BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI

ME/MF F 212: FLUID MECHANICS

FIRST SEMESTER 2015-2016

Mid Semester Examination (**CLOSED BOOK**)

Max Marks: 35 Duration: 90 mins Date: 8th October, 2015 (2 - 3:30 PM)

- *Partial marks will be awarded only when all steps are shown clearly and units written.*
- *All final answers to be highlighted by enclosing in a box.*
- *Use* ρ_{water} = 1000 kg/m^3, g = 9.81 m/s^2 *and* P_{atm} = 101 kPa

Q1a. What do you mean by Dirichlet and Neumann boundary conditions ? **[2M]**

Q1b. A concrete wall (specific gravity = 2.7) of rectangular cross-section 0.8 m high and 0.2 m wide is designed to retain mud to a depth *h* (see FigQ1b). The friction coefficient between the ground and concrete wall is 0.3, and the density of the mud (ρ_m) is 1800 kg/m^3. There is concern that the wall may slide or tip over the lower left edge (i.e. *A*) as the mud level rises. Determine the mud height (*h*) at which ***(i)*** the concrete wall will overcome friction and start sliding and ***(ii)*** the wall will tip over ***(iii)*** Which is more critical sliding or tipping? **[5M]**

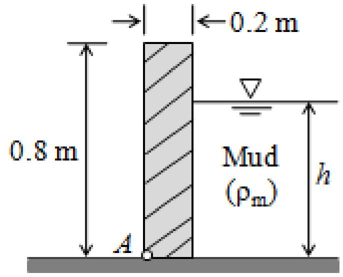

Fig Q1b

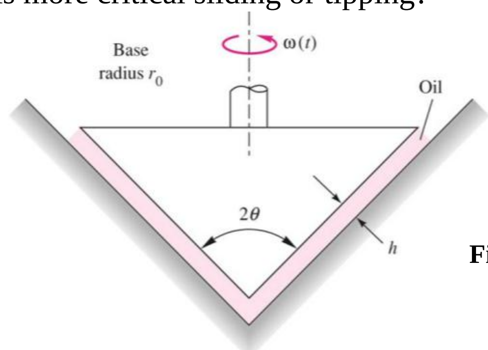

Fig Q2

Q2a. A solid cone of angle 2θ, base radius r_o, and density ρ_c is rotating with initial angular velocity ω_o inside a conical seat, as shown in Fig Q2. The clearance *h* is filled with oil of viscosity μ. Neglecting air drag and assuming the clearance is very small, derive an analytical expression for the cone's instantaneous angular velocity $\omega(t)$ if there is no applied torque. **[6M]**

Q2b. Show (i) Pseudoplastic fluid (ii) Dilatant fluid (iii) Bingham plastic fluid on shear stress-shear strain rate diagram.

Q3a. A pump is 2.5 m above the water level in the sump (*water reservoir*) (see Fig Q3a) and has a pressure of (-) 22 cm of mercury at the suction side (i.e. at *pump inlet*). The suction pipe is of 25 cm diameter and delivery pipe (*pump outlet*) is a 30 cm diameter pipe ending in a nozzle of 10 cm diameter. If the nozzle is directed vertically upwards at an elevation of 4 m above the sump water level (i.e. EL = 0 m). Neglecting all the losses, determine **[8M]**

1. The discharge (m^3/s)
2. The power input by pump (in *kW*)
3. Elevation (*m*) above the sump water level, to which the jet would reach.

*EL = *elevation*

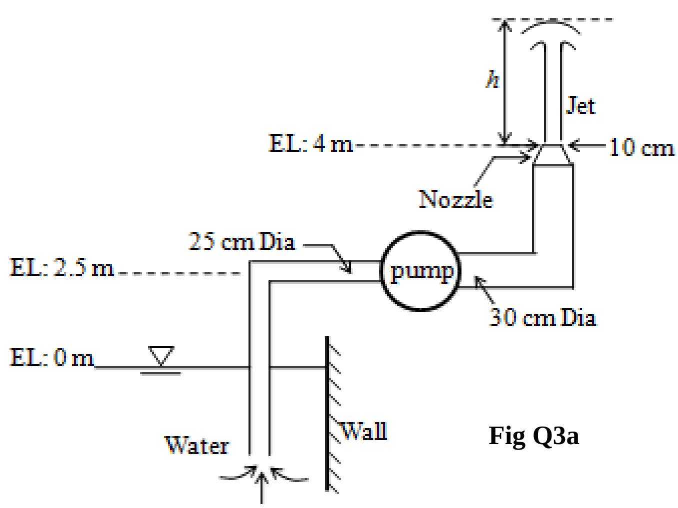

Fig Q3a

Q3b. A simple flow system to be used for steady flow tests consists of a constant head tank connected to a length of 4 mm diameter tubing as shown in FigQ3b. The liquid has a viscosity of 0.015 N-s/m^2, a density of 1200 kg/m^3, and discharges into the atmosphere with a mean velocity of 4 m/s. ***(i)*** The flow is fully developed in the last 3 m of the tube. What is the pressure at the pressure gage? ***(ii)*** What is the magnitude of the wall shearing stress, (τ), in the fully developed region? **[4M]**

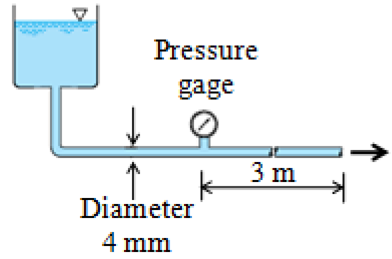

Fig Q3b

Q4. Consider steady, incompressible, fully developed laminar flow of a Newtonian fluid in the annulus (See FigQ4a) between two concentric pipes. Assume that the pressure is constant everywhere. The inner pipe is moving in axial direction (*z*-direction) with a steady velocity V_o to the right, and the outer pipe is stationary. **[10M]**

(i) State the boundary conditions and simplify z-component of Navier-Stokes equation.

(ii) Find out a general expression for the velocity profile $V_z(r)$ and the shear stress $\tau_{rz}(r)$.

(iii) A 10 cm diameter rod (FigQ4b) is pulled steadily at 0.2 m/s through a 2.5 m long fixed cylinder whose clearance of 2.5 mm filled with a lubricating oil of density ρ = 870 kg/m^3 and viscosity μ = 0.1 *Pa*-sec. Estimate the force required to pull the rod, using the velocity distribution deduced in part-(ii).

(iv) Calculate the shear stress ratio (i.e. $\tau_{rz} / \tau_{planar}$), where τ_{rz} is the shear stress obtained from (ii) and τ_{planar} is the shear stress at the surface of the inner cylinder that computed from a planar approximation obtained by assuming the annulus into a plane and a linear velocity profile in the gap.

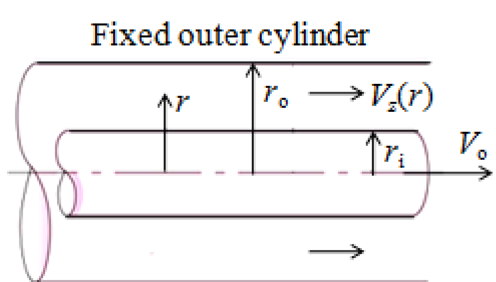

Fig Q4a

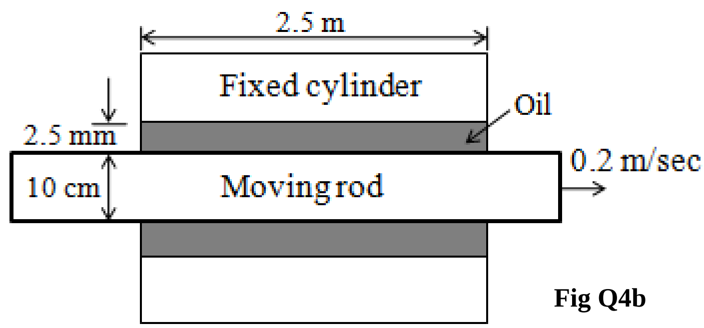

Fig Q4b

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z- momentum equation: $$\frac{\partial \upsilon_z}{\partial t} + (\bar{\upsilon}.\bar{\nabla})\upsilon_z = -\frac{1}{\rho}\frac{\partial p}{\partial z} + g_z + \frac{\mu}{\rho}\nabla^2 \upsilon_z$$

Laplacian operator: $$\nabla^2 = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2}{\partial \theta^2} + \frac{\partial^2}{\partial z^2}$$

Convective time derivative: $$\bar{\upsilon}.\bar{\nabla} = \upsilon_r\frac{\partial}{\partial r} + \frac{\upsilon_\theta}{r}\frac{\partial}{\partial \theta} + \upsilon_z\frac{\partial}{\partial z}$$

Continuity equation: $$\frac{1}{r}\frac{\partial}{\partial r}(r\upsilon_r) + \frac{1}{r}\frac{\partial}{\partial \theta}(\upsilon_\theta) + \frac{\partial}{\partial z}(\upsilon_z) = 0$$

Shear stress $$\tau_{rz} = \mu\left(\frac{\partial \upsilon_z}{\partial r} + \frac{\partial \upsilon_r}{\partial z}\right)$$