Name: **Enrolment No:**	

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

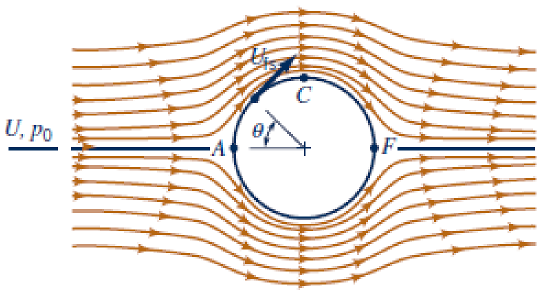
End Semester Examination, December 2022

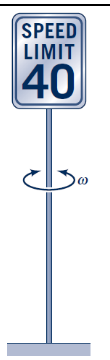
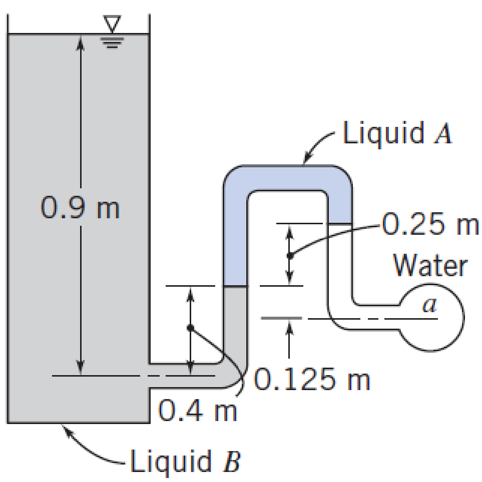
Programme Name: B.Tech Aerospace Engg **Semester : III**
Course Name : Applied Fluid Mechanics **Time : 03 hrs**
Course Code : MECH2002 **Max. Marks : 100**

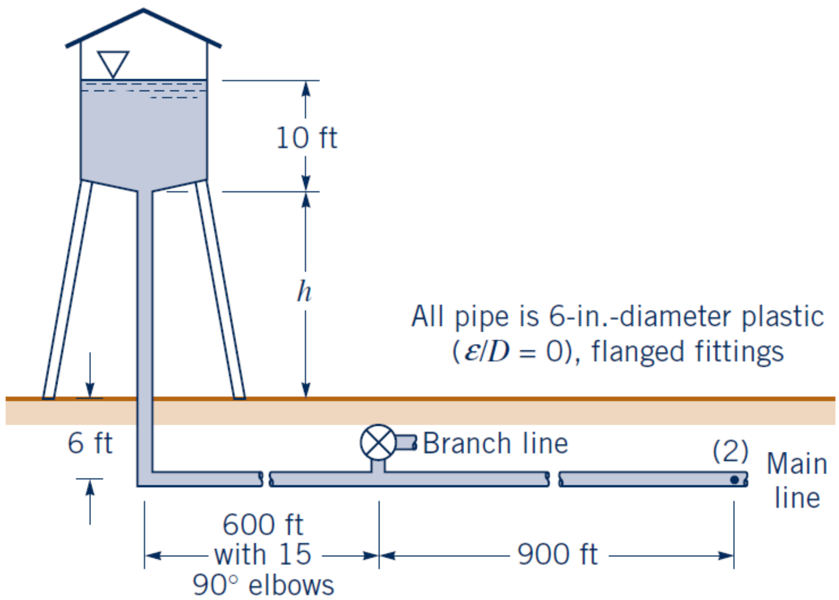
Instructions:

- Section A constitutes of 20 Marks (5 questions x 4 marks); Attempt All.
- Section B constitutes of 40 Marks (4 questions x 10 marks). Attempt All (One choice question).
- Section C constitutes of 40 Marks (2 questions x 20 marks). Attempt All (One choice question).

SECTION A

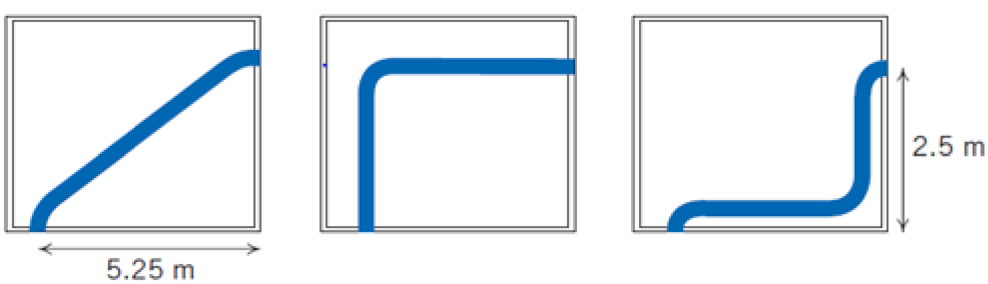
SN			CO
Q1	 The figure above shows that a table-tennis ball can be levitated in air by applying an air jet at an angle. Using a force-balance analysis, show how is this possible? Briefly state the possible physical effects and mathematical expressions underlying the phenomenon.	4	CO1
Q 2	A European Fluid Dynamicist, D' Alambert, once observed to his great surprise that  1) For $\mu = 0$, Drag Force $F_D = 0$ 2) For $\mu \sim 0$, Significant drag force F_D 3) As μ is increased, F_D is independent of μ. How do you explain such strange observations?	4	CO1
Q 3	Read these statements and answer the question that follow Mohan: Forced vortex is rotational. Murari: Free Vortex is irrotational. MadanMohan: Free Vortex is rotational. Madhusudan: Forced Vortex is irrotational.	4	CO1

	Madhava: Forced and Free Vortex are irrotational. MuraliMohan: Forced and Free Vortex are Rotational. Who is/are correct? Justify your answer with examples.		
Q 4	Imagine you are a pilot of a Boeing 757 Jet commercial aircraft. While flying this aircraft, when (and why) would you use: • Leading edge slats • Trailing edge flaps	**4**	**CO1**
Q5	a) Why is it that sometimes on narrow industrial Chimneys, spirals are made on the circumference? What specific purpose do they serve? Explain the underlying phenomenon. b) Citing the specific example of the recently launched Speedtail MaLaren sports car, enumerate what specific features can be had on a high speed car, to enable it to attain extremely high speeds? Present only the Fluid Mechanics perspectives.	**4**	
SECTION B			
Q 6	 Under certain conditions, wind blowing past a rectangular speed limit sign can cause the sign to oscillate with a frequency v. Assume that v is a function of the sign width, *b*, sign height, *h*, wind velocity, *V*, air density, r, and an elastic constant, *k*, for the supporting pole. The constant, *k*, has dimensions of *FL*. Develop a suitable set of pi terms for this problem.	**10**	**CO2**
Q 7	Determine the gage pressure in kPa at point a, if liquid A has SG = 1.20 and liquid B has SG = 0.75. The liquid surrounding point A is water, and the tank on the left is open to the atmosphere. 	**10**	**CO2**
Q 8	The pressure at section (2) shown in Fig. P8.73 is not to fall below 60 psi when the flowrate from the tank varies from 0 to 1.0 cfs and the branch line is shut off. Determine the minimum height, *h*, of the water tank under the assumption that minor losses are not negligible.	**10**	**CO4**



OR

A 5-cm-diameter portable water line is to be run through a maintenance room in a commercial building. Three possible layouts for the water line are proposed, as shown. Which is the best option, based on minimizing losses?
Assume galvanized iron, and a flow rate of 350 L/min.



(a) Two miter bends (b) A standard elbow (c) Three standard elbows

Q 9	The velocity profile in a hypothetical boundary layer is approximated by the power law equation $$\frac{u}{U} = \left(\frac{y}{\delta}\right)^{1/6}$$ a) Find displacement thickness. b) Find momentum thickness. c) Compare the case of turbulent BL with Laminar BL.	**10**	**CO3**

SECTION C

Q 10	Flow through a sudden contraction is shown. The minimum flow area at vene contracta is given in terms of the area ratio by the contraction coefficient, $$C_c = \frac{A_c}{A_2} = 0.62 + 0.38\left(\frac{A_2}{A_1}\right)^3$$ The loss in a sudden contraction is mostly a result of the vena contracta: The fluid accelerates into the contration, there is flow separation (as shown by the dashed lines), and the vena contracta acts as a miniature sudden expansion with significant secondary flow losses. Use	**20**	**CO4**

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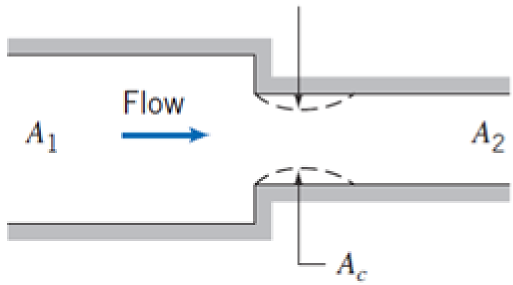
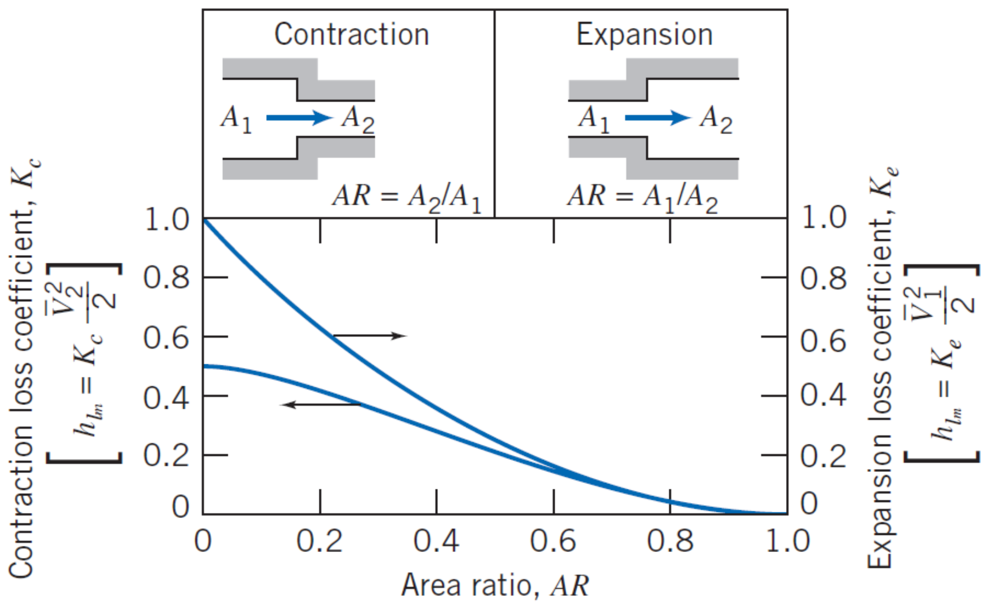
<td>these assumptions to obtain and plot estimates of the minor loss cofficient for a sudden contraction, and compare with the data presented in figure.

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<td>Q 11</td>
<td>A tornado (shown on the left) can be modeled by the superposition of a sink of strength 3000 m^2/s and a free vortex of circulation 6000 m^2/s. Further, the stream function and velocity potentials for some basic potential flows are shown below:</td>
<td>20</td>
<td>CO3</td>
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Description of Flow Field	Velocity Potential	Stream Function	Velocity Components[a]
Uniform flow at angle α with the x axis (see Fig. 6.16*b*)	$\phi = U(x\cos\alpha + y\sin\alpha)$	$\psi = U(y\cos\alpha - x\sin\alpha)$	$u = U\cos\alpha$ $v = U\sin\alpha$
Source or sink (see Fig. 6.17) $m > 0$ source $m < 0$ sink	$\phi = \frac{m}{2\pi}\ln r$	$\psi = \frac{m}{2\pi}\theta$	$v_r = \frac{m}{2\pi r}$ $v_\theta = 0$
Free vortex (see Fig. 6.18) $\Gamma > 0$ counterclockwise motion $\Gamma < 0$ clockwise motion	$\phi = \frac{\Gamma}{2\pi}\theta$	$\psi = -\frac{\Gamma}{2\pi}\ln r$	$v_r = 0$ $v_\theta = \frac{\Gamma}{2\pi r}$
Doublet (see Fig. 6.23)	$\phi = \frac{K\cos\theta}{r}$	$\psi = -\frac{K\sin\theta}{r}$	$v_r = -\frac{K\cos\theta}{r^2}$ $v_\theta = -\frac{K\sin\theta}{r^2}$

For the tornado shown above, determine :

a) The expression for velocity potential.
b) The expression for stream function.
c) The radial and tangential velocities
d) The radius beyond which the flow is incompressible.
e) Find the gauge pressure at that radius

OR

The entrance region of a parallel, rectangular duct flow is shown in figure. The duct has a width W and height H, where W >> H. The fluid density $\boldsymbol{\rho}$ is constant, and the flow is steady. The velocity variation in the boundary layer of thickness δ at station is assumed to be linear, and the pressure at any cross- section is uniform.

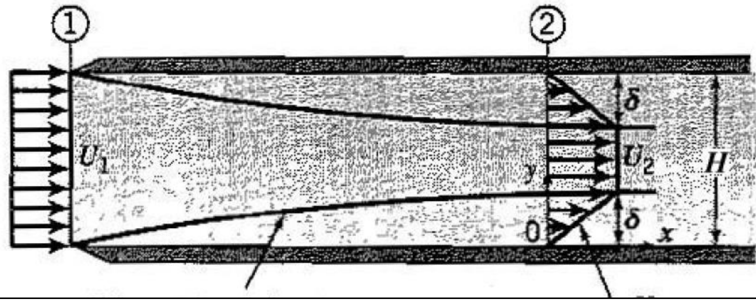
(a) Using the continuity equation, shows that $U_1/U_2 = 1 - \delta/\mathrm{H}$.

(b) Find the pressure coefficient $C_p = (p_1 - p_2)/(\frac{1}{2}\boldsymbol{\rho} {U_1}^2)$

(c) Show that

$$\frac{F_v}{\frac{1}{2}\rho {U_1}^2 WH} = 1 - \frac{{U_2}^2}{{U_1}^2}\left(1 - \frac{8\delta}{3H}\right)$$

Where F_v is the total viscous force acting on the walls of the duct?



Appendix

Haaland Equation

$$\frac{1}{\sqrt{f}} = -1.8\log\left[\frac{6.9}{\boldsymbol{Re}} + \left(\frac{\varepsilon/_D}{3.7}\right)^{1.11}\right]$$

Conservation Equations in Cylindrical Coordinates:

Continuity Equation:

$$\frac{\partial\rho}{\partial t} + \frac{1}{r}\frac{\partial(r\rho v_r)}{\partial r} + \frac{1}{r}\frac{\partial(\rho v_\theta)}{\partial\theta} + \frac{\partial(\rho v_z)}{\partial z} = 0$$

Momentum Equation:

(r direction)

$$\rho\left(\frac{\partial v_r}{\partial t} + v_r\frac{\partial v_r}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_r}{\partial\theta} - \frac{v_\theta^2}{r} + v_z\frac{\partial v_r}{\partial z}\right)$$
$$= -\frac{\partial p}{\partial r} + \rho g_r + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_r}{\partial r}\right) - \frac{v_r}{r^2} + \frac{1}{r^2}\frac{\partial^2 v_r}{\partial\theta^2} - \frac{2}{r^2}\frac{\partial v_\theta}{\partial\theta} + \frac{\partial^2 v_r}{\partial z^2}\right]$$

(θ direction)

$$\rho\left(\frac{\partial v_\theta}{\partial t} + v_r\frac{\partial v_\theta}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_\theta}{\partial\theta} + \frac{v_r v_\theta}{r} + v_z\frac{\partial v_\theta}{\partial z}\right)$$
$$= -\frac{1}{r}\frac{\partial p}{\partial\theta} + \rho g_\theta + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_\theta}{\partial r}\right) - \frac{v_\theta}{r^2} + \frac{1}{r^2}\frac{\partial^2 v_\theta}{\partial\theta^2} + \frac{2}{r^2}\frac{\partial v_r}{\partial\theta} + \frac{\partial^2 v_\theta}{\partial z^2}\right]$$

(z direction)

$$\rho\left(\frac{\partial v_z}{\partial t} + v_r\frac{\partial v_z}{\partial r} + \frac{v_\theta}{r}\frac{\partial v_z}{\partial\theta} + v_z\frac{\partial v_z}{\partial z}\right)$$
$$= -\frac{\partial p}{\partial z} + \rho g_z + \mu\left[\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial v_z}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 v_z}{\partial\theta^2} + \frac{\partial^2 v_z}{\partial z^2}\right]$$