Ref. No.: Ex/ME(M2)/ES/B/T/124/2022

**B.E. MECHANICAL ENGINEERING FIRST YEAR SECOND SEMESTER – 2022**

# FLUID MECHANICS - I

**Time: 3 Hrs.** **Full Marks: 100**

**Answer any FIVE questions. Assume any missing data. Answer all parts of a question together.**

1. (a) What do you mean by "The Fluid as a Continuum" and "no-slip boundary condition"?

(b) The clutch system shown in **Fig. Q1** is used to transmit torque through a 3-mm-thick oil film with $\mu = 0.38$ N.s/m$^2$ between two identical 30-cm-diameter disks. When the driving shaft rotates at a speed of 1450 rpm, the driven shaft is observed to rotate at 1398 rpm. Assuming a linear velocity profile for the oil film, determine the transmitted force, torque and power. (7+13)

2. (a) In **Fig. Q2** all fluids are at 20°C. Determine the pressure difference (Pa) between points $A$ and $B$. Assume the specific weights as follows: 8640 N/m$^3$ for Benzene, 133100 N/m$^3$ for Mercury, 7885 N/m$^3$ for Kerosene, and 9790 N/m$^3$ for Water.

(b) Derive the fundamental law of fluid statics considering a three-dimensional fluid element with appropriate assumptions. (12+8)

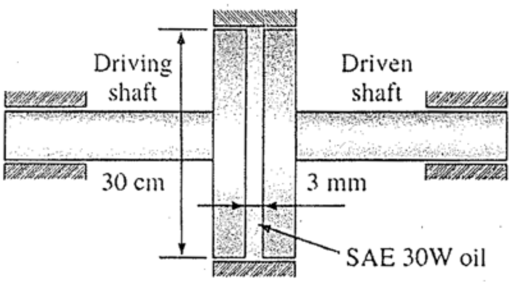


**Fig. Q1.**

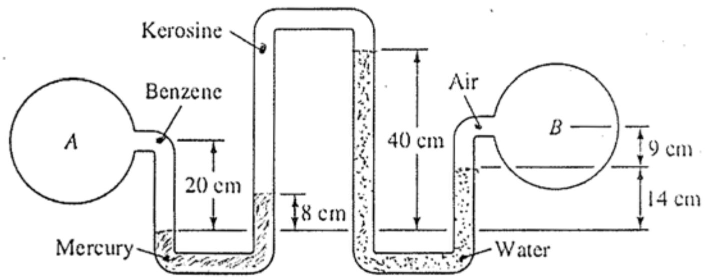


**Fig. Q2.**

3. (a) Derive the analytical expression of velocity distribution for laminar flow through a pipe, stating all required assumptions. Find the friction coefficient ($f$) and skin friction coefficient ($C_f$) for such type of flow as the function of Reynolds number ($Re$).

(b) A pipe 50 mm diameter is 6 m long and the velocity of flow of water in the pipe is 2.4 m/s. What loss of head and the corresponding power would be saved if the central 2 m length of pipe was replaced by 75 mm diameter pipe, the change of section being sudden? Take friction factor $f$ = 0.04 for the pipes of both diameters. (15+5)

4. (a) A 45$^0$-reducing bend is connected in a pipeline, and the diameters at the inlet and outlet of the bend are 600 mm and 300 mm, respectively. The intensity of pressure at the inlet is 8.829 N/cm$^2$. Find the forces exerted on the bend when the flow rates of the water are (i) 600 litres/s and (ii) zero.

(b) An incompressible fluid flows past an impermeable flat plate, as in **Fig. Q4**, with a uniform inlet profile $u = U_0$ and a cubic polynomial exit profile

$$u \approx U_0 \left( \frac{3\eta - \eta^3}{2} \right) \qquad \text{where } \eta = \frac{y}{\delta}$$

Compute the volume flow Q across the top surface of the control volume. **(15+5)**

5. (a) A three-dimensional velocity field is given by

$u(x,y,z) = cx + 2w_0 y + u_0$ $\qquad v(x,y,z) = cy + v_0$ $\qquad w(x,y,z) = -2cz + w_0$

where $u_0$, $c$, $w_0$ are the constants. Find the components of strain rates and rotational velocities.

(b) Water at 20°C flows through the elbow in **Fig. Q5** and exits to the atmosphere. The pipe diameter is $D_1 = 10$ cm, while $D_2 = 3$ cm. At a weight flow rate of 150 N/s, the pressure $p_1 = 2.3$ atm (gauge). Neglecting the weight of water and elbow, estimate the force on the flange bolts at Section 1. **(10+10)**

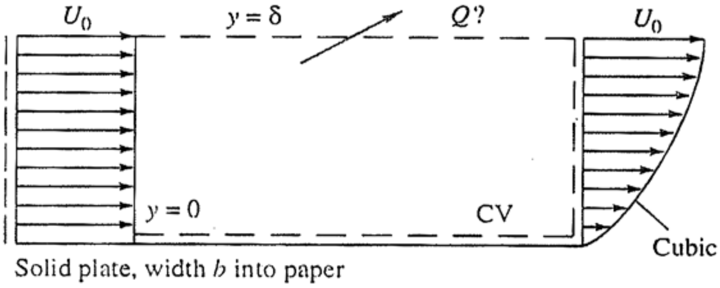


**Fig. Q4.**

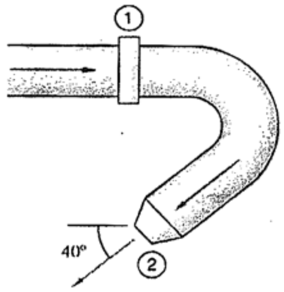


**Fig. Q5.**

6. (a) Starting from the basic assumptions, derive an expression for the volumetric flow rate through an open channel of wetted area $A$, wetted perimeter $P$, slope $S$, and surface roughness $n$.

(b) A channel of the trapezoidal section, having side slopes 3 horizontal to 2 vertical, is to carry a flow of 10 $m^3/s$ on a longitudinal slope of 1 in 5000. The channel is to be lined for which the value of friction coefficient in Manning's formula is $n = 0.012$. Find the dimensions of the most economic section of the channel. Also, find the Froude number and the state of flow.

<u>**OR**</u> (b) The finished concrete channel as shown in **Fig. Q6** is designed for a new flow rate of 14 $m^3/s$ at a normal depth of 4 m. Determine (i) the design slope of the channel and (ii) the percentage of reduction in flow if the surface is Natural streams. Assume, $n \approx 0.012$ for the finished concrete channel and $n \approx 0.035$ for natural streams. **(10+10)**

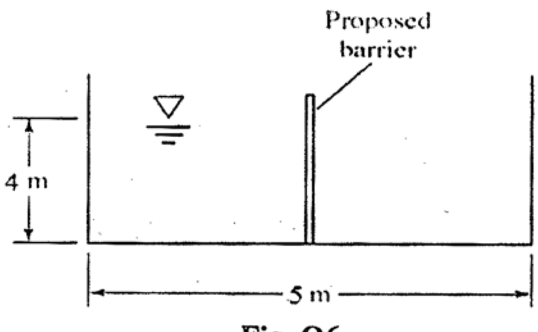


**Fig. Q6.**