Second Semester Examination
Academic Session 2018/2019

June 2019

EMH 222 – Fluid Dynamics
[Dinamik Bendalir]

Duration : 3 hours
[Masa : 3 jam]

Please check that this paper contains **TWELVE [12]** printed pages including appendix before you begin the examination.

*[Sila pastikan bahawa kertas soalan ini mengandungi **DUABELAS [12]** mukasurat bercetak beserta lampiran sebelum anda memulakan peperiksaan.]*

INSTRUCTIONS : Answer **ALL FIVE [5]** questions.
*[**ARAHAN** : Jawab **SEMUA LIMA [5]** 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.]

Thermodynamic Booklet is provided.
Buku Termodinamik adalah dibekalkan.

1. [a] **What is significant about curves of constant stream function? Discuss the flow at cross section A and at section B based on the streamlines depicted in Figure 1[a].**

Apakah kepentingan keluk fungsi aliran malar? Bincangkan aliran rentas Seksyen A dan Seksyen B berdasarkan garis arus yang digambarkan dalam Rajah 1[a].

(20 marks/*markah*)

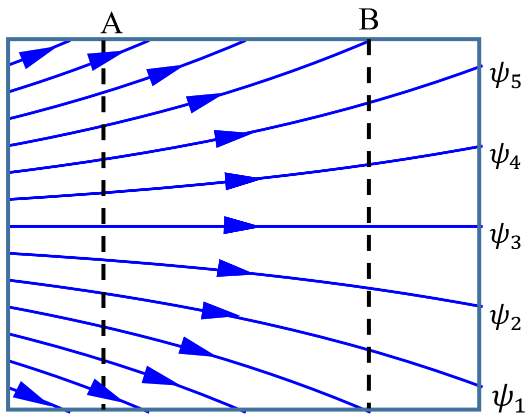

Figure 1[a]
Rajah 1 [a]

[b] **What is the distinction between a Newtonian fluid and a non-Newtonian fluid? Name at least three Newtonian and non-Newtonian fluids.**

Apakah perbezaan di antara bendalir Newtonian dan bendalir tak Newtonian? Namakan sekurang-kurangnya tiga bendalir Newtonian dan tak Newtonian?

(15 marks/*markah*)

[c] **The general control volume form of the linear momentum equation is:**

Bentuk isipadu kawalan umum persamaan linear momentum ialah:

$$\int_{CV} \rho \vec{g} d\mathcal{V} + \int_{CS} \sigma_{ij} . \vec{n}\, dA = \int_{CV} \frac{\partial}{\partial t} (\rho \vec{V}) d\mathcal{V} + \int_{CS} (\rho \vec{V}) \vec{V} . \vec{n}\, dA$$

I II III IV

Define the momentum equation. Name the four labeled terms.
Tentukan persamaan momentu. Namakan empat istilah yang berlabel.

(15 marks/*markah*)

[d] **A thin flat plate is placed in between two parallel plates (top and bottom) as shown in Figure 1[d]. The distance separating this thin flat plate with both parallel plates is *h*. Apart from having a stationary top plate, the thin flat plate is moving at the velocity of *U* and the bottom plate is moving to the left at a velocity of 0.2*U*.**

Satu plat nipis diletakkan di antara dua plat selari (atas dan bawah) seperti yang ditunjukkan dalam Rajah 1[d]. Jarak memisahkan plat ini dengan kedua-dua plat selari ialah h. Selain daripada plat atas tidak bergerak, plat nipis itu bergerak pada halaju U, manakala plat bawah bergerak ke kiri pada halaju 0.2U.

Show that the governing equation can be simplified to $\frac{d^2u}{dy^2} = 0$.

Tunjukkan bahawa persamaan pentadbiran dapat diringkaskan ke $\frac{d^2u}{dy^2} = 0$.

Also, plot the resulting velocity profile. Given, U is 10 m/s.

Juga, plotkan profil halaju terhasil. Diberi, U ialah 10 m/s.

(50 marks/*markah*)

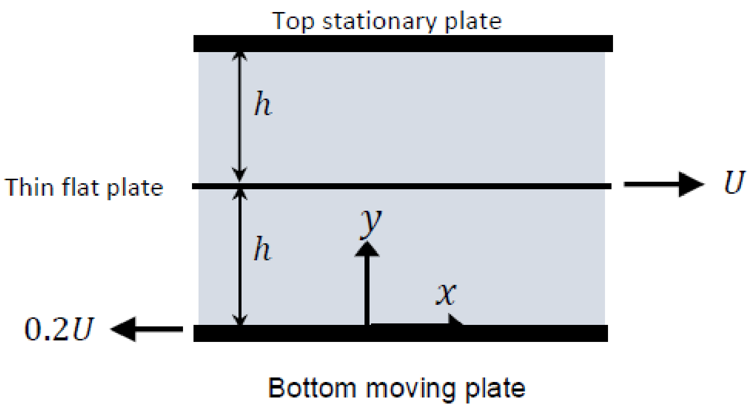

Figure 1[d]
Rajah 1 [d]

2. [a] **In the non-dimensionalized incompressible Navier-Stokes equation, there are four non-dimensional parameters. Label each parameter and explain its physical significance when the parameter is very small or large?**

Dalam persamaan Navier-Stokes tanpa dimensi, terdapat empat parameter tanpa dimensi. Labelkan setiap parameter dan terangkankepentingan fizikal apabila parameter adalah sangat kecil atau besar?

$$\left[\frac{fL}{V}\right]\frac{\partial \vec{V}^*}{\partial t^*}+\left(\vec{V}^*\cdot\vec{\nabla}^*\right)\vec{V}^*=-\left[\frac{P_0-P_\infty}{\rho V^2}\right]\vec{\nabla}^*P^*+\left[\frac{gL}{V^2}\right]\vec{g}^*+\left[\frac{\mu}{\rho VL}\right]\nabla^{*2}\vec{V}^*$$

(20 marks/*markah*)

[b] **Derive whether the following flow is rotational or irrotational?**

Takrifkan sama ada aliran berikut adalah berputar atau tak berputar?

(i) $\phi = x^2 - y^2 + z^2$

(ii) $\phi = sin(x + y + z)$

(30 marks/*markah*)

[c] **Air flows over a smooth flat plate with a free-stream velocity of 10 m/s (as shown in Figure 2c). The streamwise velocity component of the steady, incompressible and laminar flow can be approximated by a simple expression:**

Udara merentasi satu plat rata licin dengan halaju aliran bebas 10 m/s (seperti yang ditunjukkan dalam Rajah Q2c). Dalam aliran yang mantap, tak termampat dan laminar, komponen halaju boleh dianggarkan dengan ungkapan mudah:

$$\frac{u}{U}=\left(\frac{y}{\delta}\right)-\left(\frac{y}{\delta}\right)^2$$

Where U is the free-stream velocity and δ is the boundary layer thickness. Calculate:

Di mana U adalah halaju aliran bebas dan δ ketebalan lapisan sempadan. kirakan:

(i) **The thickness of the laminar boundary layer at 50 cm from the leading edge.**
Ketebalan lapisan sempadan laminar pada 50 cm daripada tepi depan

(ii) **The local velocity and the velocity gradient at (x,y) = (0.5, 0.001), located 50 cm from the leading edge and 0.1 cm above the plate.**
Halaju setempat dan kecerunan halaju pada (x, y) = (0.5, 0.001), terletak 50 cm dari tepi depan dan 0.1 cm di atas plat.

Given, the air density and dynamic viscosity are $\rho_{air} = 1.2\text{kg/ m}^3$ and $\mu_{air} = 1.9 \times 10^{-5}\text{Ns/m}^2$.

Diberi, ketumpatan udara dan kelikatan dinamik ialah $\rho_{udara} = 1.2kg/m^3$ dan $\mu_{udara} = 1.9 \times 10^{-5} Ns/m^2$.

(50 marks/*markah*)

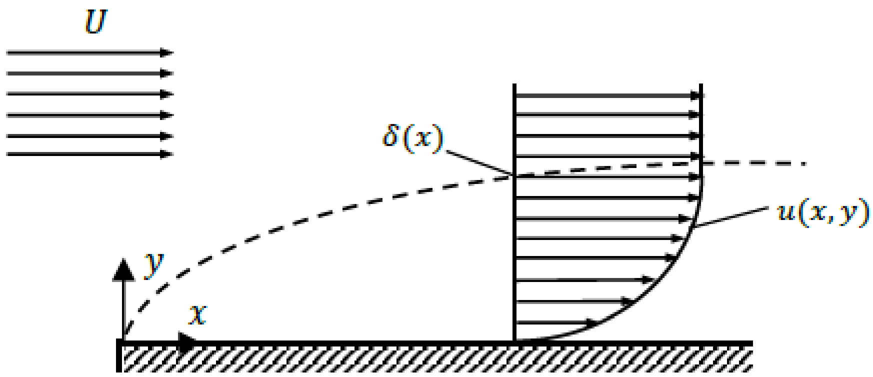

Figure 2[c]
Rajah 2 [c]

3. [a] **A 3.5 mm spherical plastic sphere with a density of 1100 kg/m^3 is dropping into water at 30°C. By assuming the fluid flow over the sphere is laminar and the drag coefficient is constant, calculate the terminal velocity of the sphere in water.**
(Given: The drag coefficient for sphere in laminar flow, C_D=0.5)

Satu sfera 3.5 mm plastik yang berketumpatan 1100 kg/ m^3 sedang jatuh ke dalam air pada 30°C. Dengan mengandaikan aliran bendalir keatas sfera ialah laminar dan pekali seretan malar, kirakan halaju terminal sfera dalam air.
(*Diberikan : Koefisien seret untuk sfera dalam aliran laminar C_D=0.5*)

(30 marks/*markah*)

[b] **Consider a circular sign with diameter 55cm as shown in Figure 3 subjected to normal air up to 160 km/h at 115 kPa and 10°C. The air flow is steady, incompressible and turbulent. If the drag force on the pole is negligible, calculate:**

Pertimbangkan sebuah papan tanda bulatan yang berdiameter 55 cm seperti yang ditunjukkan dalam Rajah 3 dikenakan udara normal sehingga 160 km/h pada 115 kPa dan 10°C. Aliran udara ialah mantap, tak boleh mampat dan bergelora. Jika daya seret ke atas tiang diabaikan, kirakan:

(i) **Drag force acting on the sign.**
Daya seret yang bertindak pada papan tanda

(ii) Bending moment at the bottom of the pole if the height from the ground to the bottom of the sign is 1.3 m.
Momen lentur pada bahagian bawah tiang jika ketinggian daripada tanah ke bahagian bawah papan tanda tersebut ialah 1.3 m.

(Given: Drag coefficient for a thin circular disk is C_D = 1.1)

(Diberi: Pekali seretan untuk cakera nipis bulatan ialah C_D= 1.1)

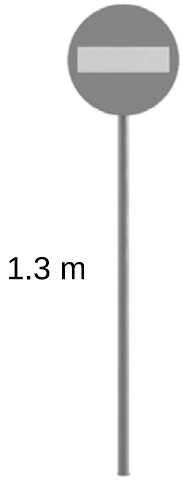

Figure 3[b]
Rajah 3[b]

(30 marks/*markah***)**

[c] A tennis ball with a diameter of 6.5 cm and a mass of 52 g is hit with an initial velocity of 80 km/h and a backspin of 4000 rpm as shown in Figure 3 [c] . The outer surface of the ball is smooth and the racquet hit the ball horizontally. Given the density and kinematic viscosity of the air at 1 atm and are 1.184 kg/m^3 and ν = 1.562 x 10^{-5} m^2/s.

Sebiji bola tenis berdiameter 6.5 cm yang berjisim 52 g dipukul dengan laju awal 80 km/j dan pusingan belakang 4000 rpm seperti ditunjukkan dalam Rajah 3 [c]. Permukaan luar bola itu lembut dan raket memukul bola dalam keadaan mendatar. Diberikan ketumpatan dan kelikatan kinematik bagi udara pada 1 atm sebagai 1.184 kg/m^3 and ν = 1.562 x 10^{-5} m^2/s.

(i) Calculate the Lift
Kirakan daya angkat

(ii) By considering the effect of gravity and lift due to short spinning, determine the condition of the ball (fall or rise).
Dengan mengambil kira kesan graviti dan daya angkat yang disebabkan pusingan pendek, tentukan keadaan bola (jatuh atau naik).

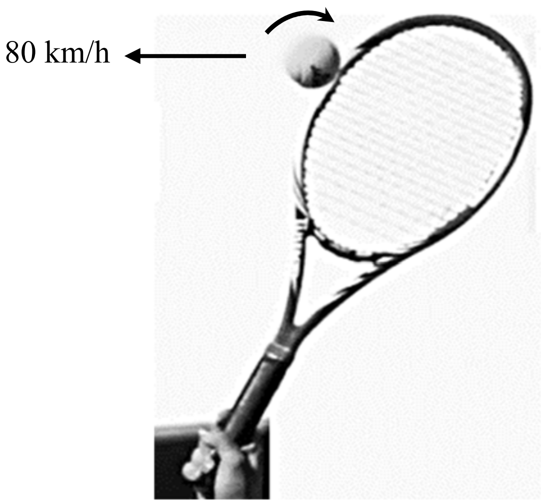

Figure 3 [c]
Rajah 3[c]

(40 marks/*markah*)

4. [a] Define Mach number.
Terangkan nombor Mach.

(20 marks/*markah*)

[b] In a supersonic wind tunnel, air is flowing with low velocity through a converging-diverging nozzle at temperature 300 K and pressure 1.5 MPa. At the exit nozzle, the normal shock wave occurs at Mach number, Ma= 2.5. By assuming the air is an ideal gas with constant specific heats and the flow is steady, calculate the Mach number, pressure, temperature, and velocity downstream the shock.

(Given: the properties of air, R = 0.287 kJ/kg.K, and k=1.4)

Di dalam terowong angin supersonik, udara sedang mengalir dengan halaju rendah melalui muncung menumpu-mencapah pada suhu 300 K dan tekanan 1.5 MPa. Pada bahagian keluar muncung, gelombang kejutan normal berlaku pada nombor Mach, Ma = 2.5. Dengan mengandaikan udara ialah gas unggul dengan haba tentu yang malar dan aliran adalah mantap, kirakan nombor Mach, tekanan, suhu dan halaju selepas kejutan

(Diberkan: sifat-sifat udara, R= 0.287 kJ/kg.K, dan k = 1.4)

(60 marks/*markah*)

[c] Give TWO (2) differences between oblique shocks and normal shocks.

*Berikan **DUA** (2) perbezaan tentang kejutan oblik dan kejutan normal.*

(20 marks/*markah*)

5. [a] Define the following terms:
Takrifkan istilah-istilah berikut:

(i) pump,
pam,
(ii) turbine,
turbin,
(iii) positive-displacement machines, and
mesin sesaran positif,
(iv) dynamic machines.
mesin dinamik.

(20 marks/*markah*)

[b] At a hydroelectric power station, the gross head from the reservoir the tailrace is 100 m and the volume flow rate of water through each turbine is 138 m^3/s at 20°C. There are 15 identical parallel turbines, each with an efficiency of 93.2%, and all other mechanical energy losses are estimated to reduce the output by 2.5%. The generator has an efficiency of 93.5%. Assume the turbines are working at their best efficiency point, and the diameter of the turbine is *D* =1.80 m, and spins at *n* = 180 rpm. Assuming the density of water at 20°C is 998 kg/m3.

Di satu stesen janakuasa hidroelektrik, turus kasar dari takungan ke alur limpah ialah 100 m dan kadar aliran isipadu air melalui setiap turbin ialah 138 m^3/s pada 20°C. Terdapat 15 turbin selari yang serupa, masing-masing dengan kecekapan sebanyak 93.2%, dan semua kerugian tenaga mekanikal lain dianggarkan mengurangkan keluaran sebanyak 2.5%. Penjana berkecekapan sebanyak 93.5%. Anggapkan turbin bekerja pada titik kecekapan yang terbaik, dan diameter turbin ialah D = 1.80 m, dan berputar pada n = 180 rpm. Anggap ketumpatan air pada 20°C ialah 998 kg/m^3.

Calculate:
Kirakan:

(i) brake horsepower of each existing turbine,
kuasa kuda brek untuk setiap turbin yang sedia ada,

(ii) **the total electric power production from the station in MW by using the existing turbines.**
jumlah kuasa elektrik yang terjana dari stesen dalam MW dengan menggunakan turbin yang sedia ada.

(30 marks/*markah***)**

If you are required to retrofit the turbines by scaling up the existing turbines. The new turbines will spin at 100 rpm and gross head is 130 m.

Jika anda diminta untuk naiktaraf turbin dengan peningkatan skala turbin yang sedia ada. Turbin baru akan berputar pada 100 rpm dan turus kasar ialah 130 m.

Calculate:
Kirakan:

(iii) **the diameter of the new turbine as it operates most efficiently,**
diameter turbin semasa ia beroperasi pada titik kecekapan yang terbaik,

(iv) **volumetric flow rate of water through each new turbine,**
kadar aliran isipadu air melalui setiap turbin baru,

(v) **brake horsepower of each new turbine,**
kuasa kuda brek untuk setiap turbin baru,

(vi) **the total electric power production from the plant in MW by using the new turbines.**
jumlah kuasa elektrik yang terjana dari stesen dalam MW dengan menggunakan turbin yang baru.

(50 marks/*markah***)**

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Appendix 1
Lampiran 1

Formula

1. $C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A}$

2. $C_L = \frac{F_L}{\frac{1}{2}\rho V^2 A}$

3. $F_D = W - F_B$

4. $W = \rho_S g V$

5. $F_B = \rho_f g V$

6. $Re = \frac{\rho V D}{\mu}$

7. $\rho = \frac{P}{RT}$

8. $M = F_D L$

9. No dimensional rate of rotation = $\omega D/2V$

10. $F_L = C_L A \frac{\rho V^2}{2}$

11. $Re_L = \frac{VD}{\nu}$

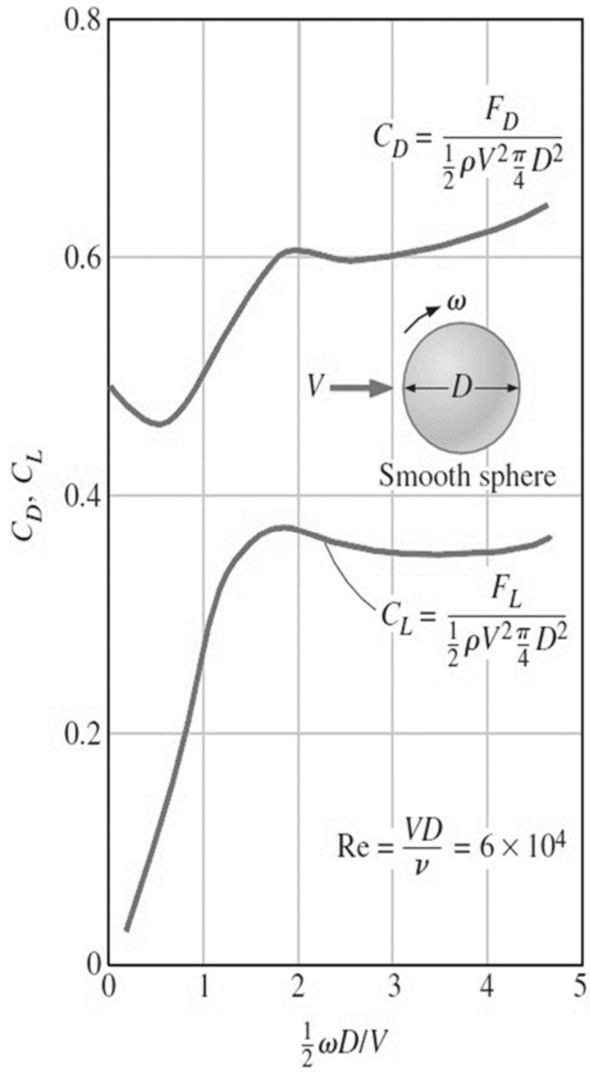
12. Sphere, $A=(\pi D^2)/4$

13. $\frac{T_o}{T} = 1 + \left(\frac{k-1}{2}\right) Ma^2$

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

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

Appendix 2
Lampiran 2



Appendix 3
Lampiran 3

Summary of expressions for laminar and turbulent boundary layer on a smooth flat plate aligned parallel to a uniform stream

Property	Laminar	Turbulent
Boundary layer thickness	$\frac{\delta}{x} = \frac{4.91}{\sqrt{Re_x}}$	$\frac{\delta}{x} = \frac{0.16}{(Re_x)^{1/7}}$
Displacement thickness	$\frac{\delta^*}{x} = \frac{1.72}{\sqrt{Re_x}}$	$\frac{\delta^*}{x} = \frac{0.020}{(Re_x)^{1/7}}$
Momentum thickness	$\frac{\theta}{x} = \frac{0.664}{\sqrt{Re_x}}$	$\frac{\theta}{x} = \frac{0.016}{(Re_x)^{1/7}}$
Local skin friction coefficient	$C_{f,x} = \frac{0.664}{\sqrt{Re_x}}$	$C_{f,x} = \frac{0.027}{(Re_x)^{1/7}}$

Water horsepower: $\dot{W}_{\text{water horsepower}} = \dot{m}gH = \rho g\dot{V}H$

Volume flow rate: $\dot{V} = 2\pi r_1 b_1 V_{1,n} = 2\pi r_2 b_2 V_{2,n}$

Tangential velocity, $V_{1,t} = V_{1,n} \tan\alpha_2$

Net head: $H = \frac{1}{g}(\omega r_2 V_{2,t} - \omega r_1 V_{1,t})$

Affinity laws

$$\frac{\dot{V}_B}{\dot{V}_A} = \frac{\omega_B}{\omega_A}\left(\frac{D_B}{D_A}\right)^3$$

$$\frac{H_B}{H_A} = \left(\frac{\omega_B}{\omega_A}\right)^2\left(\frac{D_B}{D_A}\right)^2$$

$$\frac{\text{bhp}_B}{\text{bhp}_A} = \frac{\rho_B}{\rho_A}\left(\frac{\omega_B}{\omega_A}\right)^3\left(\frac{D_B}{D_A}\right)^5$$