UNIVERSITI SAINS MALAYSIA

First Semester Examination
2015/2016 Academic Session

December 2015 / January 2016

EBB 333/3 – Transport Processes
[Proses-Proses Pengangkutan]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains FIFTEEN printed pages and THREE pages APPENDIX before you begin the examination.
[Sila pastikan bahawa kertas peperiksaan ini mengandungi LIMA BELAS muka surat dan TIGA muka surat LAMPIRAN yang bercetak sebelum anda memulakan peperiksaan ini.]

This paper consists of SEVEN questions. FOUR questions from PART A and THREE questions from PART B.
[Kertas soalan ini mengandungi TUJUH soalan. EMPAT soalan dari BAHAGIAN A dan TIGA soalan dari BAHAGIAN B.]

Instruction: Answer **FIVE** questions. Answer **TWO** questions from PART A, **TWO** questions from PART B and **ONE** question from any part. If a candidate answers more than five questions only the first five questions answered in the answer script would be examined.
*[**Arahan**: Jawab **LIMA** soalan. Jawab **DUA** soalan dari BAHAGIAN A, **DUA** soalan dari BAHAGIAN B dan **SATU** soalan dari mana-mana bahagian. Jika calon menjawab lebih daripada lima soalan hanya lima soalan pertama mengikut susunan dalam skrip jawapan akan diberi markah.]*

The answers to all questions must start on a new page.
[Mulakan jawapan anda untuk semua soalan pada muka surat yang baru.]

You may answer a question either in Bahasa Malaysia or in English.
[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

In the event of any discrepancies in the examination questions, the English version shall be used.
[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

PART A / *BAHAGIAN A*

1. [a] Prove that pressure acts equally in all directions by considering a small element of fluid which is at rest in the form of triangular prism.

Buktikan bahawa tekanan bertindak sama dalam semua arah dengan mengambil kira elemen kecil cecair yang berada dalam keadaan rehat dalam bentuk prisma segi tiga.

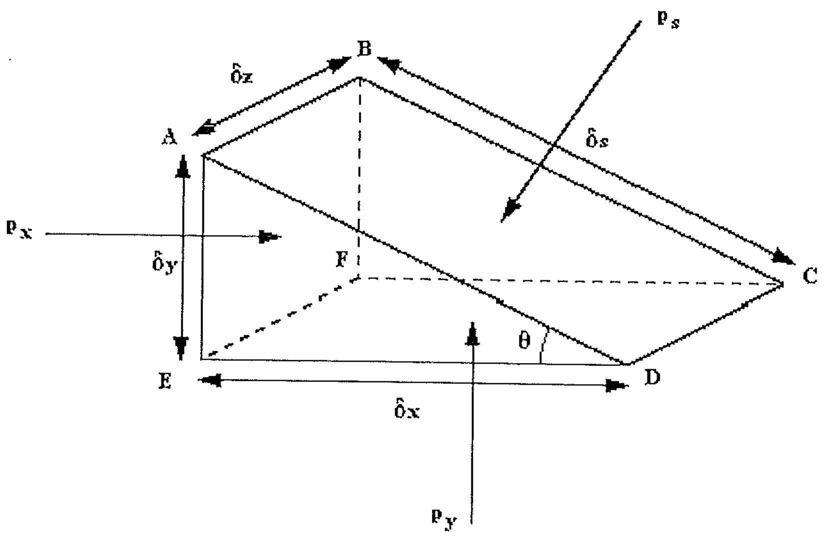

Figure 1 - Triangular prismatic element of fluid

Rajah 1 - Unsur prisma segi tiga cecair

(50 marks/*markah*)

[b] A large storage tank contains oil having a density of 917 kg/m^3. The tank is 3.66 m tall and is vented (open) to the atmosphere of 1 atm at the top. The tank is filled with oil to a depth of 3.05 m and also contains 0.61 m of water at the bottom of the tank. Calculate the pressure 3.05 m from the top of the tank and the pressure at the bottom of the tank in Pa. Also calculate the gage pressure at the tank bottom.

Sebuah tangki simpanan yang besar mengandungi minyak yang mempunyai ketumpatan 917 kg/m^3. Ketinggian tangki adalah 3.66 m dan terbuka kepada atmosfera 1 atm di bahagian atas. Tangki dipenuhkan dengan minyak sedalam 3.05 m dan juga mengandungi 0.61 m air di bahagian bawah tangki. Kira tekanan 3.05 m dari atas tangki dan tekanan di bahagian bawah tangki dalam Pa. Juga kirakan tekanan tolok di bahagian bawah tangki.

(50 marks/*markah*)

2. [a] Briefly explain the difference between Newtonian and Non-Newtonian Fluids. Give ONE example for each class of fluids.

Terangkan secara ringkas perbezaan di antara cecair Newtonian dan Bukan Newtonian. Berikan SATU contoh bagi setiap kelas cecair.

(30 marks/*markah*)

[b] An oil is being pumped inside a 10.0 mm diameter pipe at a Reynolds number of 2100. The oil density is 855 kg/m^3 and the viscosity is 2.1 x 10^{-2} Pa.s.

Minyak dipam di dalam sebuah paip berdiameter 10.0 mm pada nombor Reynolds 2100. Ketumpatan minyak adalah 855 kg/m^3 *dan kelikatan adalah 2.1 x* 10^{-2} *Pa.s.*

(i) What is the velocity of oil in the pipe?
Apakah halaju minyak dalam paip?

(15 marks/*markah*)

(ii) It is desired to maintain the same Reynolds number of 2100 and the same velocity as in part (i) using a second fluid with a density of 925 kg/m^3 and a viscosity of 1.5 x 10^{-2} Pa.s. What pipe diameter should be used?

Dikehendaki untuk mengekalkan nombor Reynolds yang sama iaitu 2100 dan halaju yang sama seperti di bahagian (i) menggunakan cecair kedua dengan ketumpatan 925 kg/m^3 *dan kelikatan 1.5 x* 10^{-2} *Pa.s. Apakah diameter paip yang harus digunakan?*

(15 marks/*markah*)

[c] A petroleum crude oil having a density of 892 kg/m^3 is flowing through the piping arrangement shown in Figure 2 at a total rate of 1.388 x 10^{-3} m^3/s entering pipe 1. The flow divides equally in each of the pipe 3. Given the internal diameter for pipe 1, 2 and 3 are 2.067 in., 3.068 in. and 1.610 in, respectively. Calculate the following in SI units:

Minyak mentah petroleum yang mempunyai ketumpatan 892 kg/m^3 mengalir melalui susunan paip yang ditunjukkan dalam Rajah 2 dengan jumlah kadar sebanyak 1.388 x 10^{-3} m^3/s memasuki paip 1. Aliran tersebut membahagi sama rata dalam setiap paip 3. Diberi diameter dalaman untuk paip 1, 2 dan 3 adalah masing-masing 2.067 inci, 3.068 inci dan 1.610 inci. Kira yang berikut dalam unit SI:

(i) The total mass flow rate *m* in pipe 1 and pipe 3.
Jumlah kadar aliran jisim m dalam paip 1 dan paip 3.

(20 marks/*markah*)

(ii) The average velocity *v* in pipe 1 and pipe 3.
Purata halaju v dalam paip 1 dan paip 3.

(20 marks/*markah*)

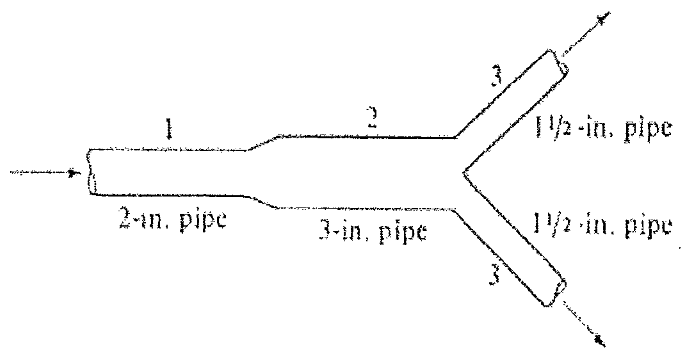

Figure 2 - Piping arrangement for petroleum crude oil
Rajah 2 - Susunan paip untuk petroleum minyak mentah

3. [a] Describe the boundary layer growth on a flat plate. Support your answer with an appropriate schematic diagram.

Huraikan pertumbuhan lapisan sempadan di atas plat rata. Sokong jawapan anda dengan gambarajah skematik yang sesuai.

(40 marks/*markah*)

[b] Show that, for steady, and fully developed laminar flow down the slope (Figure 3), the Navier-Stokes equations reduces to

Tunjukkan bahawa, untuk aliran stabil dan aliran lamina yang terbentuk sepenuhnya menuruni cerun (Rajah 3), persamaan Navier-Stokes diterbitkan kepada

$$\frac{d^2u}{dy^2} = -\frac{\rho g}{\mu}\sin\theta$$

where u is the velocity in the x-direction, ρ is the density, μ is the dynamic viscosity, g is acceleration due to gravity, and θ is the angle of the plane to the horizontal. Solve the above equation to obtain the velocity profile u and obtain the expression for the volumetric flow rate for a flowing film of thickness h.

di mana u ialah halaju dalam arah-x, ρ ialah ketumpatan, μ ialah kelikatan dinamik, g ialah pecutan disebabkan oleh graviti, dan θ ialah sudut satah mendatar. Selesaikan persamaan di atas untuk mendapatkan halaju profil u dan dapatkan ungkapan untuk kadar aliran isipadu untuk lapisan yang mengalir yang berketebalan h.

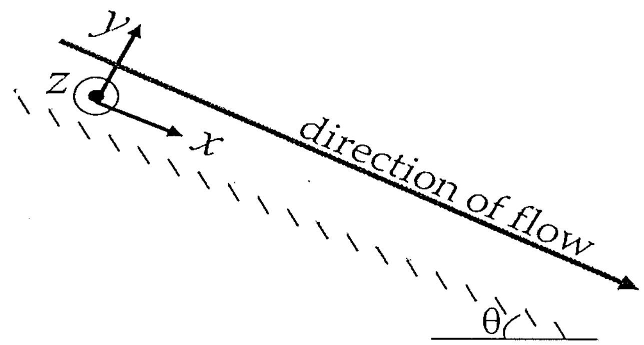

Figure 3 - Incompressible flow of a Newtonian fluid down an inclined plane
Rajah 3 - Aliran tak boleh mampat bendalir Newtonian ke bawah satah condong

(60 marks/*markah*)

4. [a] A straight stretch of horizontal pipe having a diameter of 5 cm is used in the laboratory to measure the viscosity of crude oil (γ = 0.93 tonne/m^3). During a test run a pressure difference of 1.75 tonne/m^2 is obtained from two pressure gages, which are located 6 m apart on the pipe. Oil is allowed to discharge into a weighing tank, and a total of 550 kg of oil is collected for a duration of 3 min. Determine the viscosity (μ) of the oil.

Sebatang paip lurus mendatar mempunyai diameter 5 cm digunakan di makmal untuk mengukur kelikatan minyak mentah (γ = 0.93 tan/m^3). Semasa ujian dijalankan perbezaan tekanan 1.75 tan/m^2 diperoleh daripada dua tolok tekanan, yang terletak 6 m di antara satu sama lain pada paip tersebut. Minyak dibenarkan untuk disalurkan ke dalam tangki penimbang, dan sebanyak 550 kg minyak dikumpul untuk tempoh 3 min. Tentukan kelikatan minyak tersebut (μ).

(40 marks/*markah*)

[b] A viscous, incompressible, Newtonian liquid flows in steady and 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.

Cecair likat, tak boleh mampat dan Newtonian mengalir dalam keadaan mantap, lamina dan planar mengalir menuruni suatu dinding yang 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 memberikan rintangan yang sangat kecil boleh diabaikan kepada gerakan bendalir.

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

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

(30 marks/*markah*)

(ii) Determine the shear stress acting on the wall by the fluid.
Tentukan tegasan ricih oleh bendalir yang bertindak pada dinding.

(15 marks/*markah*)

(iii) Determine the maximum velocity of the fluid.
Tentukan halaju maksimum bendalir.

(15 marks/*markah*)

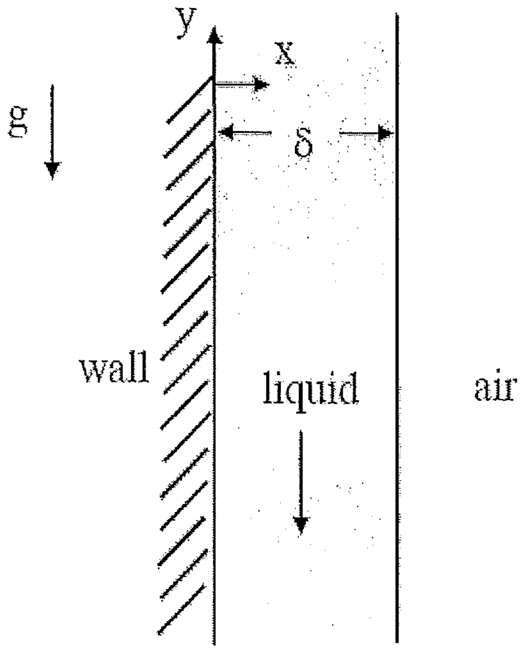

Figure 4 - A Newtonian liquid flows down a vertical wall
Rajah 4 - Cecair Newtonian mengalir ke bawah dinding menegak

PART B / *BAHAGIAN B*

5. [a] Calculate the dehumidification of water in air by estimating the flux constant given below. It is given the following parameters: P_{H20}= 0.05 psi, P_{air}= 16.0 psi, water film temperature (T_F) = 110°F, x_{H2O}= 0.010, k= 25.5E-5 $W.cm^{-1}.K^{-1}$, $D_{(H20\text{-}air)}$ = 0.346 $cm^2.s^{-1}$, $C_{p(H2O)}$ = 8.00 $cal.g^{-1}.mol^{-1}.K^{-1}$ and δ =1.05.

$$\frac{N_{Ay}\tilde{C}_{pA}\delta}{k}$$

Kirakan penyahlembapan air di dalam udara dengan menganggar pemalar fluks yang diberikan. Parameter yang ada ialah, P_{H20}= 0.05 psi, P_{air}= 16.0 psi, suhu filem air (T_F) = 110°F. x_{H2O}= 0.010, k= 25.5E-5 $W.cm^{-1}.K^{-1}$, $D_{(H20\text{-}udara)}$ = 0.346 $cm^2.s^{-1}$, $C_{p(H2O)}$ = 8.00 $cal.g^{-1}.mol^{-1}.K^{-1}$ dan δ =1.05.

(50 marks/*markah*)

[b] Compute the thermal conductivity of a mixture containing 30 mole % CO_2 and 70 mole % H_2 at 1 atmosphere and 280 K.

Kirakan kekonduksian haba untuk campuran yang mempunyai 30 mol % CO_2 dan 70 mol % H_2 pada tekanan 1 atmosfera pada suhu 280 K

Component	M	μ (x10^5), Pa.s	k, $W.m^{-1}.K^{-1}$
H_2	2	1.1944	0.1589
CO_2	44	1.806	0.01261

Table 1 : Gas properties at 280 K
Jadual 1 : Sifat gas pada suhu 280 K

(50 marks/*markah*)

6. [a] Explain the following items;

(i) Diffusion through a stagnant film

(ii) Hydrodynamic theory

(iii) Fourier's Law of Heat Conduction

(iv) Steady State versus Transient State Heat Transfer

(vi) Prandtl number

Terangkan perkara di bawah;

(i) Resapan melalui filem bertakung

(ii) Teori hidrodinamik

(iii) Hukum konduksi terma Fourier

(iv) Kekonduksian haba keadaan mantap dan pada keadaan sementara

(v) Nombor Prandtl

(50 marks/*markah*)

[b] Insulating power of a wall is given in Figure 5 below. The "insulating power" of a wall can be measured by means of the arrangement shown in the Figure 6. One places a plastic panel against the wall. In the panel, two thermocouples are mounted flush with the panel surfaces. The thermal conductivity and thickness of the plastic panel are known. From the measured steady-state temperatures shown in the Figure, estimate in SI units the following properties. It is given 1 Btu = 1055.056 J.

Kekuatan penebatan sebuah dinding diberikan pada Rajah 5 di bawah. kekuatan penebat dinding di ukur pada tempat yang di tandakan pada Rajah tersebut. Pada tempat ukuran T_2, panel plastik bersentuhan dinding. Pada panel plastik, dua thermometer dipasang pada permukaan panel. Konduktiviti haba dan ketebalan untuk panel plastik diketahui. Daripada ukuran suhu pada keadaan mantap, anggarkan sifat-sifat di bawah pada unit SI. Diberi 1 Btu = 1055.056 J.

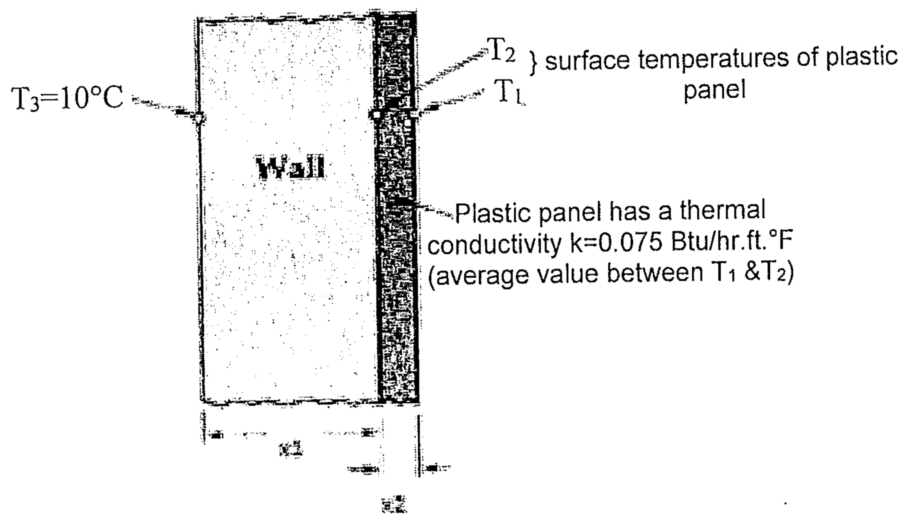

Figure 5: Determination of the thermal resistance of a wall. T_1 =50°C, T_2 =60°C, T_3 =10°C, x1= 3 cm and x2= 0.25 cm.

Rajah 5: Penentuan rintangan haba pada dinding. T_1 =50°C, T_2 =60°C, T_3 =10°C, x1= 3 cm dan x2 = 0.25 cm.

(i) The steady-state heat flux through the wall (and panel).

Keadaan mantap fluk haba melalui dinding (dan panel)

(30 marks/*markah*)

(ii) The "thermal resistance" value.

Nilai rintangan haba

(20 marks/*markah*)

7. [a] Predict D_{AB} for chlorine-air mixtures at 55°F and 1 atm. Treat air as a single substance with Lennard-Jones parameters as given Table 2 below. Use the Chapman-Enskog theory to solve this problem.

Jangkakan D_{AB} untuk campuran klorin-udara pada suhu 55°F dengan tekanan 1 atm. Anggapkan udara sebagai satu bahan dengan parameter Lennard-Jones yang dipaparkan dalam Jadual 2 di bawah. Gunakan teori Chapman-Enskog untuk menyelesaikan masalah ini.

Table 2 : Lennard-Jones parameters for Octane-Air mixture

Jadual 2 : Parameter Lennard-Jones untuk campuran oktana-udara

Component	M	σ, Angstrom	ε/k, K
C_8H_{18} (octane)	114.24	7.035	361
Air	28.97	3.617	97

(40 marks/*markah*)

[b] Consider a surface-mount type transistor on a circuit board as shown in Figure 6 whose temperature is maintained at 35°C. Air at 20°C flows over the upper surface with dimensions 4 mm by 8 mm with a convection coefficient of 50 $W/m^2.K$. Three wire leads, each of cross section 1 mm by 0.25 mm and length 4 mm, conduct heat from the case to the circuit board. The gap between the case and the board is 0.2 mm. Assuming the case is isothermal and neglecting radiation, estimate the case temperature when 150 mW was dissipated by the transistor at the following conditions.

Pertimbangkan satu transistor permukaaan di atas papan litar pada Rajah 6 di mana suhu di kekalkan pada 35°C. Suhu udara ialah 20°C mengalir di atas permukaan yang berdimensi 4 mm kali 8 mm dengan pemalar perolakan sebanyak 50 $W/m^2.K$. Tiga wayar penyambung dengan keratan rentas sebanyak 1 mm kali 0.25 mm dengan panjang 4 mm digunakan untuk mengalir haba kepada papan litar. Jarak antara papan litar dan transistor ialah 0.2 mm. Dengan mengandaikan pengaliran haba secara isoterma dan tiada penyinaran, anggarkan suhu transistor apabila 150 mW haba hilang pada keadaan di bawah.

(i) Stagnant air
Udara bergenang

(30 marks/*markah*)

(ii) A conductive paste fills the gap. The thermal conductivities of the wire leads, air, and conductive paste are 25, 0.0263, and 0.12 W/m.K, respectively.

Pes pengalir haba dengan pekali kebolehaliran terma untuk wayar, udara dan dakwat sebanyak 25, 0.0263 dan 0.12 W/m.K.

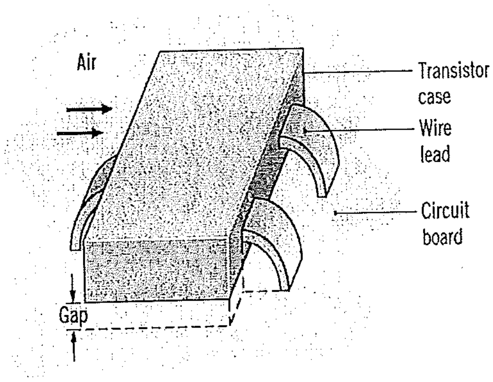

Figure 6 : A surface mount type transistor.

Rajah 6 : Permukaan transistor

(30 marks/*markah*)

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APPENDIX 1

LAMPIRAN 1

Formulas:

1 Btu= 1055.056 J, 1 ft= 0.305 m,

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

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

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

$$\Phi_{\alpha\beta} = \frac{1}{\sqrt{8}}\left(1+\frac{M_\alpha}{M_\beta}\right)^{-1/2}\left[1+\left(\frac{\mu_\alpha}{\mu_\beta}\right)^{1/2}\left(\frac{M_\beta}{M_\alpha}\right)^{1/4}\right]^2$$

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

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

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

Mass Transport

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

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

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

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

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

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

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

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

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