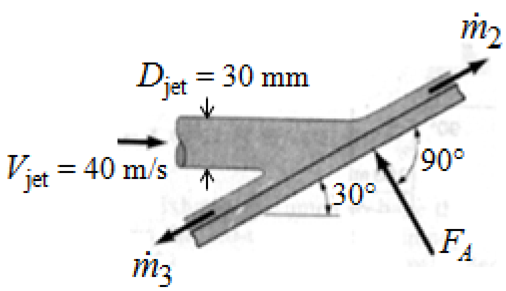
BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
FIRST SEMESTER 2016-2017
ME F212/MF F212: FLUID MECHANICS
COMPREHENSIVE EXAMINATION (Part-A) (CLOSED BOOK)

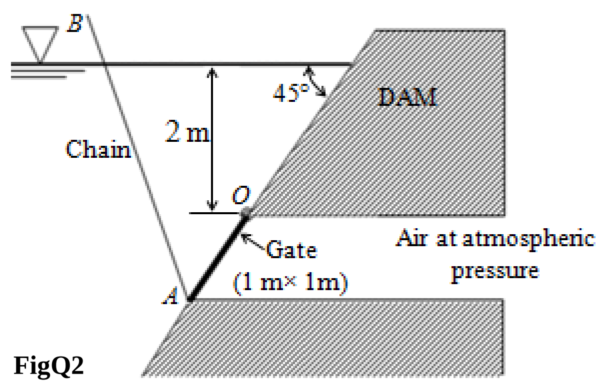
Date: 5th December, 2016 | Max. Marks: 30 | Duration: 60 Minutes

1. The exam is divided into *Part*-A (Closed-book type) and *Part*-B (Open-book type). *Part*-A and *Part*-B are to be answered in separate answer sheets.
2. Time allotted to answer *Part*-A is 60 minutes, but you can take time as per your convenience.
3. Only after submitting *Part*-A, you can take the question paper and answer sheet for *Part*-B.

Q1. A horizontal circular jet of air (ρ_{air} = 1.23 kg/m^3) strikes a stationary flat plate as indicated in FigQ1. The jet velocity is 40 m/s and the jet diameter is 30 mm. Assume that the flow over the plate is frictionless and the air velocity magnitude remains constant as the air flows over the plate surface in the directions shown, determine **(a)** the magnitude of F_A, the anchoring force required to hold the plate stationary **(b)** the ratio of mass flow rates $(\dot{m}_2/\dot{m}_3)$ along the plate surface **(c)** the magnitude of F_A, the anchoring force required to allow the plate to move to the right at a constant speed of 10 m/s. **[8M]**



FigQ1



FigQ2

Q2. An opening in a dam is closed by a gate $(1m \times 1m)$ which is hinged at the upper horizontal edge (*O-O*) as shown in FigQ2. The gate is inclined at an angle of 45^o to the horizontal and its top edge is 2*m* below the water surface in the reservoir.

If this gate is pulled by means of a chain (*AB*) attached to the centre of lower edge, find the necessary pull *P* in the chain. The line of action of the chain makes an angle of 60^o with the gate. Weight of the gate is 2.5 kN. **[8M]**

Q3. Glycerin at 20°C (ρ = 1260 kg/m^3 and μ = 4 N-s/m^2) flows between parallel plates with gap width b = 2.5 mm. The upper plate moves with speed 0.6 m/s in the positive *x*-direction; the lower plate is stationary. The pressure gradient is $\partial p/\partial x = -1150$ kPa/m and the flow is laminar. **(a)** Locate the point of maximum velocity and determine its magnitude (let $y = 0$ at the bottom plate). **(b)** Determine the volume flow rate per unit depth (m^3/sec/m) passing a given cross section. **(c)** Plot the velocity distribution. **[8M]**

Q4. A circular container, partially filled with water**,** is rotated about its central axis at constant angular speed, ω. At any time, τ, from the start of rotation, the speed in θ-direction, V_θ, at a distance r from the axis of rotation, was found to be a function of τ, ω, r and the liquid properties ρ, μ. Obtain the dimensionless parameters that characterize this problem.

If, in another experiment, honey ($\upsilon_{honey} > \upsilon_{water}$) is rotated in the same cylinder at the same angular speed, determine from your dimensionless parameters whether honey will attain steady motion as quicker as water. Explain why the Reynolds number would not be an important dimensionless parameter in scaling the steady-state motion of liquid in the container. **[6M]**

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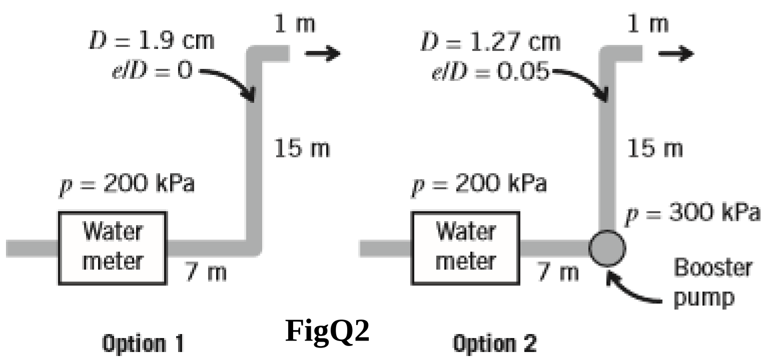
ME F212/MF F212: FLUID MECHANICS

Comprehensive Exam: PART-B (OPEN BOOK)

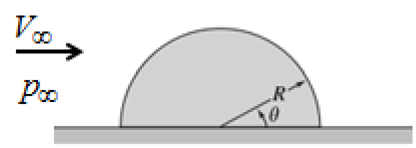
Date: 5th December, 2016 Max. Marks: 50 Duration: 2 Hours

Q1. At a large fish hatchery, the fishes are brought up in open, water-filled tanks. Each tank is approximately square in shape with curved corners, and the walls are smooth. To create motion in the tanks, water is supplied through a pipe at the edge of the tank. The water is drained from the tank through an opening at the center. A model with a length scale of 1:13 is to be used to determine the velocity, V, at various locations within the tank.
Assume that $V = f(l, l_i, \rho, \mu, g, Q)$ where l is some characteristic length such as tank width, l_i represents a series of other pertinent lengths, such as inlet pipe diameter, fluid depth etc., ρ is the fluid density, μ is the fluid viscosity, g is the acceleration of gravity, and Q is the discharge through the tank. **(a)** Determine the suitable set of dimensionless parameters for this problem. **(b)** If water is to be used for the model, can all of the similarity requirements be satisfied? Explain and support your answer with necessary calculations. **(c)** To ensure complete similarity, what would be kinematic viscosity of the model fluid? **[8M]**

Q2. You recently bought a house and want to improve the flow rate of water on top floor. The poor flow rate is due to three reasons: The city water pressure at the water meter is poor (p = 200 kPa gage); the piping has a small diameter (D = 1.27 cm) and has been contaminated, increasing its roughness (e/D = 0.05); and top floor of the house is 15 m higher than the water meter. You are considering two options (FigQ2) to improve the flow rate: *Option* 1 is replacing all the piping after the water meter with new smooth piping with a diameter of 1.9 cm; and *Option* 2 is installing a booster pump while keeping the original pipes. The booster pump has an outlet pressure of 300 kPa.
Which option would be more effective (in terms of flow rate)? Neglect minor losses. Assume pressure at pipe exit (i.e. top floor) is p_{atm} = 0 kPa gage. Use Colebrook's equation for friction factor 'f' calculation. Perform two iterations for 'f' calculation. **[14M]**



FigQ2



FigQ3

Q3. The semicircular building shown in FigQ3 is 18 m long and is subjected to a steady uniform wind. During a storm the wind speed reaches 100 km/hr; the outside temperature is 20°C. A barometer inside the hut reads 720 mm of mercury; pressure p_∞ is also 720 mm of Hg. The building has a diameter of 6 m. Assuming *potential flow* over the building, determine the net force tending to lift the building off its foundation. **[8M]**

Q4. Two immiscible fluids are contained between infinite parallel horizontal plates. The plates are separated by distance $2h$, and the two fluid layers are of equal thickness h = 5 mm. The dynamic viscosity of the upper fluid is four times that of the lower fluid, which is μ_{lower} = 0.1 N-s/m^2.

If the plates are stationary and the applied pressure gradient is -50 kPa/m, find the velocity at the interface. For convenience the origin of coordinates is placed at centerline. What is the maximum velocity of flow? Plot the velocity distribution.

Assume fully developed laminar flow. **[12M]**

Q5. A smooth flat plate 1.5 m wide and 4 m long is subjected to flow of water along its length with a velocity of 2 m/s. The flow in the boundary layer is laminar at the leading edge of the plate. The laminar boundary layer undergoes a transition ($Re_{trans} = 5\times10^5$) to turbulent boundary layer as the flow proceeds in the downstream. It is observed that a cubic laminar profile is finally changed into a $1/7^{th}$ power law velocity profile in the turbulent regime.

Find **(a)** the distance from the leading edge where the boundary layer flow changes from laminar to turbulent flow **(b)** the thickness of the boundary layer at the edge of the laminar boundary layer and at the trailing edge **(c)** the shear stress at the trailing edge **(d)** the portion of frictional drag due to turbulent boundary layer **(e)** the ratio of drag forces created due to turbulent boundary layer flow to laminar boundary layer flow i.e. F_{turb}/F_{lam} **[8M]**

Take $\rho = 1000\,\text{kg/m}^3$ and $\upsilon = 1\times10^{-6}\,\text{m}^2/\text{s}$