Name: **Enrolment No:**	

UPES

End Semester Examination, December 2024

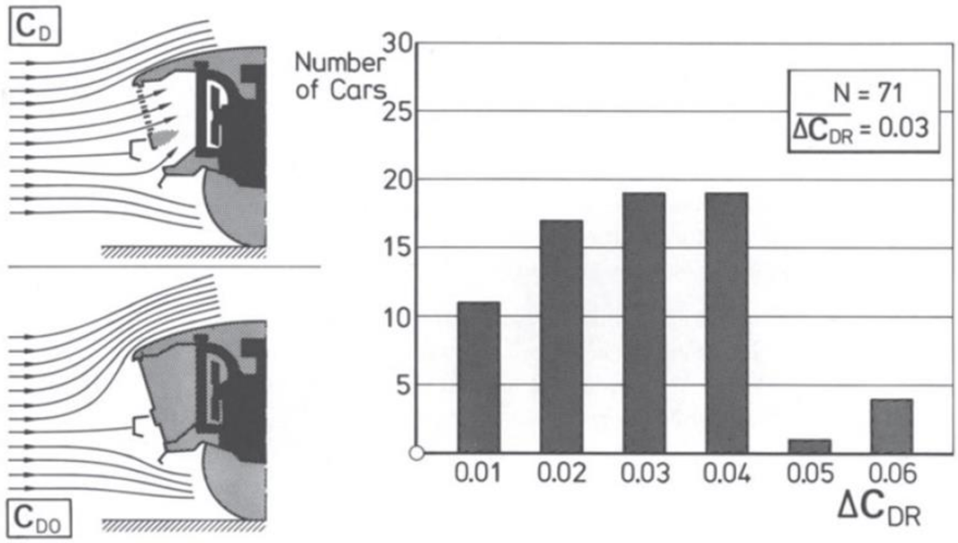
Programme Name: B.Tech Aerospace Engg **Semester : III**
Course Name : Fluid Mechanics **Time : 03 hrs**
Course Code : MECH2079 **Max. Marks : 100**

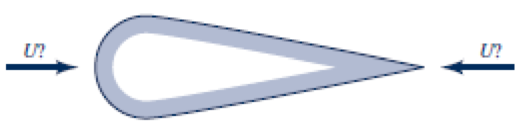
Instructions:

- 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).

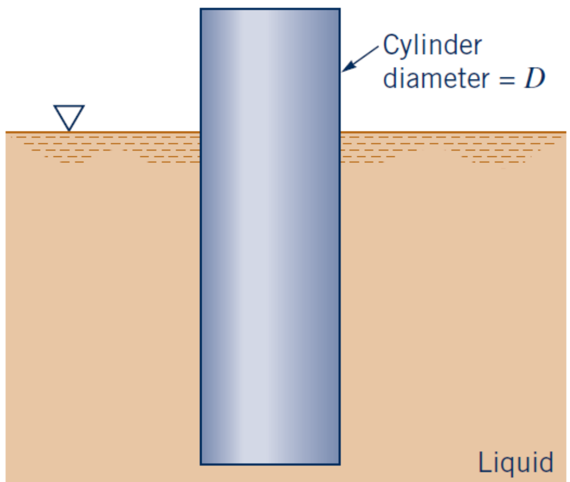
SECTION A

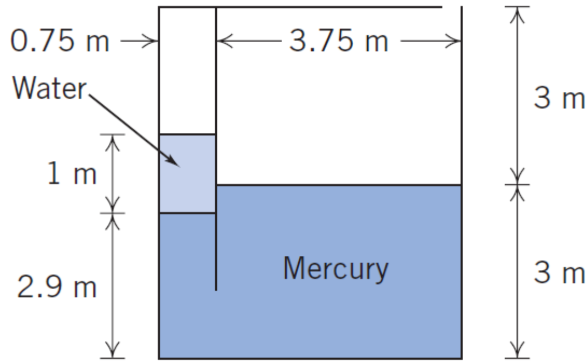
S. No.			**CO**
Q 1	Read these statements and answer the question that follow Raghav: All inviscid flows are irrotational. Raghunath: All irrotational flows are inviscid. Raghuram: All viscous flows are rotational. Raman: All viscous flows are irrotational. Ramesh: All irrotational flows are inviscid. Who is/are correct? Justify your answer with examples. (None/All of the choices may also be correct)	**4**	**CO1**
Q 2	Automobiles need to breathe in air for purposes such as cooling of engines. This may lead to an additional ‘cooling drag’ on the automobiles The pictures and the plots below represent this phenomenon:   The figure above shows two set up of experiments conducted for which drag coefficient was estimated. The difference between the drag coefficient is shown below:	**4**	**CO1**

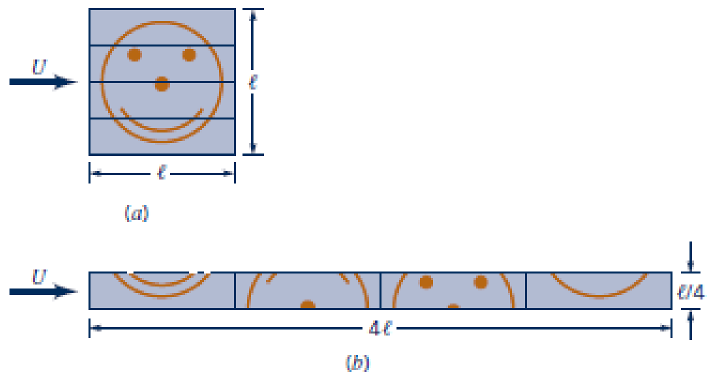
<table>
<tr><td></td><td>

Explain briefly in which case is the drag coefficient larger. Why? (Be brief!)</td><td></td><td></td></tr>
<tr><td>Q 3</td><td>Consider the flow field given by
$$V = xi + ytj$$
This flow is unsteady (it depends on time) and two-dimensional (it depends on two space coordinates, x and y). Find the shape of
(a) The streamline and;
(b) The pathline passing through the point [1,1] at time t = 0.
Plot the streamline and pathlines in both cases.</td><td>4</td><td>CO1</td></tr>
<tr><td>Q 4</td><td>It is often assumed that “sharp objects can cut through the air better than blunt ones.” Based on this assumption, the drag on the object shown in Figure should be less when the wind blows from right to left than when it blows from left to right. Experiments show that the opposite is true. Explain.
</td><td>4</td><td>CO1</td></tr>
<tr><td>Q5</td><td>

Fastback Notchback Squareback
The figure above shows three Volkswagen car designs, which may be categorized into ‘Fastback’, ‘Notchback’ and ‘Square back’ cars. What would be your firsthand intuition</td><td>4</td><td>CO1</td></tr>
</table>

	regarding the total drag experienced by these cars? Make a comparison, briefly explaining the reason behind it and also the Assumptions you are making to state your conclusion. (Be brief!)		
	SECTION B		
Q 6	A cylinder with a diameter *D* floats upright in a liquid as shown in the figure. When the cylinder is displaced slightly along its vertical axis it will oscillate about its equilibrium position with a frequency, v. Assume that this frequency is a function of the diameter, *D*, the mass of the cylinder, *m*, and the specific weight, g, of the liquid. Determine, with the aid of dimensional analysis, how the frequency is related to these variables. If the mass of the cylinder were increased, would the frequency increase or decrease? 	**10**	**CO2**
Q 7	For flow over a hypothetical flat plate of length *L*, the velocity profile can be approximated as $$\frac{u}{U} = 0.7\frac{y}{\delta}$$ Find: a) Boundary layer thickness at a distance x. b) Shear stress at a distance x c) Local drag coefficient **d)** Coefficient of Drag	**10**	**CO2**
Q 8	A partitioned tank as shown contains water and mercury. What is the gage pressure in the air trapped in the left chamber? What pressure would the air on the left need to be pumped to in order to bring the water and mercury free surfaces level?	**10**	**CO3**

	 **OR** A high school project involves building a model ultralight airplane. Some of the students propose making an air foil from a sheet of plastic 5 m long 3.7 m wide at an angle of attack of 10 degrees. At this air foil's aspect ratio and angle of attack the lift and drag coefficients are $C_L = 0.75$ and $C_D = 0.19$. If the airplane is designed to fly at 40 m/s, what is the maximum total payload? What will be the required power to maintain flight? Does this proposal seem feasible?		
Q 9	For the following 2D flow fields: $\vec{V} = (u, v) = u(x, y)\vec{i} + v(x, y)\vec{j}$ or $\Psi(x, y)$ $(a)\ Couette\ flows: u = y, v = 0$ $(b)\ \Psi = x^2 - y^2$ For each case, determine if the flow is incompressible, if it is irrotational and if it can be treated as potential flows.	**10**	**CO4**
SECTION C			
Q 10	Using Continuity and Navier-Stokes Equation in cylindrical coordinates for fluid flow through a pipe, derive expressions for a) Velocity profile in a pipe of diameter *D* b) Relationship between discharge and pressure drop over length *L* of this pipe.	**20**	**CO3**
Q11	The square, flat plate shown in first figure is cut into four equal-sized pieces and arranged as shown in the second figure (let's refer to them as two cases). Assuming laminar boundary flow, (a) Determine the ratio of the drag on the original plate to the drag on the plates in the configuration shown. Explain your answer physically. (b) Determine the ratio of the boundary layer thickness at the trailing edge for the two cases. (c) Determine the ratio of average shear stress in the two cases.	**20**	**CO4**



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)

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