UNIVERSITI SAINS MALAYSIA

First Semester Examination
2015/2016 Academic Session

December 2015 / January 2016

EAH221– Fluid Mechanics for Civil Engineers

[*Mekanik Bendalir Untuk Jurutera Awam*]

Duration : 3 hours
[*Masa : 3 jam*]

Please check that this examination paper consists of **SEVENTEEN (17)** printed pages including **ONE (1)** appendix before you begin the examination.
*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **TUJUH BELAS (17)** muka surat yang bercetak termasuk **SATU (1)** lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper contains **SIX (6)** questions. Answer **FIVE (5)** questions.
*[**Arahan** : Kertas ini mengandungi **ENAM (6)** soalan. Jawab **LIMA (5)** soalan.]*

All questions **MUST BE** answered on a new page.
*[Semua soalan **MESTILAH** dijawab pada muka surat baru.]*

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

1. [a] Describe Newtonian Fluid and Non-Newtonian fluid and provide **TWO (2)** examples for each fluid type.

*Terangkan bendalir Newtonan dan bendalir bukan Newtonan dan berikan **DUA (2)** contoh bagi setiap jenis bendalir.*

[4 marks/*markah*]

[b] For a parallel plate arrangement, it is found that when the distance between plates is 2.5mm, a shearing stress of 170 kPa develops at the upper plate when it is pulled at a velocity of 1.8 m/s. Determine the kinematik viscosity of the fluid between the plates if the density of the fluid is 1.26 g/cm^3.

Untuk susunan plat selari, didapati bahawa apabila jarak antra plat ialah 2.5 mm, tegasan ricih 170 kPa terhasil pada plat atas apabila ia ditarik pada kelajuan 1.8 m/s. Tentukan kelikatan bendalir kinematik antara plat jika ketumpatan bendalir adalah 1.26 g/cm^3

[6 marks/*markah*]

[c] U-tube manometer is connected to a closed tank containing air and water as shown in **Figure 1**. If the local atmospheric pressure is 755 mm of mercury (S.G = 13.6). Determine:

*Manometer tiub-U disambungkan kepada tangki tertutup mengandungi udara dan air seperti yang ditunjukkan dalam **Rajah 1**. Jika tekanan atmosfera tempatan adalah 755 mm merkuri (SG = 13.6). Tentukan:*

[i] the absolute pressure of air in the tank
tekanan mutlak udara dalam tangki

[ii] the reading on the pressure gage
bacaan tekanan tolok

[10 marks/*markah*]

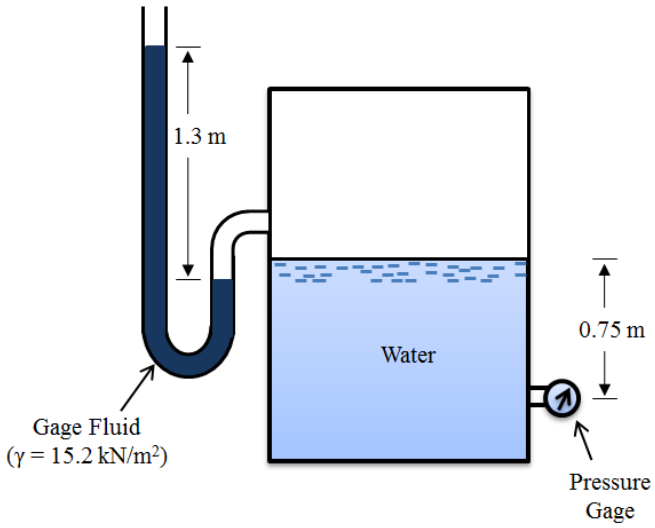


Figure 1 / *Rajah 1*

2. [a] Derive expression for average pressure and centre of pressure for a vertically immerse surface.

Terbitkan ungkapan untuk tekanan purata dan tekanan pusat permukaan menegak yang tenggelam.

[6 marks/*markah*]

[b] A rectangular tank wall with 1.2 m width that contains water has a shape as shown in **Figure 2**. Determine:

*Satu dinding tangki yang lebarnya 1.2 m mengandungi air mempunyai bentuk seperti yang ditunjukkan dalam **Rajah 2**. Tentukan:*

[i] Horizontal and vertical force on the curved section

Daya tekanan mendatar dan menegak yang bertindak di bahagian lengkung

[ii] Total resultant force and the angle of inclination

Jumlah daya tekanan dan sudut kecondongan

[8 marks/*markah*]

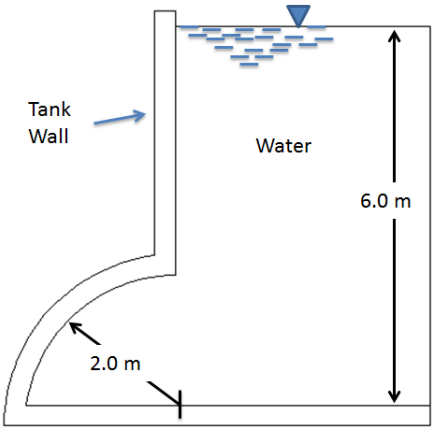


Figure 2 / *Rajah 2*

[c] A solid cylinder 2 m in diameter and 4 m high is floating in water with its axis vertical as shown in **Figure 3**. If the specific gravity of the material of a cylinder is 0.65, find its metacentric height. State also whether the equilibrium is stable or unstable.

*Sebuah pepejal silinder bergarispusat 2 m dan tinggi 4 m terapung di dalam air dengan paksinya menegak seperti di **Rajah 3**. Jika graviti tentu bahan silinder adalah 0.65, tentukan ketinggian pusatmeta pepejal silinder yang terapung itu. Nyatakan juga sama ada keseimbangan stabil atau tidak stabil.*

[6 marks/*markah*]

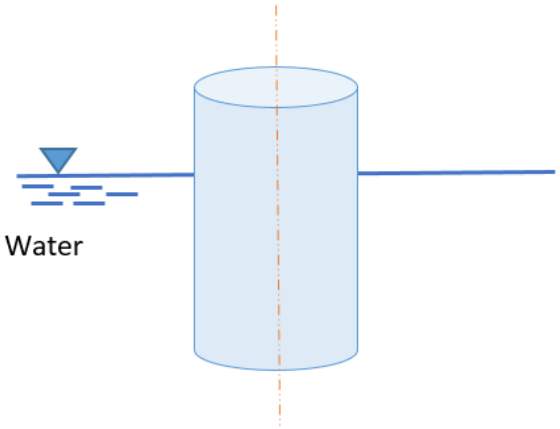


Figure 3 / *Rajah 3*

3. [a] Piezometric tubes are tapped into a venturi meter as shown in **Figure 4**. The liquid is incompressible. The piezometer heads are 1.5 meter at section 1 and 0.75 meter at section 2, respectively. Determine the velocity in section 2 if the cross-sectional area of section 2 is half the cross-section area in section 1.

*Tiub piezometric dipasang pada sebuah meter venturi seperti yang ditunjukkan dalam **Rajah 4**. Cecair yang mengalir adalah cecair tidak mampat. Turus piezometer adalah 1.5 meter di seksyen 1 dan 0.75 meter di seksyen 2. Tentukan halaju di seksyen 2 jika keluasan di seksyen 2 adalah separuh daripada seksyen 1 .*

[5 marks/*markah*]

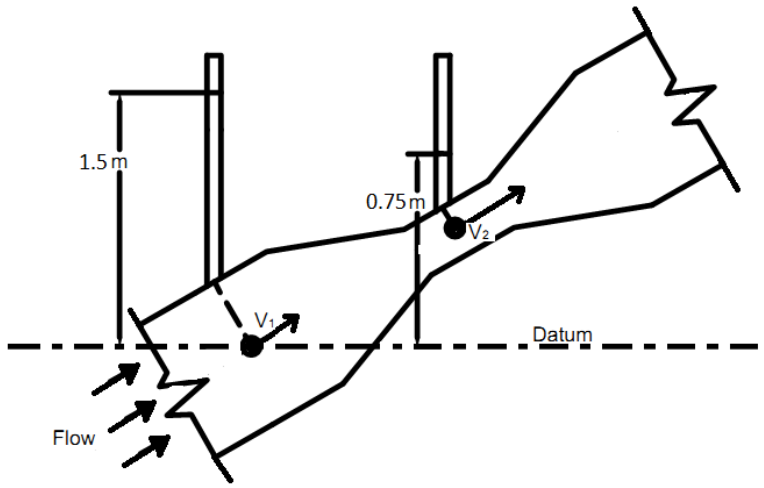


Figure 4 / *Rajah 4*: Venturi Meter

[b] A sluice gate is used to control the water flow rate over a dam as shown in **Figure 5**. The gate is 10 meter wide. The depth of the water upstream of the gate is 8.0 m and the head of the discharge is 1.2 m. Determine:

*Pintu air digunakan untuk mengawal kadar aliran air dari sebuah empangan seperti yang ditunjukkan dalam **Rajah 5**. Pintu air tersebut adalah 10 meter lebar. Kedalaman air di hulu pintu gerbang adalah 8.0 m dan kedalaman air buangan ialah 1.2 m. Tentukan:*

[i] the flow rate under the sluice gate
kadar aliran di bawah pintu sluis

[ii] the force on the gate
daya ke atas pintu air

[8 marks/*markah*]

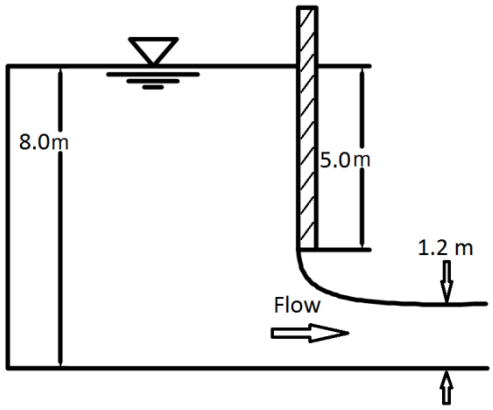


Figure 5 / *Rajah 5* : Sluice Gate

[c] A square tank is connected to a 40 cm diameter discharge pipe as shown in **Figure 6.** By neglecting the head losses, determine

*Sebuah tangki segiempat di sambungkan kepada sebatang paip bergarispusat 40 sm luahan seperti rajah **Rajah 6** dengan mengabaikan kehilangan turus, tentukan*

[i] the velocity at d_2 (V_1)
halaju pada d_2 (V_1)

[ii] the pressure and velocity at section B
tekanan dan halaju pada bahagian B

[7 marks/*markah*]

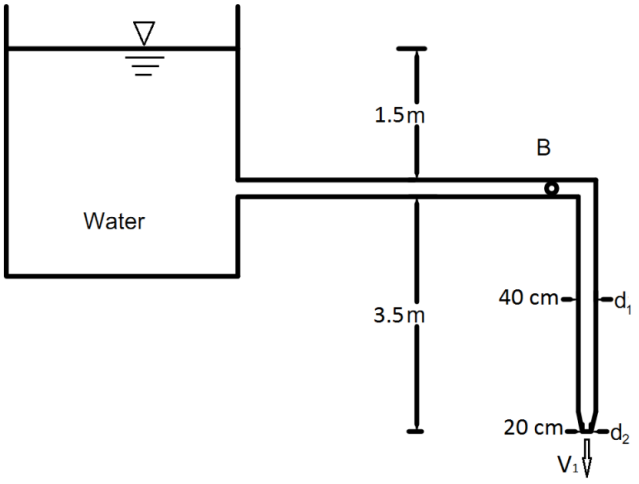


Figure 6 / *Rajah 6*

4. [a] An inflow into a reservoir is at a rate of 12,500 m^3/hr and the outflow rate at 7,500 m^3/hr as shown in **Figure 7**. Determine the rate of rise of water if the reservoir surface area is 125 km^2.

*Air mengalir ke dalam takungan pada kadar 12,500 m^3/jam dan kadar aliran keluar di 7,500 m^3/jam seperti yang dirujuk di **Rajah 7**. Tentukan kadar kenaikan air jika luas kawasan permukaan takungan adalah 125 km^2.*

[6 marks/*markah*]

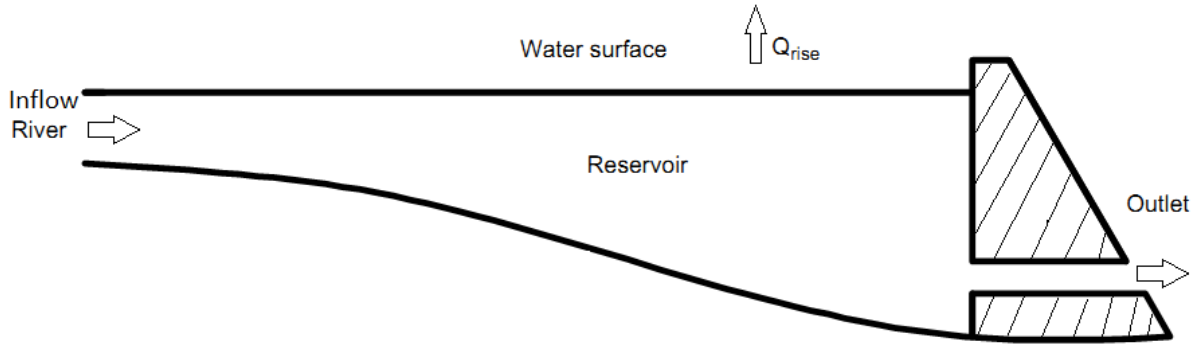


Figure 7 / *Rajah 7*

[b] A nozzle produces a water jet with a speed of 25 m/s with a cross-sectional area of 5 cm^2. The jet strikes a concrete block and the jet is deflected 90^o relative to the block as shown in **Figure 8**.

Muncung jet menghasilkan jet air dengan kelajuan 25 m/s dan luas keratan rentasnya adalah 5 sm^2. Jet tersebut menghentak sebuah bungkah konkrit dan pancutan jet dipesongkan 90^o berbanding dengan bungkah tersebut seperti yang ditunjukkan dalam ***Rajah 8****.*

[i] Determine the resisting force required to ensure the block remain stationary.

Tentukan daya yang diperlukan untuk mengekalkan bungkah pada kedudukan pegun.

[ii] If the block is sliding at the constant speed of 12 m/s on a flat surface. Determine the friction factor on the block.

Jika bungkah tersebut gelongsor pada kelajuan malar 12 m/s di atas permukaan yang rata. Tentukan faktor geseran ke atas bungkah tersebut.

[14 marks/*markah*]

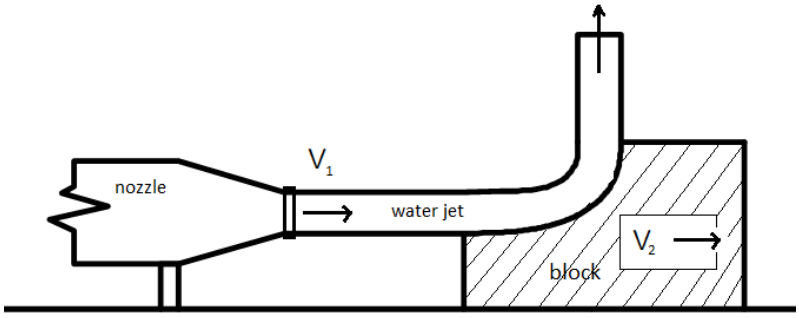


Figure 8 / *Rajah 8*

5. [a] A sharp crested weir is shown in **Figure 9** where H is the weir head and h_w is the height of the weir. With the assumption that the pressure above the weir is atmospheric ($P_B=0$) and by considering the conservation of energy along a streamline connecting point A at the upstream and point B which is situated above the weir, prove that the velocity distribution at the weir section can be expressed as follows,

$$V_B = 2g\left(h + \frac{V_A^2}{2g}\right)^{1/2}$$

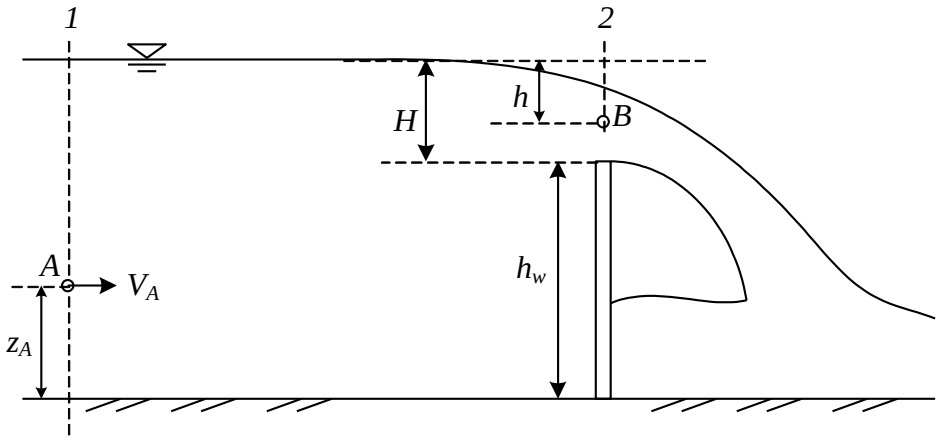
Assume no energy loss along the streamline connecting point A and B

Rajah 9 *menujukkan sebuah empangan limpah yang mempunyai turus empangan limpah H and ketinggian empangan* h_w*. Dengan anggapan bahawa tekanan di dalam aliran di atas empangan ialah tekanan atmosfera* ($P_B=0$) *dan dengan menggunakan prinsip keabadian tenaga sepanjang garis arus yang menyambungkan titik A di hulu dan titik B di atas empangan limpah, buktikan bahawa halaju di empangan limpah boleh diungkapkan seperti berikut,*

$$V_B = 2g\left(h + \frac{V_A^2}{2g}\right)^{1/2}$$

Anggap tiada kehilangan tenaga di sepanjang garis alir yang menyambungkan titik A dan B.

[5 marks/*markah*]



side view of a weir

Figure 9 / *Rajah 9*

[b] By using the result in part 5(a) and continuity equation between section 1 and section 2, if $h_w \gg H$, show that V_B can be expressed as follows,

$$V_B = \sqrt{2gh}$$

Dengan menggunakan jawapan di bahagian 5(a) dan persamaan keselanjaran antara keratan rentas 1 dan keratan rentas 2, tunjukkan bahawa sekiranya $h_w \gg H$*, maka halaju* V_B *boleh diringkaskan kepada ungkapan berikut,*

$$V_B = \sqrt{2gh}$$

[5 marks/*markah*]

[c] The discharge Q over a weir can be derived by integrating the velocity in 5[b] across the flow section area. Derive the flow discharge for the following weir shapes.

Kadar alir Q di empangan limpah boleh diterbitkan dengan mengamirkan halaju di soalan 5[b] merentasi keratan rentas aliran. Terbitkan kadar alir empangan limpah yang berbentuk berikut:

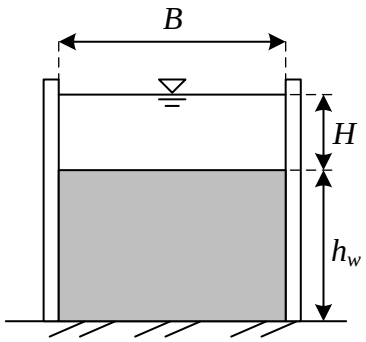
[i] rectangular weir with width *B* shown in **Figure 10**. Express your answer in [*g, B, H*] only.

empangan limpah segiempat yang mana lebarnya ialah B seperti dalam ***Rajah 10.*** *Nyatakan jawapan anda dalam sebutan* [*g, B, H*] *sahaja.*

[ii] triangular weir with angle of opening θ shown in **Figure 11**. Express you answer in [g, θ, H] only.

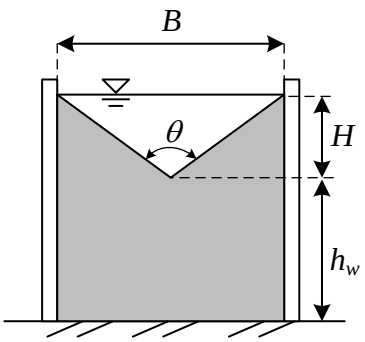
empangan limpah segi tiga yang mana bukaan sudutnya ialah θ *seperti dalam* ***Rajah 11****. Nyatakan jawapan anda dalam sebutan* [g, θ, H] *sahaja.*

[10 marks/*markah*]



front view of a rectangular weir

Figure 10 /*Rajah 10*



front view of a triangular weir

Figure 11 /*Rajah 11*

6. [a] The lift force and drag force acting on a moving body can be evaluated by considering the pressure and shear stress distribution on the body. An element from such body is shown in **Figure 12** where P is the pressure and τ is the shear stress acting on the element with surface area dA. Therefore, formulate the lift and drag force acting on the element in terms of P, τ, θ and dA.

Daya seret dan daya angkat yang bertindak pada sebuah jasad yang bergerak boleh dinilai dengan mengambil kira taburan tekanan dan tegasan ricih di permukaan jasad. Sebuah elemen dari jasad tersebut ditunjukkan di dalam ***Rajah 12*** *di mana P ialah tekanan dan* τ *ialah tegasan ricih yang bertindak ke atas permukaan elemen yang luasnya dA. Dengan demikian, rumuskan daya seret dan daya angkat yang bertindak ke atas elemen tersebut dalam sebutan* P, τ, θ dan dA.

[5 marks/markah]

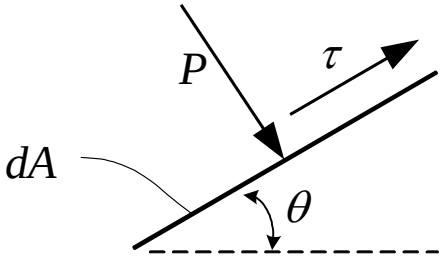


Figure 12 / *Rajah 12*

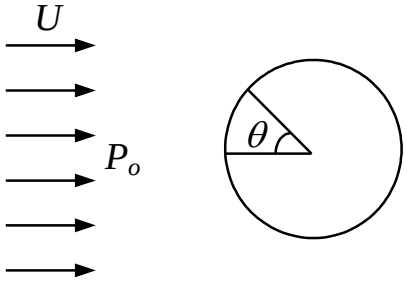


Figure 13 / *Rajah 13*

[b] A circular body subjected to flow is shown in **Figure 13**. The undisturbed velocity and pressure at the far upstream are given as *U* and *P* respectively. Draw the flow pattern (streamline) for the following cases:

*Sebuah jasad berbentuk bulat yang tertakluk kepada aliran ditunjukkan di dalam **Rajah 13**. Halaju and tekanan di hulu aliran masing-masing diberi sebagai U dan P. Lukis corak aliran (garis aliran) untuk kes-kes yang berikut:*

[i] the fluid is inviscid.
bendalir tidak mempunyai kelikatan (inviscid fluid)

[ii] the fluid is viscous and the flow is laminar.
bendalir mempunyai kelikatan dan aliran adalah laminar

[iii] the fluid is viscous and the flow is turbulent.
bendalir mempunyai kelikatan dan aliran adalh bergelora.

You must include and show the following features in the drawing (if any): boundary layer, boundary layer separation point, wakes and stagnation point.

Lukisan anda harus menunjukkan ciri-ciri aliran berikut (sekiranya ada) : lapisan sempadan, titik permisahan lapisan sempadan, "wakes" dan titik "stagnant"

[7 marks/markah]

[c] The study of drag force acting on a bridge column subjected to flow can be simplified into the problem of flow over an immersed circular as shown in **Figure 13**. By using Bernoulli equation and potential flow velocity, the pressure distribution on the surface of the circular body can be derived and is expressed as follows,

$$P_s = P_o + \frac{1}{2}\rho U^2(1 - 4\sin^2\theta)$$

Consequently, the drag force and lift force acting on the circular body can be calculated as follows,

$$\text{drag force}, F_x = -\int_0^{2\pi} P_s \cos\theta \; a \; d\theta$$

$$\text{lift force}, F_y = -\int_0^{2\pi} P_s \sin\theta \; a \; d\theta$$

Therefore, evaluate the following:

Daya heretan yang bertindak pada tiang jambatan yang berada di dalam air yang mengalir boleh dikaji dengan menggunakan model jasad bulat yang diletakkan di dalam aliran cecair seperti yang ditunjukkan di ***Rajah 13****. Dengan aplikasi persamaan Bernoulli dan halaju potensi, taburan tekanan di permukaan jasad bulat boleh diterbitkan dan dinyatakan seperti berikut:*

$$P_s = P_o + \frac{1}{2}\rho U^2(1 - 4\sin^2\theta)$$

Dengan demikian, daya heretan and daya angkat boleh dikira dengan definisi berikut:

$$\text{drag force}, F_x = -\int_0^{2\pi} P_s \cos\theta \; a \; d\theta$$

$$\text{lift force}, F_y = -\int_0^{2\pi} P_s \sin\theta \; a \; d\theta$$

Justeru itu, kira nilai untuk yang berikut :

[i] pressure on the surface of the circular body at the following positions where $\theta = 0^o, 90^o, 180^o$ and 270^o

tekanan di permukaan jasad bulat di lokasi $\theta = 0^o,\ 90^o, 180^o$ *dan* 270^o

[ii] the drag force acting on the body

daya heretan yang bertindak ke atas jasad bulat

[iii] the lift force acting on the body

daya angkat yang bertindak ke atas jasad bulat

Subsequently, explain briefly the D'Alembert paradox to justify to your answers in [i], [ii] and [iii].
Assume that density of fluid is 1000 kgm^{-3} and radius of the circular body a=1 m if their values are required.

Selanjutnya, terangkan dengan ringkas paradoksi D'Alembert untuk menjustifikasikan jawapan anda di [i], [ii] dan [iii].
Anggap bahawa ketumpatan cecair ialah 1000kgm^{-3} dan jejari jasad bulat ialah a=1 m sekiranya nilai-nilai ini diperlukan di dalam pengiraaan anda.

[8 marks/markah]

APPENDIX / *LAMPIRAN*

$$\Delta p = \gamma h$$

$$P = \gamma h + P_o$$

$$F_R = \gamma \left(h/2 \right) A$$

$$h_c = L_c \sin \theta$$

$$F_R = \gamma h_c A$$

$$L_p = L_c + \frac{I_c}{L_c A}$$

$$h_p = h_c + \frac{I_c \sin^2 \theta}{h_c A}$$

Approximate Physical Properties of Some Common Liquids (SI Units)

Liquid	Temperature (°C)	Density, ρ (kg/m^3)	Specific Weight, γ (kN/m^3)	Dynamic Viscosity, μ (N · s/m^2)	Kinematic Viscosity, ν (m^2/s)	Surface Tension,[a] σ (N/m)	Vapor Pressure, p_v [N/m^2 (abs)]	Bulk Modulus,[b] E_v (N/m^2)
Carbon tetrachloride	20	1,590	15.6	9.58 E − 4	6.03 E − 7	2.69 E − 2	1.3 E + 4	1.31 E + 9
Ethyl alcohol	20	789	7.74	1.19 E − 3	1.51 E − 6	2.28 E − 2	5.9 E + 3	1.06 E + 9
Gasoline[c]	15.6	680	6.67	3.1 E − 4	4.6 E − 7	2.2 E − 2	5.5 E + 4	1.3 E + 9
Glycerin	20	1,260	12.4	1.50 E + 0	1.19 E − 3	6.33 E − 2	1.4 E − 2	4.52 E + 9
Mercury	20	13,600	133	1.57 E − 3	1.15 E − 7	4.66 E − 1	1.6 E − 1	2.85 E + 10
SAE 30 oil[c]	15.6	912	8.95	3.8 E − 1	4.2 E − 4	3.6 E − 2	—	1.5 E + 9
Seawater	15.6	1,030	10.1	1.20 E − 3	1.17 E − 6	7.34 E − 2	1.77 E + 3	2.34 E + 9
Water	15.6	999	9.80	1.12 E − 3	1.12 E − 6	7.34 E − 2	1.77 E + 3	2.15 E + 9

[a] In contact with air.
[b] Isentropic bulk modulus calculated from speed of sound.
[c] Typical values. Properties of petroleum products vary.

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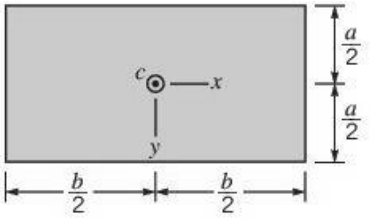


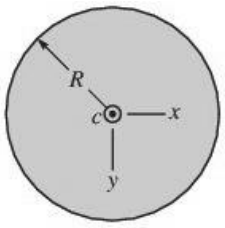
$A = ba$

$I_{xc} = \frac{1}{12}ba^3$

$I_{yc} = \frac{1}{12}ab^3$

$I_{xyc} = 0$

(*a*) Rectangle

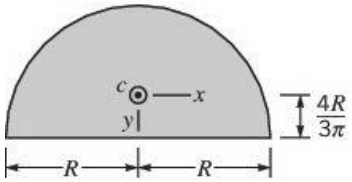


$A = \pi R^2$

$I_{xc} = I_{yc} = \frac{\pi R^4}{4}$

$I_{xyc} = 0$

(*b*) Circle



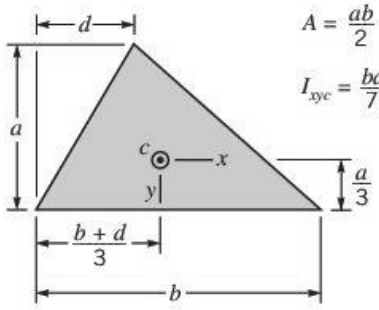
$A = \frac{\pi R^2}{2}$

$I_{xc} = 0.1098R^4$

$I_{yc} = 0.3927R^4$

$I_{xyc} = 0$

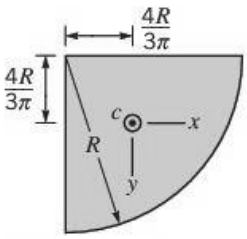
(*c*) Semicircle



$A = \frac{ab}{2}$ $I_{xc} = \frac{ba^3}{36}$

$I_{xyc} = \frac{ba^2}{72}(b - 2d)$

(*d*) Triangle



$A = \frac{\pi R^2}{4}$

$I_{xc} = I_{yc} = 0.05488R^4$

$I_{xyc} = -0.01647R^4$

(*e*) Quarter circle