00042

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: DMX4203 – Applied Fluid Dynamics I**
Academic Year	: 2019/2020
Date	: 17th October 2020
Time	: 1330-1630hrs
Duration	: **3 hours**

General Instructions

1. Read all the instructions carefully before answering the questions.
2. This question paper consists of 8 questions. All questions carry equal marks.
3. Answer **any 5** questions only.
4. Take acceleration due to gravity and the density of water as **9.81 N/kg** and **1000 kg/m³** respectively where necessary.

Q1.

(a). Figure Q1 shows a fluid flowing pipe bend that lies in a ground. Show that the net forces F_x and F_y in the directions of x and y respectively, are given by:

10-marks

$$F_X = \rho Q(V_1 - V_2\cos\theta) + p_1A_1 - p_2A_2\cos\theta$$

$$F_Y = \rho Q(-V_2\sin\theta) - p_2A_2\sin\theta$$

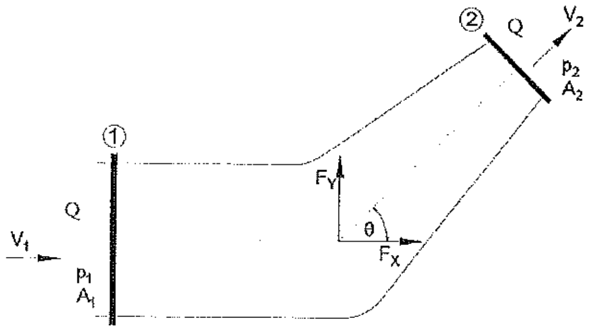

Figure Q1

10-marks

(b). A 45⁰ reducing bend is used to connect a pipe line in the horizontal plane as shown in figure Q1, the diameters at the inlet and the outlet of the bend being 600mm and 300mm respectively. Find the magnitude and the direction of the resultant force exerted by water on the bend if the intensity of pressure at the inlet is 9N/cm² and rate of flow of water is 600 litres/sec.

Q2.

A plane surface of area $\boldsymbol{A}$ is totally immersed in a liquid of density $\boldsymbol{\rho}$ as shown in **Figure Q2-a**. The surface is inclined at an angle θ to the horizontal and its centroid is at a vertical depth $\boldsymbol{h_c}$ below the free surface.

(a). Derive an expression for the resultant force $\mathbf{F_R}$ on one side of the surface. **3-marks**

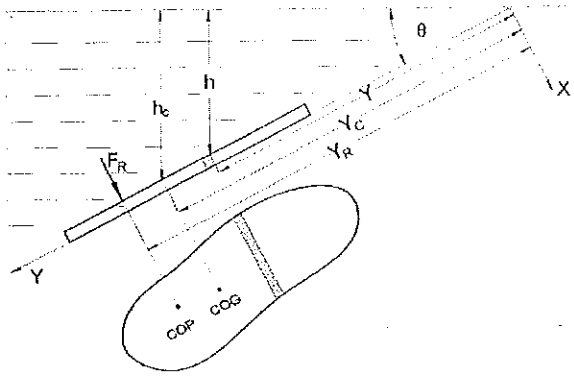

Figure Q2-a

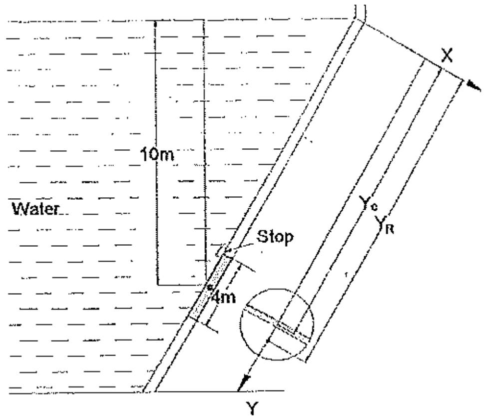

Figure Q2-b

(b). Show that the distance to the center of pressure from the free surface is given by the expression,

$$Y_R = \frac{I_{xc}}{AY_c} + Y_c$$ **7-marks**

Where I_{xc} is the second moment of inertia about the x axis

(c). A circular sluice gate of diameter $4m$ is located in the inclined wall of a water reservoir as shown in Figure Q2-b. The gate is mounted on a shaft along its horizontal diameter and the distance from the free surface to the shaft is $10m$ below the water surface. Determine the following, **10-marks**

I. The magnitude and location of the resultant force exerted on the gate by water

II. The moment that should be applied to the shaft to open the gate.

It is given that the second moment of inertia of a circular plate of radius r, about an axis perpendicular to it and through its centre is $\pi r^4/2$.

Q3.

(a). What is meant by a Newtonian fluid? , state 2 examples. *4-marks*

(b). By drawing graphs of shear rate (du/dy) vs. shear stress (τ), explain the non-Newtonian fluid flows *shear-thickening* and *shear-thinning*. State an example for each flow type. *4-marks*

(c). A liquid film of thickness(h) $3mm$ flows steadily down an inclined surface of angle $\theta=30^0$. The velocity profile is given by,

$$u_x = \frac{\rho g}{\mu}\left(hy - \frac{y^2}{2}\right) \sin\theta$$

12-marks

Determine the magnitude of the shear stress on the surface if the density of the liquid is $890\ kg/m^3$.

Q4.

a) By considering a differential fluid element, show that the vector form of the continuity equation, for a compressible, unsteady fluid flow, in usual notation is given by, *6-marks*

$$\frac{\partial \rho}{\partial t} + \nabla(\rho u) = 0$$

Where $\nabla = \left(\frac{\partial}{\partial x} i + \frac{\partial}{\partial y} j + \frac{\partial}{\partial z} k\right)$

4-marks

b) Obtain the expressions for the continuity equations for the following fluid flows.

I. Steady compressible flow.

II. Incompressible flow.

10-marks

c) The velocity components in the x and y directions of an incompressible, steady-flow field are $\mathbf{u=2xt+yz^2}$ and $\mathbf{v=t-xy^2}$ respectively. Determine the velocity component in the z direction (w), required to satisfy the law of conservation of mass.

Q5.

(a). By means of dimensional analysis, show that the frictional torque (τ) of a disc of diameter (D) rotating at a speed of (N) in a fluid of dynamic viscosity (μ) and the density (ρ) in a turbulent flow is given by,

8-marks

$$\tau = D^5 N^2 \rho \phi\left(\frac{\mu}{D^2 N \rho}\right)$$

4-marks

(b). What is meant by dynamic similarity?

(c). In order to predict the torque on a disc of 0.5 m diameter which rotates in oil at 150 rev/min, a model is made to a scale of 1/5. The model is rotated in water. Calculate the speed of rotation for the model which produces dynamic similarity.

(d). When the model is tested at 20 rev/min the torque was 0.02 Nm. Predict the torque on the full size disc at 150 rev/min.

8-marks

	Density (kg/m3)	Dynamic viscosity (Ns/m2)
Oil	800	0.15
Water	1000	0.001

Q6.

(a). A sharp edge triangular weir with an included angle of θ is shown in Figure Q6.

8-marks

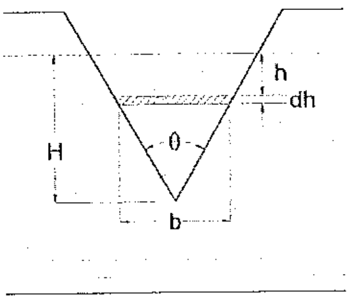

Figure Q6

Show that the total discharge can be theoretically expressed as,

$$Q = \frac{8}{15}\sqrt{2g}\tan\left(\frac{\theta}{2}\right)H^{\frac{5}{2}}$$

4-marks

(b). What do you understand by *coefficient of discharge*?

8-marks

(c). A triangular weir is used to measure the flow rate of a 3m wide open channel as shown in Figure Q6. If the head of water H, over the apex is 1.5m and the notch angle(θ) is 60^0, determine the flow rate of water through the channel. The coefficient of discharge c_d , for the weir is 0.60.

Q7.

(a). Explain the significance of the boundary layer displacement thickness (δ^*) and the momentum thickness (**Θ**), and express them as integrals of the boundary layer velocity profiles for a smooth flat plate. **5-marks**

(b). Calculate the ratio (δ^* / δ) for a laminar boundary layer with a velocity profile given by, **10-marks**

$$\frac{u}{U_\infty} = 2\frac{y}{\delta} - \frac{y^2}{\delta^2}$$

(c). Show that the frictional drag force per unit width (F_d) due to the boundary layer is given by, **5-marks**

$$F_d = \frac{2\delta}{15}\rho U_\infty^{\ 2}$$

Q8.

(a). What are the major losses and the minor losses in pipe flow? Explain.

Two reservoirs R_1 and R_2 are connected using the pipe line AB, BC and CD as shown in the Figure Q8. **5-marks**

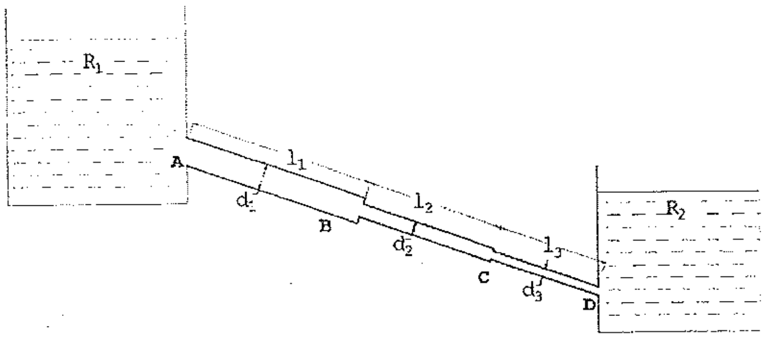

Figure Q8.

Pipe	Diameter-mm	Length-m	Friction factor-(f)
AB	500	200	0.018
BC	400	150	0.019
CD	250	120	0.02

(b). Write down the expression for the total head-loss by considering all the losses, using the usual notation. **5-marks**

(c). Determine the head loss of the pipe line, by neglecting the minor losses if the flow rate is $0.05 m^3 s^{-1}$. The friction loss of a pipe line (h_f) is given by, **5-marks**

$$h_f = \frac{4fl}{D}\frac{v^2}{2g}$$

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