UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: December 2018

Module Number: ME6301   Module Name: Advanced Fluid Mechanics
[Three Hours]
[Answer **all questions**, each question carries **twelve (12) marks**]

Q1 a) With the aid of necessary sketches, explain how flow separation occurs when a real fluid flows passing a spherical (blunt) body.

[3.0 Marks]

b) What are the basic drag coefficients contributing for the total drag coefficient of a body?

[1.0 Mark]

c) Describe, how the drag coefficients identified at Q1 b) vary with the Reynolds number.

[3.0 Marks]

d) In an experiment, sharp (thin) flat plate with 3 m of length (L) and 1 m of width (b) is immersed parallel to a flow stream of velocity 2 m/s. Find the drag force on one side of the plate, and boundary layer thickness at the trailing edge separately for the fluids of Air and Water. Do a comparison for drag force induced by particular fluids and give reasons for difference in the drag.

[5.0 Marks]

Q2 a) With the aid of neat sketches, explain the "**topspin**" effect of a tennis ball and its influence to the trajectory of the ball.

[3.0 Marks]

b) **Figure Q2(b)** shows a cross-section of bridge, which is constructed over a river on reinforced concrete columns. Height of each column is 6 m and the cross-section is a square of 15 cm sides. On a rainy day, columns are completely covered by a uniform flow of water, flowing at a velocity of 1.6 m/s. Estimate the maximum bending moment exerted by the flow at bottom of the column A.

[4.0 Marks]

c) A Boeing 727-200 jet aircraft which its gross mass of 68040 kg leaves from Bandaranaike International Airport with stall speed of 282 km/h at sea level. The aircraft has wing planform area (A_p) of 150 m², and aspect ratio (AR) of 6.5. Calculate the total drag force induced on the air-craft at stalling speed and, also for its cruising speed of Mach number (M) of 0.6.

NOTE: For low velocities of, $V <$ (M × 0.6), drag due to compressibility effects is negligible, and $C_D = C_{D,0} + \dfrac{C_L^2}{\pi AR}$ can be used to estimate the total drag coefficient of the aircraft. Where, $C_{D,0}$ is the drag coefficient at zero lift, which is 0.0182.

[5.0 Marks]

Q3 a) State five characteristic qualities of a reliable hydraulic fluid?

[2.0 Marks]

b) Briefly explain the importance of using **counterbalance valves** in hydraulic systems.

[2.0 Marks]

c) For an industrial application, two double-acting hydraulic cylinders are to be synchronized connecting them in series as shown in **Figure Q3(c)**. The load acting on each cylinder is 4000 N. Cylinder 1 has the piston diameter 50 mm and rod diameter 20 mm. If the cylinder 1 extends 200 mm in 0.05 s, find the followings:

i) Diameter of the second cylinder
ii) The pressure requirement of the pump
iii) Capacity of the pump, if its efficiency is 85% and the overall efficiency of the system is 90%

[4.0 Marks]

d) Figure Q3(d) shows a hydraulic cylinder (ISO Style MX3), placed in a production line which it has to exert a forward thrust of 150 kN and a retractive thrust of 15 kN. The retraction speed should be 5 m/min utilizing full pump flow, under the maximum pump pressure is 150 bar. Pressure drops over the following components and their associated pipe work are shown in **Figure Q3 (d)**; Find the followings,

i) Select a suitable cylinder for this application from **Table Q3(d)**, by assuming a 2:1 ratio for the piston area to the rod area
ii) Estimate the required pump capacity
iii) Relief-valve setting pressure

[4.0 Marks]

Q4 a) State the six basic components of any hydraulic circuit must be employed and, give a brief description for each.

[4.0 Marks]

b) At a construction site, an earth drilling machine in which the boring tool driven by a hydraulic motor (1A) is used for piling purposes as shown in **Figure Q4**. The earth drill is lowered slowly by a hydraulic cylinder (2A) at a speed appropriate to the in-situ soil layers to be drilled. The retracting stroke of the drill is to be executed as quickly as possible. This particular motion requires a higher volumetric flow of hydraulic fluid than the pump can deliver. This is produced by the additional installation of an accumulator. After the control circuit has been switched off, the hydraulic components must not be dismantled until the pressure in the accumulator has been re-leased and the accumulator has been isolated from the control circuit by means of the built-in shut-off valve. The same valve is used to relieve the accumulator to the tank. In this process, slowly opening this particular valve provides a throttle effect during the relief of the pressure. Based on the above given information, redraw the hydraulic circuit diagram given in **Figure Q4(a)** and complete the remaining part of.

[8.0 Marks]

Q5 a) What is meant by **Conformal** and **Nonconformal** surfaces of bearings? Give examples for each.

[2.0 Marks]

b) Briefly describe and distinguish between the **Hydrostatic lubrication** and **Hydrodynamic Lubrication**.

[2.0 Marks]

c) By using usual notations, derive a mathematical expression for lubricant film velocity of hydrodynamic lubrication and, sketch the velocity profile by naming the certain regions.

[3.0 Marks]

d) If a solid particle is falling under the action of gravity through a fluid medium, the body will attain a constant terminal velocity of u_t, when the net (corrected for buoyancy) gravitational accelerating force, F_g, equals the resisting upward drag force, F_r, acting on the body. Based on the given description, derive a mathematical expression for terminal velocity of the particle using standard notations. Furthermore, if the particle is a sphere, re-adopt the above derived equation to find terminal velocity of it.

[3.0 Marks]

e) In a water treatment plant, water is contaminated by small sand particles density (ρ_P) of $2,635 \, kg/m^3$. If each sand particle is assumed to be spherical with diameter of $8.3312 \times 10^{-4} \, m$ and, the temperature of water is 20 °C, calculate the **free settling velocity** of a sand particle.

NOTE: Assume that sand particles are not interfered by each other. Take the drag coefficient as 1.02.
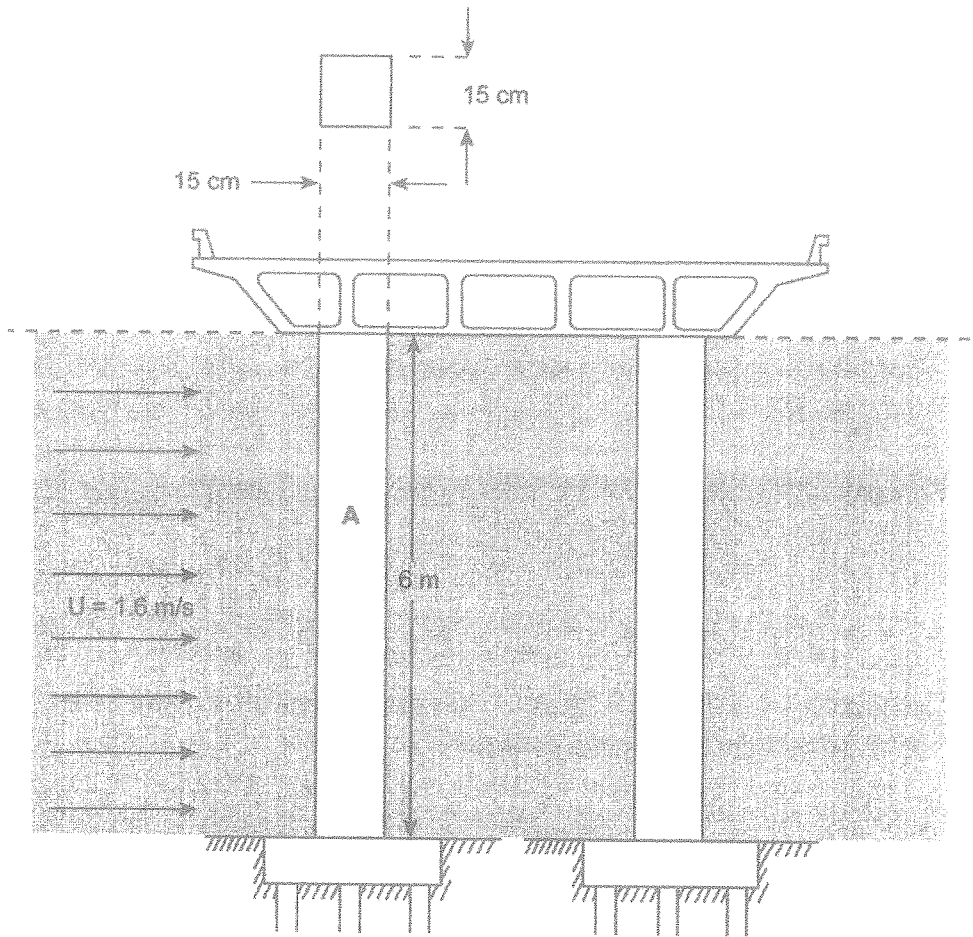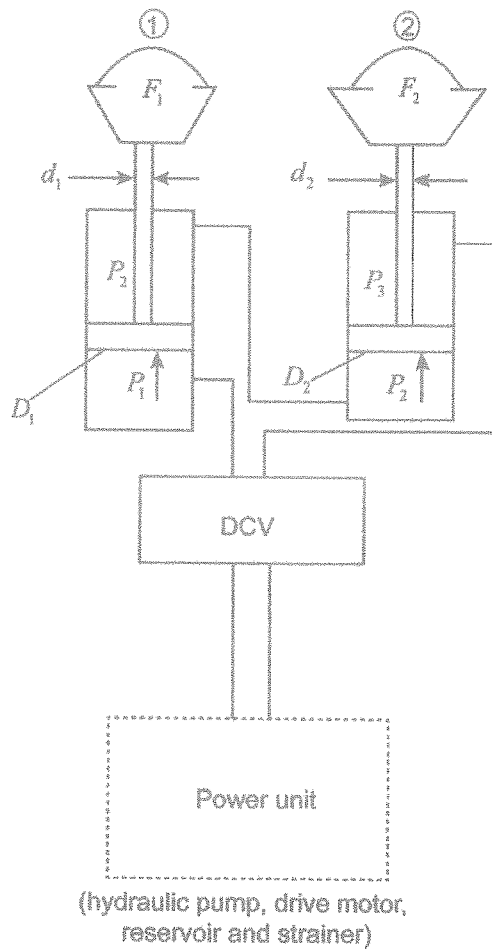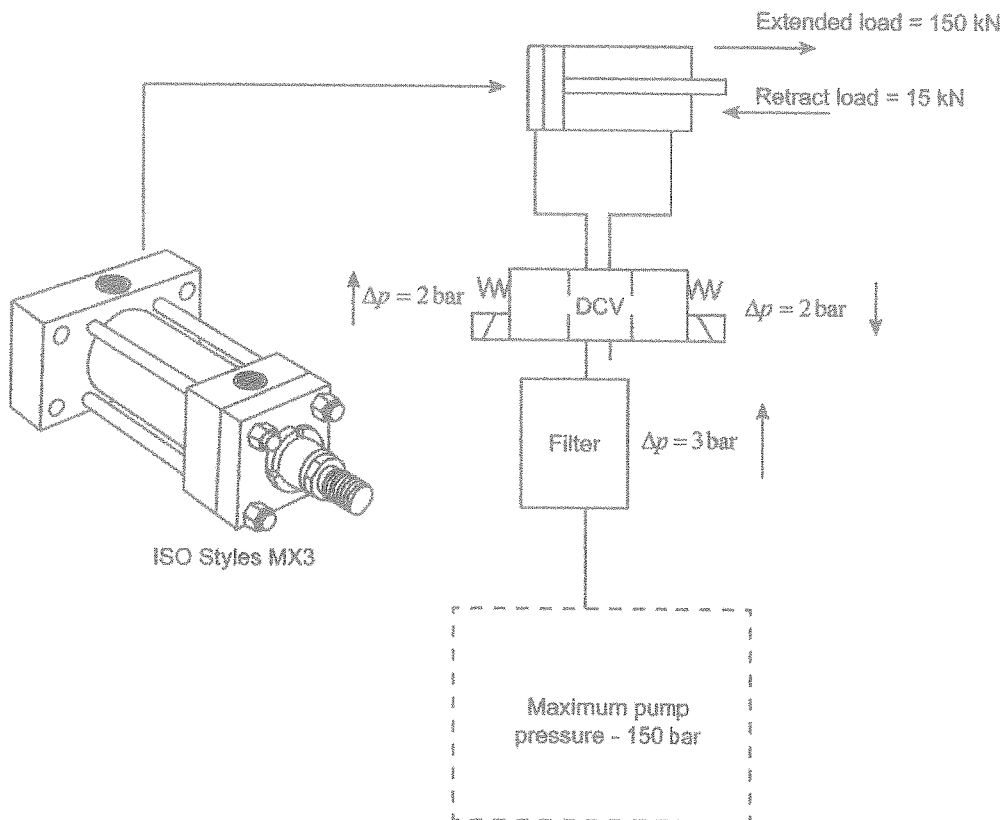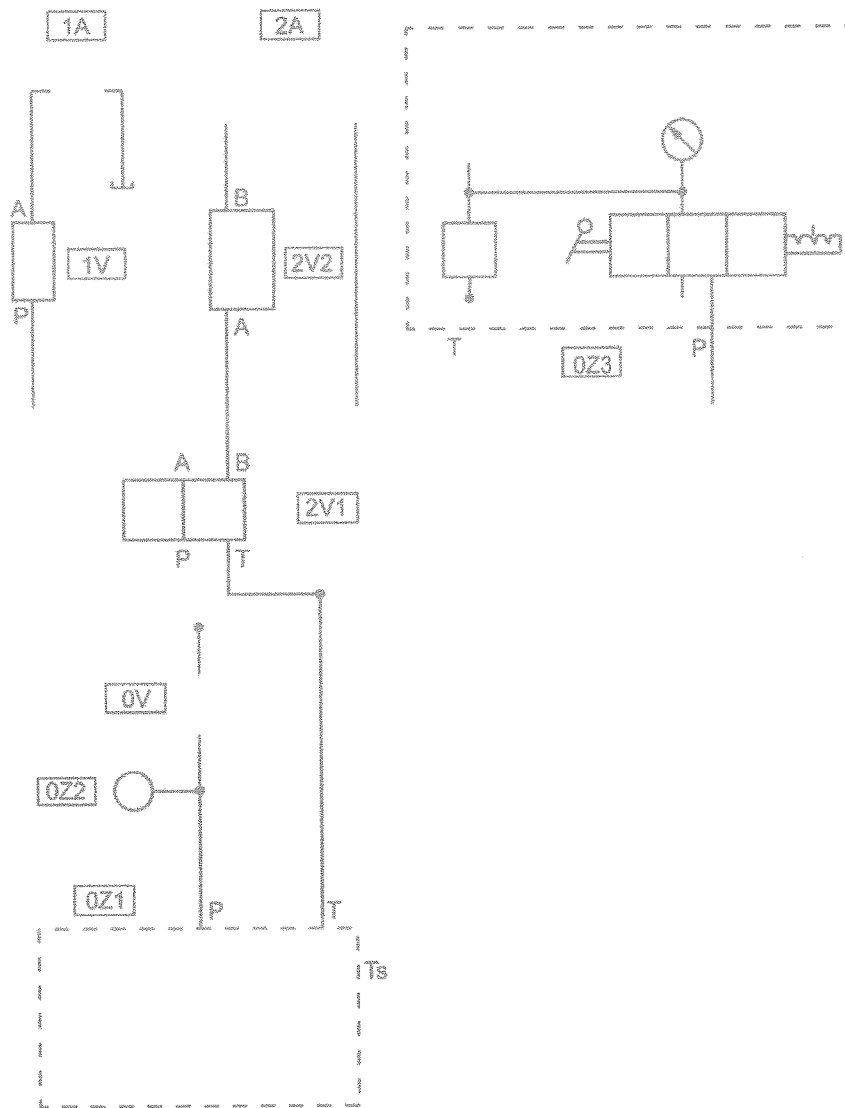
[2.0 Marks]

Figure Q2(b)

Figure Q3(c)

Figure Q3(d)

Figure Q4 (a)

USEFULL INFORMATION

$\rho_{Water} = 997 \, kgm^{-3}$

$\rho_{Air} = 1.23 \, kgm^{-3}$

$\nu_{Water} = 1.02 \times 10^{-6} \, m^2/s$

$\nu_{Air} = 1.46 \times 10^{-5} \, m^2/s$

$\dfrac{\delta}{x} = \dfrac{5.0}{\sqrt{Re_x}}$

$M = 343 \, ms^{-1}$

Drag coefficients of smooth bodies versus the Reynolds number