*markah*)

(4). (a). A pressurized tank of water has a 10-cm diameter orifice at the bottom, where water discharges to the atmosphere as shown in Figure 3. The water level is 3 m above the outlet. The tank air pressure above the water level is 300 kPa (absolute) while the atmospheric pressure is 100 kPa. Neglecting frictional effects, determine the initial discharge rate from the tank.

Sebuah tangki air bertekanan mempunyai orifis berdiameter 10-cm di bahagian bawah, di mana air mengalir keluar ke atmosfera seperti ditunjukkan dalam Rajah 3. Paras air adalah 3 m di atas saluran keluar. Tekanan udara tangki di atas paras air ialah 300 kPa (mutlak) manakala tekanan atmosfera ialah 100 kPa. Dengan mengabaikan kesan geseran, tentukan kadar nyahcas awal dari tangki.

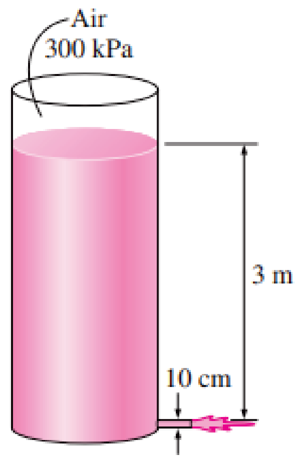

Figure 3 / *Rajah 3*

(5 marks/*markah*)

(b). What is the importance of laminar and turbulent flow in our daily application? Briefly discuss the advantage of having laminar and turbulent flow in transport phenomena. Support your answer by providing an appropriate example.

Apakah kepentingan aliran lamina dan gelora dalam aplikasi harian kita? Bincangkan secara ringkas kelebihan mempunyai aliran lamina dan gelora dalam fenomena pengangkutan. Sokong jawapan anda dengan memberikan contoh yang sesuai.

(5 marks/*markah*)

(c). A viscous, incompressible, Newtonian liquid flows in steady, laminar, planar flow down a vertical wall (Figure 4). The thickness, δ, of the liquid film remains constant. Since the liquid free surface is exposed to atmospheric pressure, there is no pressure gradient in the liquid film. Furthermore, the air provides a negligible resistance to the motion of the fluid. Determine:

…8/-

Cecair *likat, tak boleh mampat dan Newtonian mengalir dalam keadaan mantap, lamina dan satah mengalir ke bawah suatu dinding menegak (Rajah 4). Ketebalan, δ, filem cecair kekal malar. Oleh kerana permukaan bebas cecair terdedah kepada tekanan atmosfera, tidak ada kecerunan tekanan dalam lapisan cecair. Tambahan pula, udara menyediakan rintangan yang diabaikan kepada gerakan bendalir. Tentukan.*

(i). The velocity distribution for this gravity driven flow. Clearly state all assumptions and boundary conditions.

Taburan halaju untuk aliran graviti pacuan ini. Nyatakan dengan jelas semua andaian dan keadaan sempadan.

(4 markah/*marks*)

(ii). The shear stress acting on the wall by the fluid.

Tegasan ricih oleh bendalir yang bertindak pada dinding.

(3 marks/*markah)*

(iii). The maximum velocity of the fluid.

Halaju maksimum bendalir.

(3 markah/*marks*)

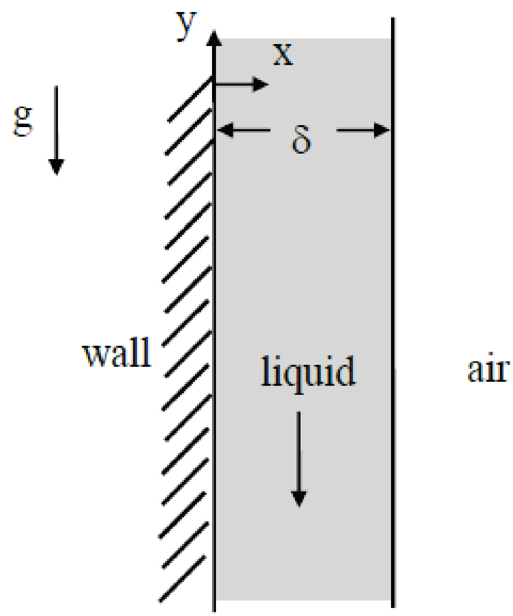

Figure 4 / *Rajah 4*

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PART C / *BAHAGIAN C*

(5). (a). Explain the following items;
Terangkan perkara di bawah;

(i). 2D heat conduction equation
Persamaan konduksi haba 2D

(ii). Radiative heat transfer coefficient
Pemalar Pemindahan Haba Sinaran

(iii). Thermal diffusivity
Resapan termal

(iv). Steady state versus Transient heat transfer.
Keadaan mantap melawan pemindahan haba sementara.

(10 marks/*markah)*

(b). Calculate the thermal conductivity of a mixture containing 40 mole % CO_2 and 60 mole % H_2 at 1.5 atmosphere and 330 K. Refer to Table 1.

Kirakan keberaliran haba untuk campuran yang mempunyai 40 mol % CO_2 dan 60 mol % H_2 pada tekanan 1.5 atmosfera pada suhu 330 K. Rujuk Jadual 1.

Table 1: Gas properties at 330 K
Jadual 1: Sifat gas pada suhu 330 K

Component	M	μ (x10^5), Pa.s	K, $W.m^{-1}.K^{-1}$
H_2	2	0.8944	0.1789
CO_2	44	1.506	0.01661

(10 marks/*markah)*

(6). (a). Estimate the diffusivity for a dilute aqueous solution of acetic acid at 15.0 °C, using the Wilke-Chang equation below. The density of pure acetic acid is 0.937 g/cm^3 at its boiling point. ψ_B= 2.8 (constant), M_w = 60.05 g/mol. Use the equation below and estimate the dilute-viscosity using the Table 2 given.

Anggarkan pembauran untuk larutan cair asid asetik pada suhu 15.0 °C dengan menggunakan persamaan Wilke-Chang di bawah. Ketumpatan asid asetik ialah 0.937 g/cm^3 pada tahap didih. Pemalar ψ_B= 2.8 dan berat jisim asid asetik, M_w = 60.05 g/mol. Gunakan persamaan di bawah dan anggarkan kelikatan cair mengunakan Jadual 2 di bawah.

$$\mathcal{D}_{AB} = 7.4 \times 10^{-8} \frac{\sqrt{\psi_B M_B}\, T}{\mu \widetilde{V}_A^{0.6}}$$

Table 2 : Viscosity of Water and Air at 1 atm Pressure

Jadual 2 : Kelikatan air dan udara pada 1 atmosphera

	Water (liq.)[a]		Air[b]	
Temperature T (°C)	Viscosity μ (mPa · s)	Kinematic viscosity ν (cm^2/s)	Viscosity μ (mPa · s)	Kinematic viscosity ν (cm^2/s)
0	1.787	0.01787	0.01716	0.1327
20	1.0019	0.010037	0.01813	0.1505
40	0.6530	0.006581	0.01908	0.1692
60	0.4665	0.004744	0.01999	0.1886
80	0.3548	0.003651	0.02087	0.2088
100	0.2821	0.002944	0.02173	0.2298

[a] Calculated from the results of R. C. Hardy and R. L. Cottington, *J. Research Nat. Bur. Standards*, **42**, 573–578 (1949); and J. F. Swidells, J. R. Coe, Jr., and T. B. Godfrey, *J. Research Nat. Bur. Standards*, **48**, 1–31 (1952).

[b] Calculated from "Tables of Thermal Properties of Gases," *National Bureau of Standards Circular* **464** (1955), Chapter 2.

(10 marks/*markah)*

(b). A 15 liter vessel contains CO_2 at 22°C and 3 bar as shown in Figure 5. The vessel is fitted with a 20 mm cork whose surface area is 300 mm^2. It was given $D_{CO2-Cork}$ = 1.1 × 10−10 m^2/s and solubility (S) of CO_2 in the plug = 0.04015 kmol/m^3-bar. Determine the following;

Sebuah bekas 15 Liter yang mengandungi CO_2 pada 22°C dan tekanan 3 bar seperti Rajah 5. Bekas ini di pasang gabus 20 mm dengan luas permukaan 300 mm^2. Diberikan $D_{CO2-Cork}$ = 1.1 × 10−10 m^2/s dan keterlarutan (S) gas dalam gabus = 0.04015 kmol/m^3-bar. Tentukan perkara berikut;

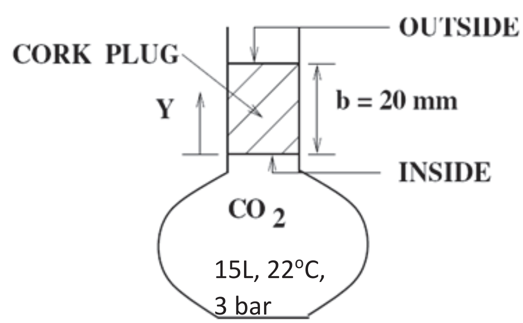

Figure 5 : CO_2 diffusion through cork plug

Rajah 5 : Resapan CO_2 didalam gabus.

(i). Initial rate of mass loss of CO_2

Kadar awal kehilangan jisim CO_2

(5 marks/*markah)*

(ii). Reduction in vessel pressure after 6 months

Pengurangan tekanan bekas selepas 6 bulan

(5 marks/markah)

(7). (a). From the Table 3 , compute cD_{AB} for binary mixtures of H_2 and CO at T=100°C (1.5 atm). Calculate the Schmidt numbers for the above gases at H_2 molar ratio of 0.0, 0.25, 0.50, 0.75 and 1.00 at 100°C and 2.0 atm. Given the gas viscosity relationship is $\mu = 0.0046x^4 - 0.0056x^3 + 0.0012x^2 - 0.0022x + 6.10^{-4}$ where x= molar ratio of H_2.

Table 3 / *Jadual 3*

Species	M, g/mol	σ, angstrom	ε/k, K
H_2	2.00	1.90	58.00
CO	28.00	4.60	140.00

Daripada Jadual 3, kirakan cD_{AB} campuran dedua H_2 dan CO pada T= 100°C dan tekanan 2.0 atm. Kirakan nombor Schmidt untuk gas H_2 pada nisbah umpan molar 0.0, 0.25, 0.50, 0.75 dan 1.00 pada suhu dan tekanan tersebut. Diberikan kelikatan gas ialah $\mu = 0.0046x^4 - 0.0056x^3 + 0.0012x^2 - 0.0022x + 6.10^{-4}$ di mana x = nisbah molar H_2.

(10 marks/markah)

(b). An 10-cm-internal-diameter, 30-cm-high pitcher half filled with water is left in a dry room at 25°C and 70 kPa with its top open like Figure 6. If the water is maintained at 15°C at all times, determine how long it will take for the water to evaporate completely.

Jag air dengan dimensi 10 cm diameter dalam dan ketinggian 30 cm di letakkan pada bilik kering pada suhu 25°C dan tekanan udara 70 kPa seperti Rajah 6. Sekiranya air di dalam jag itu ditetapkan pada suhu 15°C pada setiap masa, tentukan berapa lama untuk air itu sejat sepenuhnya.

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Figure 6 – Evaporation of water from water jug.

Rajah 6 – Penyejatan air di dalam jag

(10 marks/*markah)*

–oooOooo –

Appendix of Formulas:

1 Btu= 1055.056 J, 1 ft= 0.305 m, 1 atm = 1.01325 bar.

k_b=1.38 E-23 J.K^{-1} , R= 8.314 J/(g-mol. K) , R=82.0578 cm^3 atm/(g-mol. K),

g = 9.8 m/s^2, ρ_{air} = 1.29 g/liter, Average M_{air} = 28.97 g/mol.

$$°C = \frac{(F-32)*5}{9}$$

Heat Transport

$$q_{avg} = \frac{1}{H}\int_0^H \left(-k\frac{\partial T}{\partial y}\right)\bigg|_{y=0} dz$$

$$\mu_{mix} = \sum_{\alpha=1}^{N} \frac{x_\alpha \mu_\alpha}{\Sigma_\beta x_\beta \Phi_{\alpha\beta}}$$

$$\Phi_{\alpha\beta} = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{\dot{g}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t} \quad \left(\frac{M_\beta}{M_\alpha}\right)^{1/4}\Bigg]^2$$

$$-kA_r\frac{dT}{dr} = \dot{e}_{gen}V_r$$

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right) + \frac{\dot{g}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

$$\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial T}{\partial r}\right) + \frac{\dot{g}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$$

Mass Transport

$$J = -D\frac{\Delta c}{\Delta x}$$

$$\frac{\partial c}{\partial t} = \frac{\partial}{\partial x}\left(D\frac{\partial c}{\partial x}\right)$$

$$\frac{x_A(x,t) - x_{A,s}}{x_{A,i} - x_{A,s}} = \operatorname{erf}\left(\frac{x}{2(D_{AB}t)^{1/2}}\right)$$

$$N_{Az} = -c\mathcal{D}_{AB}\frac{\partial x_A}{\partial z} + x_A(N_{Az} + N_{Bz})$$

combined flux — molecular flux — convective flux

$$\Omega_{AB} = 1.147\left(\frac{k_B T}{\varepsilon_{AB}}\right)^{-0.145} + \left(\frac{k_B T}{\varepsilon_{AB}} + 0.5\right)^{-2}$$

$$\mathcal{D}_{AB} = 0.0018583\sqrt{T^3\left(\frac{1}{M_A} + \frac{1}{M_B}\right)}\frac{1}{p\sigma_{AB}^2\Omega_{\mathcal{D},AB}}$$

$$N_{Ay} = \frac{\rho_A * D_{AB} * dw_{Ay}}{(1 - w_{Ay})dy} = constant$$

$$where\ \rho = density, D_{AB} = diffusion\ \ coefficient, w_A = mass\ fraction$$

$$\Delta V(t) = S_{x_{AO}} * \Psi * \sqrt{\frac{4D_{AB} * t}{\pi}}$$

$$\phi = \sqrt{k_1''a/\mathcal{D}_A}R$$

$$\psi_1 = \frac{C_A}{C_{A_s}} = \frac{1}{\lambda}\left(\frac{\sinh\phi * \lambda}{\sinh\phi}\right)$$

$$\psi = \varphi\sqrt{\pi / x}$$

$$Sh = 0.3 + \frac{0.62\,Re^{0.5}\,Sc^{1/3}}{\left[1 + (0.4/Sc)^{2/3}\right]^{1/4}}\left[1 + \left(\frac{Re}{28200}\right)^{5/8}\right]^{4/5}$$

$$h_{mass} = \frac{ShD_{AB}}{D}$$