UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 6 Examination in Engineering: February 2020

Module Number: ME6301 **Module Name: Advanced Fluid Mechanics**

[Three Hours]

[Answer **all questions**; each question carries **twelve marks**; provide neat sketches where necessary; make reasonable assumptions and state them clearly]

Q1 a) What are the kinds of drag forces acting on a bluff body which is moving through a fluid?

[2 Marks]

b) For the design of a chimney, it is important to estimate the drag force created by the wind. If the chimney has a circular uniform cross-section with a height h and diameter d, calculate the drag force on it, assuming that it is a straight vertical chimney where the velocity profile of the wind is $u = U(z/h)^{2n}$ and the density of air is ρ.

[4 Marks]

c) The periscope of a submarine is a streamlined strut and its plan view is given in Fig.Q1(c). The optical parts of the periscope are housed in a cylinder, where the diameter (D) is 32.40 cm.

(i) What should be the chord (c) of the strut to ensure minimum drag if the thickness of the metal strut is 12.5 mm and its height is 6 m?

(ii) Determine the power saved using the streamlined strut over the bear cylinder if the velocity (V) of the submarine is 0.28 m/s and the sea water has a kinematic viscosity (υ) of $9.3\text{x}10^{-7}$ m^2/s and a density (ρ) of 997 kg/m^3.

Note: the minimum drag occurs at $t/c = 0.25$.

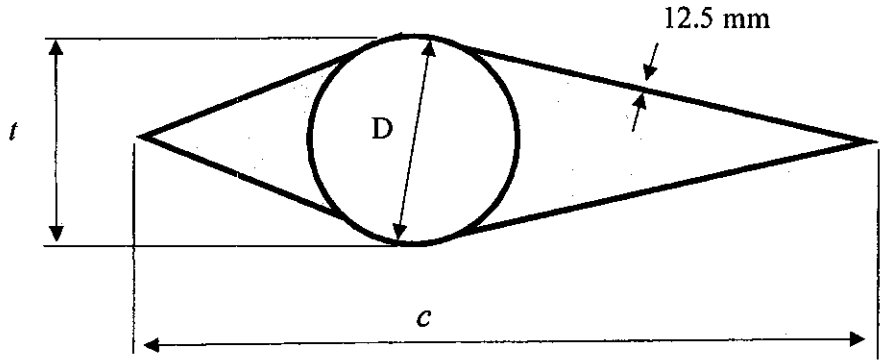

Figure Q1 (c) The plan view of a periscope of a submarine

[6 Marks]

Q2 a) What are the advantages of hydraulic power transmission systems?

[2 Marks]

b) Explain with clear sketches the construction and the working principle of a radial flow positive displacement pump.

[2 Marks]

c) Figure Q2(c) shows a hydraulic circuit designed for a particular industrial application. By investigating the circuit, identify the devices in it and briefly explain the main functions of the following.

(i) The unit C and its components.

(ii) The device D and its actuation methods.

(iii) The devices E, F, G and H.

(iv) The devices A and B.

(v) The overall hydraulic circuit.

[8 Marks]

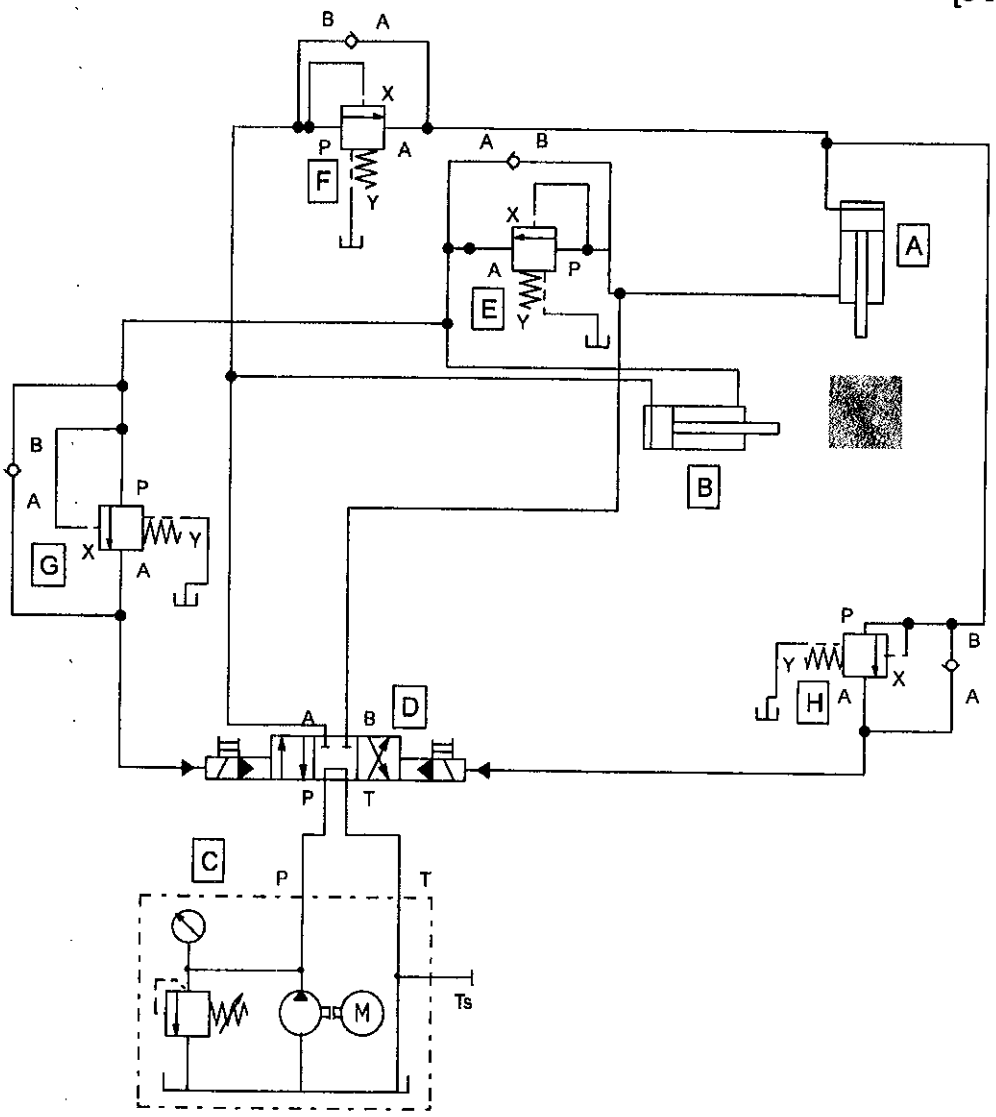

Fig. Q2 (c) A hydraulic circuit designed for a particular industrial application

Q3 a) A hydraulic motor control circuit consists of a Fixed Capacity Hydraulic Pump (FCP) and a Variable Capacity Hydraulic Motor (VCM). Investigating performance of this circuit, show that this circuit is not suitable for constant torque applications.

[4 Marks]

b) For an industrial hydraulic transmission system, a FCP supplies oil to a VCM. The FCP is directly coupled to an electric motor and is driven at a constant speed of 1400 rpm. The capacity of the FCP is 45 ml/rev. The maximum capacity and speed of the VCM are 55 ml/rev and 2800 rpm, respectively. Hydraulic losses in pipes and fitting between FCP and VCM are estimated to be 4.2 bar. For both FCP and VCM the volumetric efficiency and overall efficiency are 92% and 82%, respectively. If the relief valve pressure is set at 32 bar, determine the following.

(i) The minimum capacity of the VCM to be set mechanically for ensuring safe operation.

(ii) The maximum load of the VCM.

(iii) The speed range of the VCM associated with a 10 Nm torque load.

[8 Marks]

Q4 a) What is meant by "Terminal velocity" of a particle moving through a fluid?

[1 Mark]

b) Discuss two assumptions made to simplify the typical packed bed systems.

[2 Marks]

c) Explain the main difference between fixed beds and fluidized beds.

[2 Marks]

d) A particle of 2 mm diameter and density of 2500 kg/m^{3}is settling in a stagnant fluid in the Stokes' flow regime.

i) Calculate the viscosity of the fluid if its density is 1000 kg/m^{3}and the particle falls at a terminal velocity of 4 mm/s.

[1 Mark]

ii) What is the drag force on the particle at these conditions?

[1 Mark]

iii) What is the particle drag coefficient at these conditions?

[1 Mark]

iv) What is the particle acceleration at these conditions?

[2 Marks]

v) What is the apparent weight of the particle?

[2 Marks]

Q5 a) List out **four** objectives of lubrication.

[2 Marks]

b) Briefly discuss the importance of the "Total Base Number (TBN)" in lubricants.

[1 Mark]

c) List out regimes of lubrication.

[1 Mark]

d) Illustrate the variation of pressure in the converging film of a hydrodynamically lubricated bearing.

[2 Marks]

e) Hydrostatically lubricated flat circular pad thrust bearing rotates at 14 rev/s by maintaining film thickness of 100μm. The load capacity, outer radius, recess radius and dynamic viscosity of the bearing are respectively 60kN, 80mm, 55mm, and 2.4×10^{-2}Ns/m^2. Consider the recess depth is 16 times the bearing film thickness. Determine the followings for 1Mpa of the recess pressure.

i) Calculate the radius where 0.5Mpa pressure presents.

[2 Marks]

ii) Required flow rates of the lubricants.

[1.5 Marks]

iii) Frictional power loss of the bearing.

[1.5 Marks]

Useful equations with usual notations.

$$V_T = \frac{D_p^2 (\rho_p - \rho_f) g}{18\mu}$$

$$F_D = 3\pi\mu U D_P$$

$$\Delta P = \frac{150\,\mu L U_\infty (1-\varepsilon)^2}{D_p^2 \varepsilon^3} + \frac{1.75 \rho L U_\infty{}^2 (1-\varepsilon)}{D_p \varepsilon^3}$$

$$P = \frac{6\eta Q}{\pi h^3 \cos\phi} \ln\left(\frac{R}{r}\right)$$

$$W = \frac{P_r \pi}{2\cos\phi}\left[\frac{R^2 - R_0^2}{\ln(R/R_0)}\right]$$

$$H_f = 2\pi^3 \eta n^2 \left[\frac{R_0^4}{h_r} + \frac{(R^4 - R_0^4}{h\cos\phi}\right]$$