BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI, PILANI

FIRST SEMESTER 2023– 2024

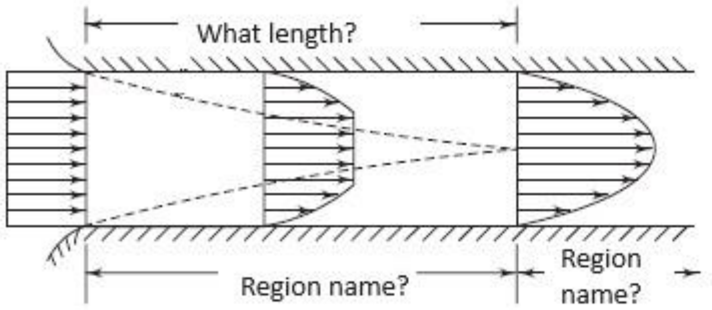
CE F231 (FLUID MECHANICS) COMPREHENSIVE EXAMINATION (CLOSED BOOK)

Duration: **90 mins** **Max Marks**: **40**

Note: Please write the answers in SI units and up to three decimal points with units. Use g=9.81 m/s^2.

- **Use density of air = 1.2 kg/m^3 and density of water = 1000 kg/m^3 wherever not given.**

Q1. Redraw the figure below and mark necessary regions with their names. Mention boundary layer region and hydrodynamic flow region as well. Show the zone which has irrotational flow? Consider the figure as flow inside a circular conduit.



[2]

Q2. Match the following: (All three columns)

Reynolds number – Compressibility effects significant – Capillary rise
Froude number – Surface tension dominated flow – Pipe flow in steady water distribution networks
Weber number – Viscosity dominated flow – Flow in irrigation open channel canals
Euler number – Pressure dominated flow – Supersonic jets
Mach number – Gravity dominated flow – Hydraulic transients in pipe flow to turbines

What is the common force in the above flows and nondimensional numbers? [6]

Q3.

a) Write the names of each equation below. **[1]**
b) Show the terms representing different forces considered in this equation. **[1]**
c) How Euler's equation is different from the equation below? **[1]**
d) The following equations are applicable for: **[1]**
e) How Bernoulli equation is applicable in head form for a flow of water between two sections of a pipe irrespective of streamlines? (What are the assumptions needed in following equations leads to validity of Bernoulli's equation?) **[2]**

Note: Pick answers for c) and d) from the following terms: **Steady, unsteady, rotational, irrotational, uniform, nonuniform, compressible, incompressible, viscous, inviscid, surface tension is significant/insignificant, Two dimensional, three dimensional.**

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

$$\rho\left[\frac{\partial u}{\partial t}+\frac{\partial u}{\partial x}u+\frac{\partial u}{\partial y}v+\frac{\partial u}{\partial z}w\right]=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)+\rho g_x$$

$$\rho\left[\frac{\partial v}{\partial t}+\frac{\partial v}{\partial x}u+\frac{\partial v}{\partial y}v+\frac{\partial v}{\partial z}w\right]=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+\rho g_y$$

$$\rho\left[\frac{\partial w}{\partial t}+\frac{\partial w}{\partial x}u+\frac{\partial w}{\partial y}v+\frac{\partial w}{\partial z}w\right]=-\frac{\partial p}{\partial z}+\mu\left(\frac{\partial^2 w}{\partial x^2}+\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+\rho g_z$$

[Total 1+2+1+2+2 =6]

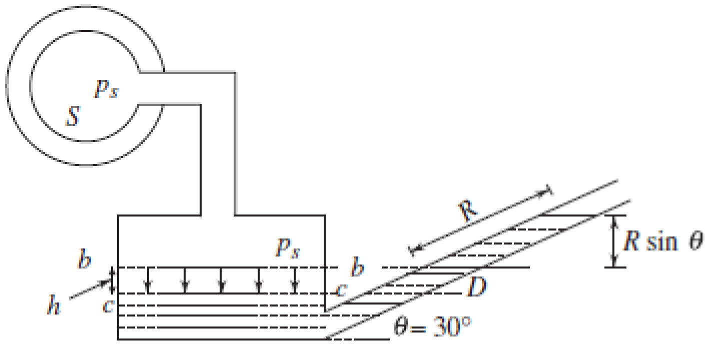
Q6. What is cavitation? Explain cavitation in siphon and venturimeter. **[2]**

Q7. If there is an error of 1% in measurement of head in an v-notch, then error in discharge is __%. If same 1% error in measurement of head in a rectangular notch, then the error in discharge is ___% **[2]**

Q8. A 0.80-m-high rectangular weir is used to measure the flow rate of water in a 5-m-wide rectangular channel. The flow depth well upstream from the weir is 1.8 m. Determine the maximum flow rate if the crest length is 2.5 m. **[2]**

Q9. Water flows at the rate of 0.02 m^3/s through a 100 mm diameter orifice used in a 300 mm pipe. Take coefficient of contraction C_c and coefficient of velocity C_v are 0.6 and 0.98 respectively. The difference in pressure head between the upstream section and vena contracta section is ___ m of water. Express up to three decimals. **[2]**

Q10. An inclined tube manometer measures the gauge pressure Ps of a system S. The reservoir and tube diameters of the manometer are 50 mm and 5 mm respectively. The inclination angle of the tube is 30 degrees. The percentage error in measuring Ps if the reservoir deflection is neglected is ______ (**up to three decimal places**).



[2]

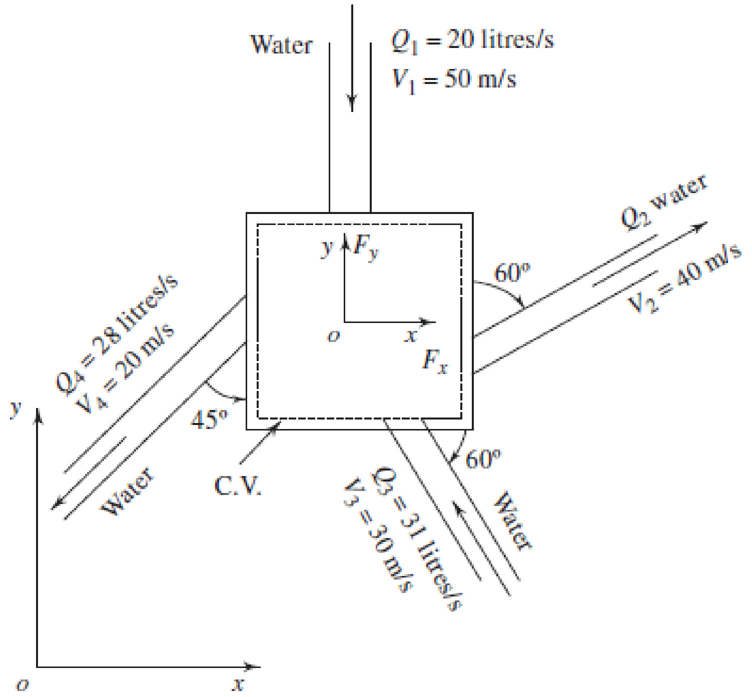
Q11. A cast iron pipe is used for water supply is of 200 mm and the discharge is 60 m/s. Find the Darcy-Weisbach friction factor. **[2]**

Q12. Consider the flow between two fixed plates with lateral width is very large. The flow is laminar and the oil thickness between the plates is 70 mm. The viscosity of the oil is 2 Pa.s and maximum velocity of the flow is 1.8 m/s. Calculate,

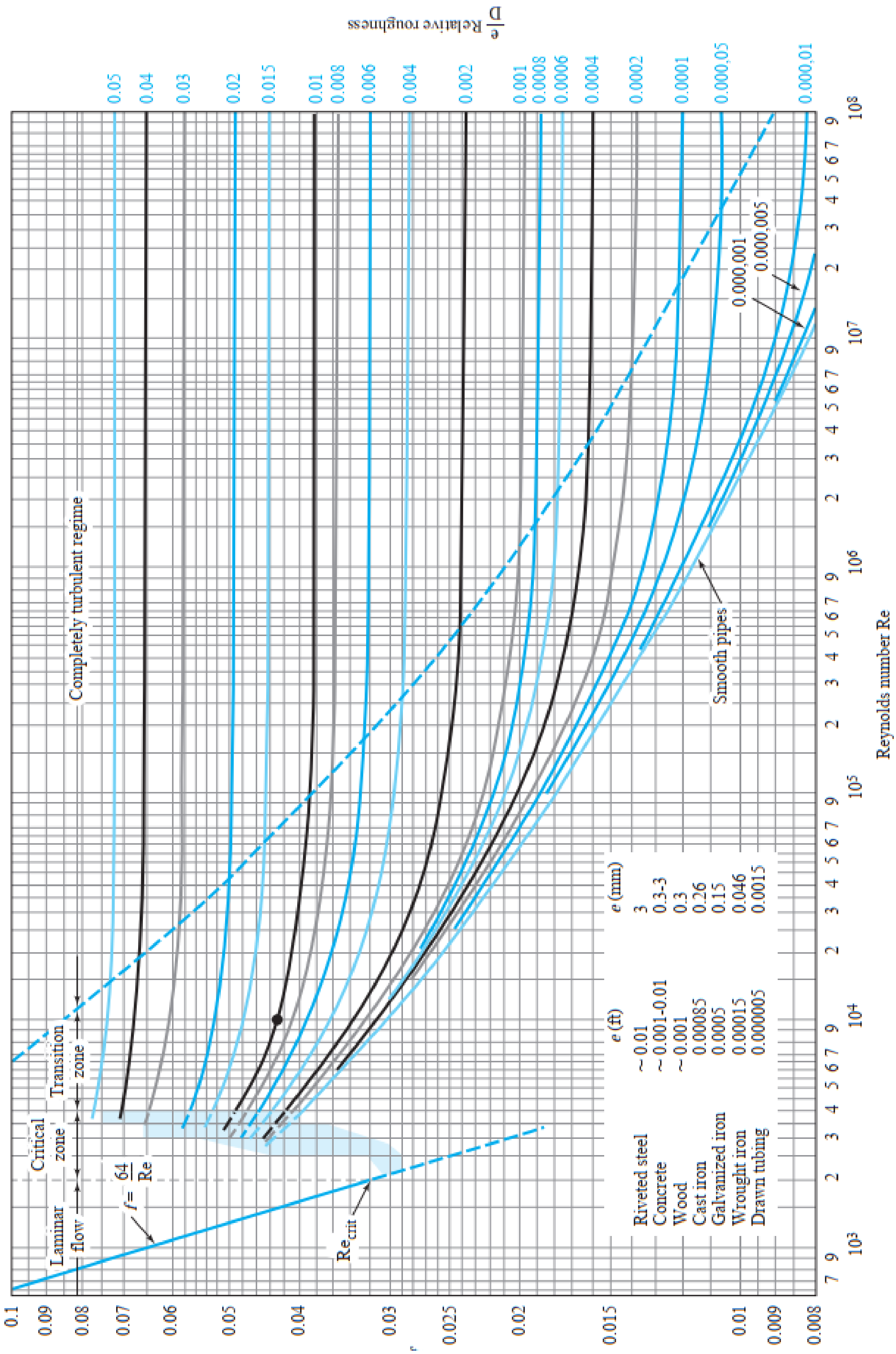
a) The pressure gradient (mention if it is adverse or favorable pressure gradient) in N/m^2 per m
b) Maximum shear stress location(s) and shear stress value in N/m^2
c) Discharge per unit width in m^3/s **[4]**

Q13. Two pipes have a length L each. The diameter of two pipes are d and d/3. Find the ratios of head loss of two pipes if the pipes are parallel and if the pipes are series. Take head loss of bigger pipe as h_1 and head loss of smaller pipe as h_2. **[4]**

Q14. What force components F_x and F_y are required to hold the black box shown in figure stationary. Assume no mass accumulated in the black box and all pressures are zero gauge.



[6]



Laminar flow
Critical zone
Transition zone
Completely turbulent regime
f = 64/Re
Re_crit
Smooth pipes
Reynolds number Re
e/D Relative roughness
f
0.05
0.04
0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.000,05
0.000,01
0.000,005
0.000,001
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
10³
10⁴
10⁵
10⁶
10⁷
10⁸
e (ft)
e (mm)
Riveted steel ~0.01 3
Concrete ~0.001-0.01 0.3-3
Wood ~0.001 0.3
Cast iron 0.00085 0.26
Galvanized iron 0.0005 0.15
Wrought iron 0.00015 0.046
Drawn tubing 0.000005 0.0015

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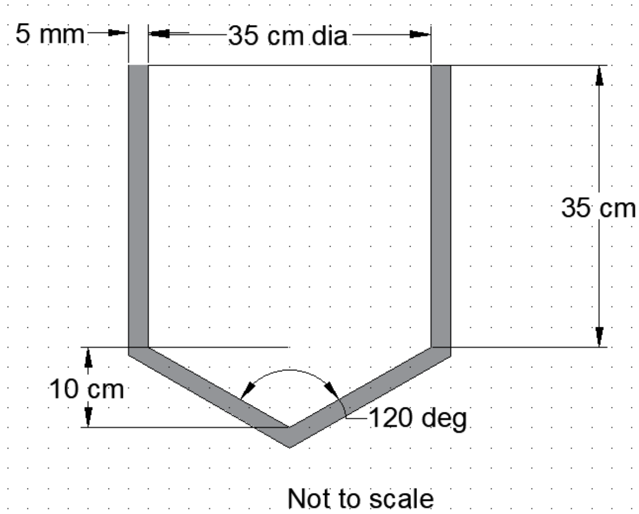
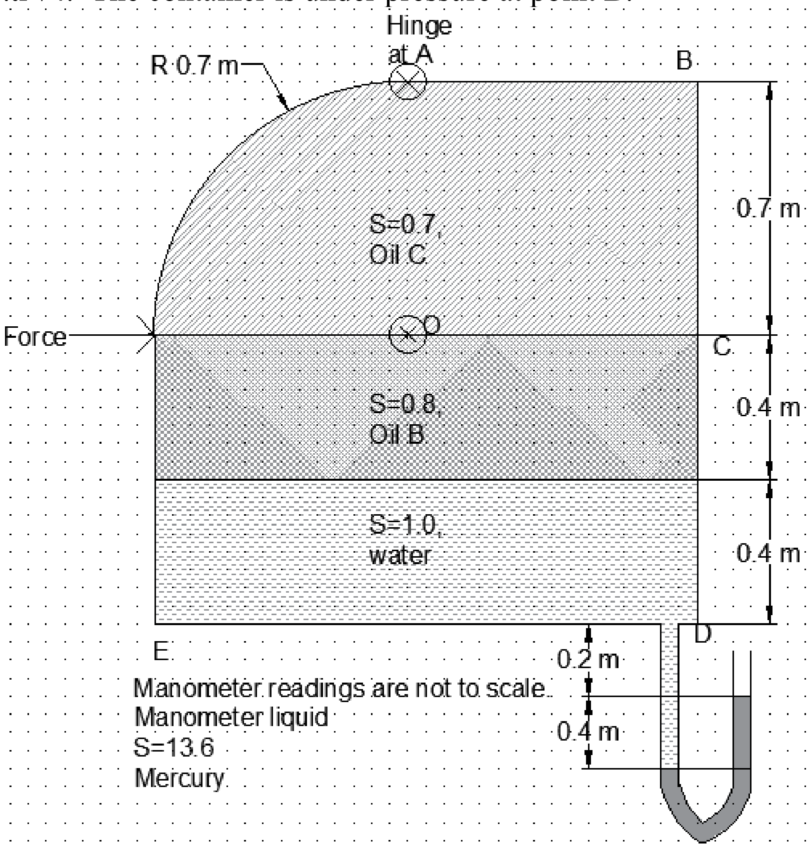
Q1. A shaft of cylinder with conical bottom is rotating in a groove of similar shape (Figure below) with an uniform gap of 5 mm everywhere. The viscosity of the liquid is 0.01 Pa.s. Determine the frictional torque on the shaft when it rotates at a constant speed of 5000 rpm. Also determine the reduction in the required power input when the liquid is replaced with another liquid with the viscosity 0.0078 Pa.s. Note: Consider bottom, and side surface.



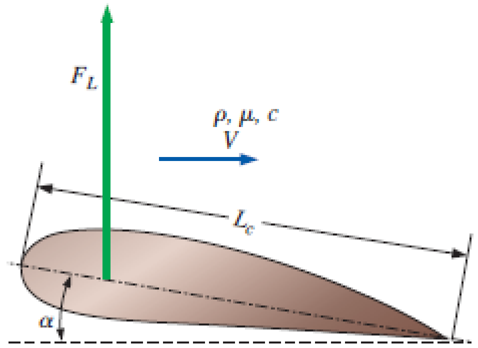
[12]

Q2. Calculate the force F required to hold the gate in a closed position for the setup shown in figure below. Note: Centroid of quarter circle is at **4r/3π** distance from its center for both x and y direction. Moment of Inertia of **full circle** is $\pi r^4/4$. The container is under pressure at point B.



[12]

Q3. An aircraft design is tested in a wind tunnel for lift force. F_L is the lift force on the wing, V is the fluid speed, L_c is the chord length, ρ is the fluid density, μ is the fluid viscosity, c is the speed of sound in the fluid, and α is the angle of attack of the wing. **Find functional relationship for lift force by Buckingham pi method.** If the wind tunnel used to test has a limitation that the pressure cannot go beyond 5 atm, and the aircraft prototype should work under subsonic condition (maximum value of non-dimensional parameter related to it is approximately 0.3), what would be the wind tunnel speed if the prototype is supposed to fly at 52 m/s?
Note: wind tunnel maximum pressure is not a variable governing the lift force. Consider that at constant temperature, viscosity and speed of sound are weak functions of pressure.



[8]

Q4. Velocity distribution in a circular pipe is given by $\boldsymbol{v} = v_{max}\left(1-\frac{r}{r_0}\right)^k$, where r is the variable radius, k is a constant, v_{max} is maximum velocity and $r_0$is radius of the pipe. Derive the expression for average velocity and kinetic energy correction factor in terms of k. What is the ratio of average velocity to maximum velocity if k is one and corresponding value for kinetic energy correction factor? Similarly, what is the ratio of average velocity to maximum velocity if k is two and corresponding value for kinetic energy correction factor? **[8]**