Second Semester Examination
2017/2018 Academic Year

May/June 2018

MSG422 - Fluid Mechanics
[Mekanik Bendalir]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of SIX (6) pages of printed material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM (6) muka surat yang bercetak sebelum anda memulakan peperiksaan ini.]

Instructions: Answer **all FOUR** (4) questions.

*[**Arahan**: Jawab **semua EMPAT** (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.]

Question 1

(a) Define

(i) Newtonian fluid,
(ii) no-slip condition,
(iii) bulk modulus,
(iv) streamline,
(v) fluid.

(b) A velocity distribution is given by $\mathbf{V} = y^2\,\hat{\mathbf{i}} - 2xt\,\hat{\mathbf{j}}$ m/s.

(i) Describe the flow with the velocity distribution above.
(ii) Obtain the equation for the streamline passing through (2 m, 3 m) at $t = 3$ s.
(iii) Find the acceleration at the point (2 m, 1 m) at $t = 5$ s.

[20 marks]

Soalan 1

(a) Takrifkan

(i) bendalir Newtonan,
(ii) syarat tanpa gelincir,
(iii) modulus pukal,
(iv) garis strim,
(v) bendalir.

(b) Suatu taburan halaju diberi oleh $\mathbf{V} = y^2\,\hat{\mathbf{i}} - 2xt\,\hat{\mathbf{j}}$ *m/s.*

(i) Terangkan aliran dengan taburan halaju di atas.
(ii) Dapatkan persamaan bagi garis strim yang melalui (2 m, 3 m) pada $t = 3$ *s.*
(iii) Cari pecutan pada titik (2 m, 1 m) pada $t = 5$ *s.*

[20 markah]

Question 2

The Reynolds transport theorem for the rate of change of an extensive integral quantity is given by

$$\frac{\mathrm{D}N_{\mathrm{sys}}}{\mathrm{D}t} = \frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathrm{c.v.}} \eta\rho \ \mathrm{d}\forall + \int_{\mathrm{c.s.}} \eta\rho\hat{\mathbf{n}}\cdot\mathbf{V} \ \mathrm{d}A,$$

where N_{sys} represents an integral quantity, η is the property of the system per unit mass, ρ is the density of the fluid, $\mathrm{d}\forall$ is the volume occupied by the fluid particle, $\hat{\mathbf{n}}$ is a unit vector normal to the area element $\mathrm{d}A$ and $\mathbf{V}$ is the velocity vector.

(a) State the Newton's second law.

(b) Based on the above equation, derive the momentum equation for a steady uniform fluid flow through a device with one inlet and one outlet. State all the assumptions made.

(c) Air flows steadily between two cross sections (1) and (2) inside a long, straight pipe of 6 cm diameter. At section (1), the average air velocity is 65 m/s with 704 kPa pressure and 319 K temperature. At section (2), the average air velocity is 240 m/s with 150 kPa pressure and 251 K temperature. Determine the frictional force exerted by the pipe wall on the airflow between section (1) and (2), assuming the uniform velocity distributions at these two sections. Take gas constant $R = 287$ J/kg ·K.

[25 marks]

Soalan 2

Teorem angkutan Reynolds bagi kadar perubahan kuantiti penting ekstensif diberi oleh

$$\frac{\mathrm{D}N_{sys}}{\mathrm{D}t} = \frac{\mathrm{d}}{\mathrm{d}t}\int_{c.v.} \eta\rho \ \mathrm{d}\forall + \int_{c.s.} \eta\rho\hat{\mathbf{n}}\cdot\mathbf{V} \ \mathrm{d}A,$$

dengan N_{sys} mewakili kuantiti penting, η ialah cirian sistem per unit jisim, ρ ialah ketumpatan bendalir, $\mathrm{d}\forall$ ialah isipadu zarah bendalir, $\hat{\mathbf{n}}$ ialah vektor unit normal kepada unsur luas $\mathrm{d}A$ dan $\mathbf{V}$ ialah vektor halaju.

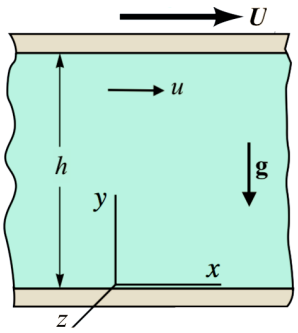
(a) Nyatakan hukum Newton kedua.

(b) Berdasarkan persamaan di atas, terbitkan persamaan momentum bagi suatu aliran mantap bendalir yang seragam melalui suatu peranti dengan satu salur masuk dan satu salur keluar. Nyatakan kesemua andaian yang dibuat.

(c) Suatu aliran mantap udara melalui keratan rentas (1) dan (2) di dalam suatu paip yang panjang dan lurus berdiamater 6 cm. Pada keratan (1), halaju purata udara ialah 65 m/s dengan tekanan 704 kPa dan suhu 319 K. Pada keratan (2), halaju purata udara ialah 240 m/s dengan tekanan 150 kPa dan suhu 251 K. Dapatkan daya geseran yang dikenakan oleh dinding paip ke atas aliran udara di antara keratan (1) dan (2), dengan mengandaikan bahawa taburan halaju pada kedua-dua keratan adalah seragam. Ambil pemalar gas $R = 287$ J/kg ·K.

[25 markah]

Question 3



(a) Consider a steady flow of an incompressible Newtonian fluid between the two horizontal, infinite parallel plates a distance h apart. The fluid flows only in the x direction, parallel to the plates. The lower plate is fixed but the upper plate moves with constant velocity U. Using the continuity equation

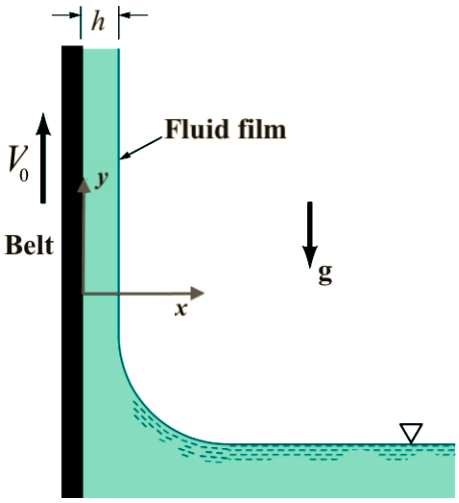
$$\nabla \cdot \mathbf{V} = \mathbf{0},$$

and the Navier-Stokes equation

$$\rho \frac{\mathrm{D}\mathbf{V}}{\mathrm{D}t} = -\nabla p + \rho \mathbf{g} + \mu \nabla^2 \mathbf{V},$$

where $\mathbf{V}$ is the velocity of the fluid, t denotes time, ρ is the density of the fluid, p is the pressure, $\mathbf{g}$ is the gravitational force and μ is the viscosity of the fluid, with proper boundary conditions, determine the velocity profile of the flow.

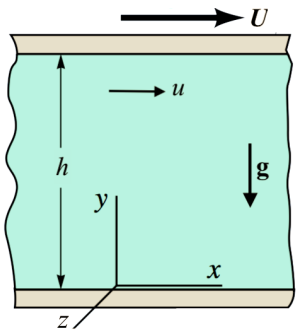
(b) A wide moving belt passes through a container of a viscous, incompressible fluid. The belt moves vertically upward with a constant velocity V_0. It picks up a film of fluid of thickness h because of viscous force, whereas gravitational force tends to drain fluid down the belt. Assume that the flow is steady, laminar and fully developed, with zero shearing stress on the film surface. Using the Navier-Stokes equation, determine the expression for the average velocity of the fluid film.



(c) Consider a plane flow in which only the x- and y- components are nonzero, with viscous and gravity effects are negligible. Using a differential momentum equations for incompressible uniform flow, find the expression for the pressure gradient, ∇p.

[30 marks]

Soalan 3



(a) *Pertimbangkan suatu aliran mantap bendalir Newtonan yang tak mampat di antara dua plat selari yang mengufuk, tak terhingga dan berjarak h antara satu sama lain. Bendalir tersebut mengalir hanya pada arah x, selari dengan plat. Plat bawah pegun, manakala plat atas bergerak dengan kelajuan malar U. Menggunakan persamaan keselanjaran*

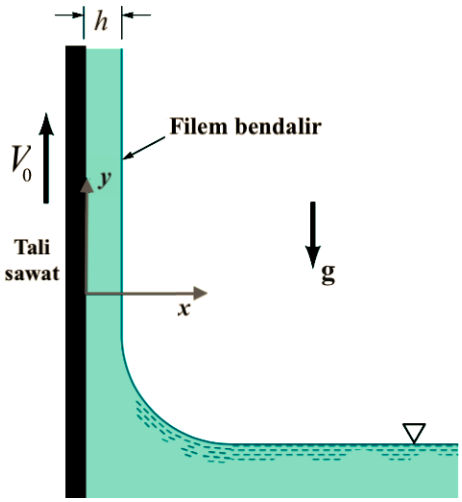
$$\nabla \cdot \mathbf{V} = \mathbf{0},$$

dan persamaan Navier-Stokes

$$\rho \frac{\mathrm{D}\mathbf{V}}{\mathrm{D}t} = -\nabla p + \rho \mathbf{g} + \mu \nabla^2 \mathbf{V},$$

dengan $\mathbf{V}$ *ialah halaju bendalir,* t *mewakili masa,* ρ *ialah ketumpatan bendalir,* p *ialah tekanan,* $\mathbf{g}$ *ialah daya graviti dan* μ *ialah kelikatan bendalir, beserta syarat-syarat sempadan yang bersesuaian, dapatkan profil halaju bagi aliran tersebut.*

(b) *Tali sawat lebar bergerak melalui suatu bekas yang mengandungi bendalir likat tak mampat. Tali itu bergerak menegak ke atas dengan halaju malar* V_0*. Ia akan mengumpulkan filem bendalir berketebalan h disebabkan oleh daya likat, manakala daya graviti pula menyebabkan bendalir mengalir menuruni tali sawat. Anggapkan bahawa aliran tersebut mantap, berlamina dan terbangun penuh, dengan tegasan ricih sifar pada permukaan filem. Dengan menggunakan persamaan Navier-Stokes, dapatkan ungkapan bagi halaju purata filem bendalir tersebut.*



(c) *Pertimbangkan aliran satah dengan komponen-komponen x dan y bukan sifar, beserta kesan likat dan graviti boleh diabaikan. Menggunakan persamaan pembezaan momentum bagi aliran seragam tak mampat, dapatkan ungkapan bagi kecerunan tekanan,* ∇p*.*

[30 markah]

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Question 4

The mass flux entering the fixed infinitesimal control volume of a fluid in the positive x-direction is given as

$$\left[\rho u - \frac{\partial(\rho u)}{\partial x}\frac{\mathrm{d}x}{2}\right] \mathrm{d}y\ \mathrm{d}z,$$

where ρ represents the density of the fluid.

(a) Derive the three-dimensional differential continuity equation. State all the assumptions made.

(b) The radial velocity component in an incompressible, two-dimensional flow field (where $v_z = 0$) is $v_r = 4r^2 - 3r\cos\theta$. What is the corresponding tangential velocity component, v_θ required to satisfy the conservation of mass principle? [The differential continuity equation in cylindrical coordinate: $\frac{1}{r}\frac{\partial}{\partial r}(rv_r) + \frac{1}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{\partial v_z}{\partial z} = 0$.]

(c) The stream function for a two-dimensional, inviscid, incompressible flow field is

$$\psi = -3.7(x-y).$$

(i) Is the continuity equation satisfied?
(ii) Is the flow field irrotational? If so, find the corresponding velocity potential.
(iii) Find the pressure gradient in the horizontal x direction at the point $x = y = 0.4$.

[25 marks]

Soalan 4

Fluks jisim yang memasuki unsur isipadu kawalan tetap bagi bendalir dalam arah x positif diberi oleh

$$\left[\rho u - \frac{\partial(\rho u)}{\partial x}\frac{\mathrm{d}x}{2}\right] \mathrm{d}y\ \mathrm{d}z,$$

dengan ρ mewakili ketumpatan bendalir.

(a) Terbitkan persamaan pembezaan keselanjaran tiga dimensi. Nyatakan kesemua andaian yang dibuat.

(b) Komponen halaju jejarian dalam suatu medan aliran tak mampat dua dimensi (yang mana $v_z = 0$) diberi oleh $v_r = 4r^2 - 3r\cos\theta$. Apakah komponen halaju tangen, v_θ yang sepadan yang diperlukan bagi memenuhi prinsip pengabadian jisim? [Persamaan pembezaan keselanjaran dalam koordinat silinder: $\frac{1}{r}\frac{\partial}{\partial r}(rv_r) + \frac{1}{r}\frac{\partial v_\theta}{\partial \theta} + \frac{\partial v_z}{\partial z} = 0$.]

(c) Fungsi strim bagi medan aliran dua dimensi, tak likat dan tak mampat diberi oleh

$$\psi = -3.7(x-y).$$

(i) Adakah persamaan keselanjaran dipenuhi?
(ii) Adakah medan aliran ini tak berputar? Jika ya, cari keupayaan halaju yang sepadan.
(iii) Cari kecerunan tekanan dalam arah x yang mengufuk pada titik $x = y = 0.4$.

[25 markah]

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