



Module Number: ME6318

Module Name: Advanced Fluid Mechanics

[Three Hours]

[Answer all questions, each question carries twelve marks]

- Q1 a) When a viscous fluid flows over a **curved** surface, the streamlines get separated from the surface at some point from the leading edge.
- (i) Explain the separation of the streamlines from the surface by taking into account velocity and pressure variation from leading edge to the separation point.
  - (ii) Plot the variation of the pressure along the curved surface.
- [3 Marks]
- b) When a viscous fluid flows over a **cylinder** or a **ball**, drag forces are exerted on them. Those drag forces are generated mainly due to pressure distribution and shear stresses of the viscous fluid. This nature is used in many application in favour of the situation.
- (i) Plot the variation of the drag with respect to velocity of flow over a smooth and rough surfaced circular balls. Hence describe why the table-tennis balls are made with smooth surfaces whilst the golf ball are roughen with 'dimpling'.
  - (ii) Football players makes the football spins on the air for the ball to go in a curvy path. That force excreted perpendicular to the fluid flow makes the football go on a curvy path. Explain the distribution of the drag forces on the ball in order it to fly in a curve.
- [3 Marks]
- c) An airplane is cruising at an altitude of 8 km. At that altitude, the air density is  $0.4105 \text{ kg/m}^3$ . Mass of the airplane including the all passengers can be approximated as 6500 kg. The Surface area of the airplane parallel and perpendicular to the air flow are  $70 \text{ m}^2$  and  $30 \text{ m}^2$ , respectively,



- (i) If the Lift Coefficient ( $C_L$ ) is 0.025, calculate the velocity of the airplane.
- (ii) If the Drag Coefficient  $C_D$  is 0.015, determine the drag force.
- (iii) Calculate the power requirement of the engine at the above conditions.

[6 Marks]

Q2 a) Differentiate between:

- (i) Steady Flow and Uniform Flow
- (ii) Lamina Flow and Turbulent Flow
- (iii) Streamline and streakline
- (iv) Rotational and Irrotational flow

[2 Marks]

b) A packed bed of solid particles of density 2500 kg/m<sup>3</sup>, occupies a depth of 1 m in a vessel of cross-sectional area 0.04 m<sup>2</sup>. The mass of solids in the bed is 50 kg and the surface-volume mean diameter of the particles is 1 mm. A liquid of density 800 kg/m<sup>3</sup> and viscosity 0.002 Pas flows upwards through the bed.

- (i) Define the porosity of the void fraction. Then, calculate the voidage (volume fraction occupied by voids) of the bed.
- (ii) Find the wetted surface area per unit volume (S) in the packed bed.
- (iii) Calculate the pressure drop across the bed when the volume flow rate of liquid is 1.44 m<sup>3</sup>/h. The pressure drop in the packed bed of solid particles can be estimated by the formula ,

$$\frac{\Delta p}{l} = \frac{180 (1 - \epsilon)^2 \mu U_m}{\epsilon^3 d_p^2}$$

Where, symbols indicate usual notations.

- (iv) Calculate the power needed for a pump to work against the pressure drop of the packed bed under the given condition.

[10 Marks]

Q3 a) List five advantages and disadvantages of a fluid power system.

[2 Marks]

b) What is the difference between an open-center and close-center type of Directional Control Valves (DCV)?

[2 Marks]

c) In a product manufacturing process, an automatic drilling operation is performed

Question Q3.(c) is continued on page 3



by a specially design machine which consists of two double-acting cylinders and two sequence valves. One cylinder is used as a clamp cylinder and other cylinder as a drill cylinder. At first, a clamp cylinder extends and clams a work piece. Then, a drill cylinder extends to drive a spindle to drill a hole on the work piece. After drilling the drill cylinder retracts the drill spindle and then clamp cylinder retracts to release the work piece for removal. Design a hydraulic circuit to accomplish above operations with a suitable 4/3 DVC by facilitating automatic repetition of the operations.

[8 Marks]

Q4 a) A hydraulic circuit consists of a Variable Capacity Pump (VCP) and a Fixed Capacity Motor (FCM). Explain by analyzing characteristics of the circuit that this circuit is not suitable for a high power load.

[3 Marks]

b) A hydraulic circuit used in a production line consists of a Variable Capacity Pump (VCP) and a Fixed Capacity Motor (FCM). The maximum capacity of hydraulic oil supplied by the VCP is 45 ml/rev and the capacity of the FCM is 35 ml/rev. The VCP is driven by an electric motor of which rotational speed is 1800 rpm. The VCP supplies oil to the FCM through pipes and fittings and estimated hydraulic pressure losses of them are equivalent to 4.5 bar. For both VCP and FCM the mechanical efficiency and volumetric efficiency are 80% and 90%, respectively. If the relief valve setting is 25 bar, calculate,

- (i) The maximum torque available at the FCM.
- (ii) The speed range associated with a constant power load of 700 W.
- (iii) The relief valve pressure to increase the speed range in (ii) by 30%.

[9 Marks]

Q5 a) What is the difference between Hydrostatic Lubrication and Hydrodynamic Lubrication?

[2 Marks]

b) Derive the slot leakage formula considering steady viscous flow between very close parallel plates under a pressure gradient.

[2 Marks]

Question Q5 is continued on page 4



- c) Figure Q5 shows a schematic diagram of a circular footstep bearing used in a hydroelectric power plant. The radius of the end plate of the shaft  $r_2 = 0.5$  m and the radius of the cylindrical recess  $r_1 = 0.15$  m. An oil at pressure 7 MPa with a dynamic viscosity  $0.25$  Ns/m<sup>2</sup> is pumped to the bearing recess. The metal to metal contact is prevented by maintaining oil film thickness of  $t = 0.15$  mm between the bottom surface of the end plate and the bearing. If the generator shaft of the power plant is rotating at a speed of 2400 rpm, determine,
- The rate of oil pump-in to the recess.
  - The load carrying capacity of the bearing.
  - The rate of energy dissipation in the bearing.

**Note:** Followings are two derived equations for pressure distribution ( $P$ ) and load carrying capacity ( $W$ ) with usual notations for footstep bearings.

$$P = \frac{6\mu Q}{\pi t^3} \log \left[ \frac{r_2}{r} \right]$$

$$W = \frac{3\mu Q}{t^3} [r_2^2 - r_1^2]$$

[8 Marks]

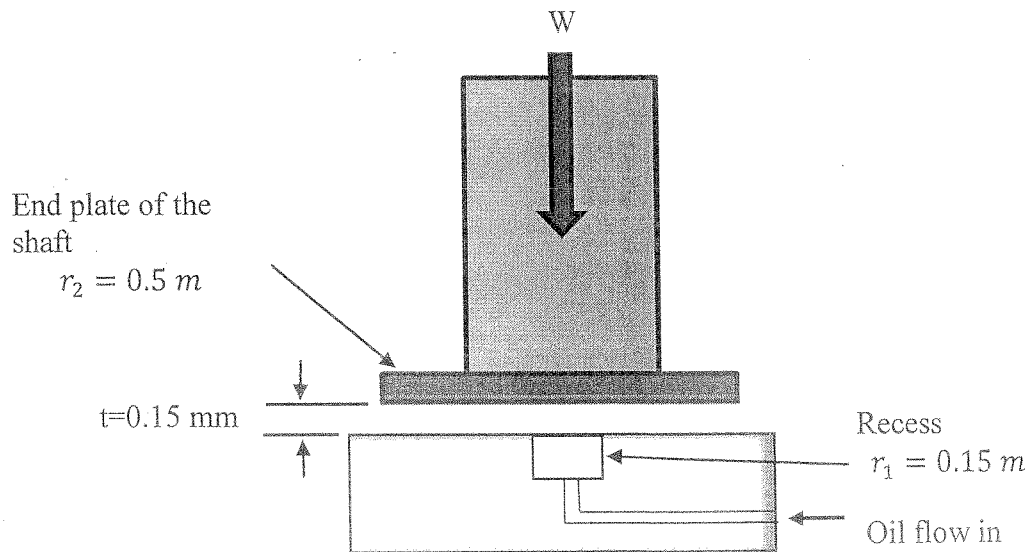


Figure Q5