Name: **Enrolment No:**	UPES UNIVERSITY OF TOMORROW

UPES

End Semester Examination, December 2023

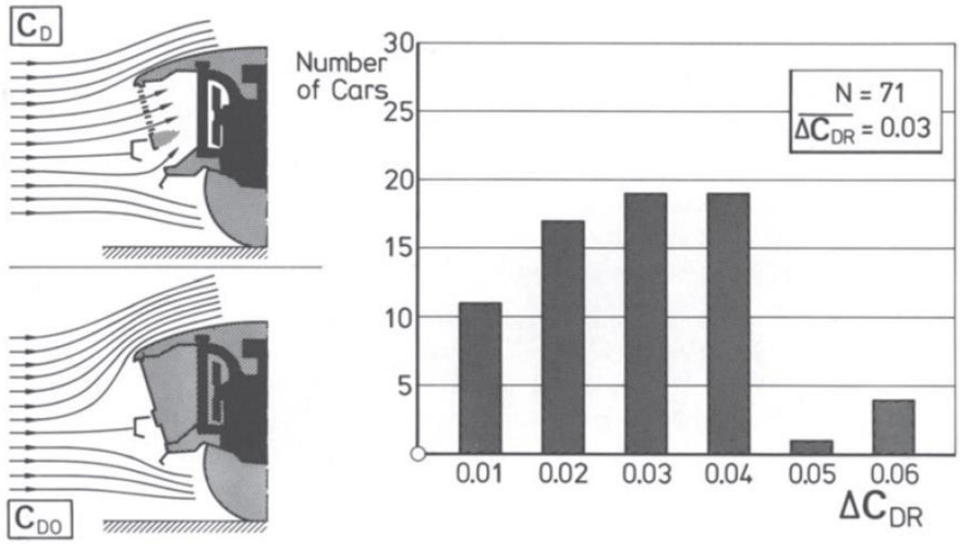
Course: Applied Fluid Mechanics **Semester: III**
Program: B. Tech Aerospace Engineering **Time : 03 hrs.**
Course Code: MECH2002 **Max. Marks: 100**

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
(5Qx4M=20Marks)

S. No.		**Marks**	**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**



Explain briefly in which case is the drag coefficient larger. Why? (Be brief!)

Q 3 — **4** — **CO1**

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.

Q 4 — **4** — **CO1**

The Martian atmosphere behaves as an ideal gas with mean molecular mass of 32.0 and constant temperature of 200 K. The atmospheric density at the planet surface is ρ = 0.015 kg/m^3 and Martian gravity is 3.92 m/s^2. Calculate the density of the Martian atmosphere at height =520 km above the surface.

Q5 — **[5]** — **CO3**

A centrifugal water pump running at speed ω= 800 rpm has the following data for flow rate, Q, and pressure head, Δp.

Q (L/min)	0	50	75	100	120	140	150	165
$\Delta P\ (psf)$	7.54	7.29	6.85	6.12	4.80	3.03	2.38	1.23

The pessure head is a function of the flow rate, speed, impller diameter D, and water density $\boldsymbol{\rho}$. Plot the pressure head versus flow rate curve. Find the two Π parameters for this problem, and, from above data, plot one against the other.

SECTION B

Q 6 — **10** — **CO2**

The Colebrook equation for computing the turbulent friction factor is implicit in f. An explicit expression [31] that gives reasonable accuracy is

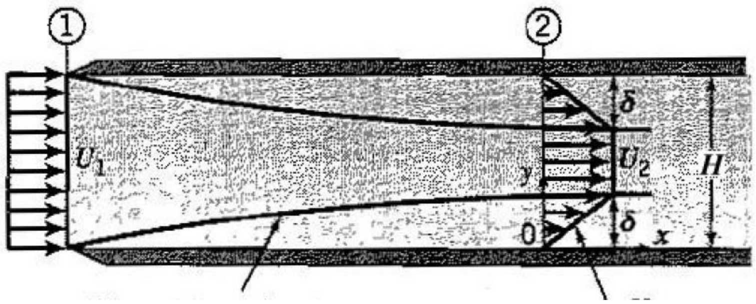
$$f_0 = 0.25\left[\log\left(\frac{e/D}{3.7} + \frac{5.74}{Re^{0.9}}\right)\right]^{-2}$$

Compare the accuracy of this expression for f with the equation above by computing the percentage discrepancy as a function of Re and e/D, for Re = 10^4 to 10^8 , and e/D = 0, 0.0001, 0.001, 0.01, and 0.05. What is the maximum discrepancy for these Re and e/D values? Plot f against Re with e/D as a parameter.

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	Gasoline flows in a long, underground pipeline at a constant temperature of 15 degree Celsius. Two pumping stations at the same elevation are located 13 km apart. The pressure drop between the stations is 1.4 MPa. The pipeline is made from 0.6-m-diameter pipe. Although the pipe is made from commercial steel, age and corrosion have raised the pipe roughness to approximately that for galvanized iron. Compute the volume flow rate. How long will it take for the Gasoline flowing through such a pipeline to fill a 10,000 L tank? **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?	**10**	**CO3**
Q 9	Two immiscible fluids of equal density are flowing down a surface inclined at a 60 degree angle. The two fluid layers are of equal thickness h= 10 mm; the kinematic viscosity of the upper fluid is $1/5^{th}$ that of the lower fluid, which is V lower = 0.01 m^2/s. Find the velocity at the interface and the velocity at the free surface. Plot the velocity distribution.	**10**	**CO4**
SECTION-C **(2Qx20M=40 Marks)**			
Q 10	Using Continuity and Navier-Stokes Equation in cylindrical coordinates for fluid flow between two parallel plates, derive expressions for a) Velocity profile between two plates spaced distance D apart. b) Relationship between discharge and pressure drop over length L of the plates.	**20**	**CO3**
Q 11	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	**20**	**CO4**

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

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



OR

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:

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.

Appendix

Haaland Equation :

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

Potential Flows:

Description of Flow Field	Velocity Potential	Stream Function	Velocity Components[a]
Uniform flow at angle α with the x axis (see Fig. 6.16b)	$\phi = U(x\cos\alpha + y\sin\alpha)$	$\psi = U(y\cos\alpha - x\sin\alpha)$	$u = U\cos\alpha$ $v = U\sin\alpha$
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)	$\phi = \frac{K\cos\theta}{r}$	$\psi = -\frac{K\sin\theta}{r}$	$v_r = -\frac{K\cos\theta}{r^2}$ $v_\theta = -\frac{K\sin\theta}{r^2}$

Momentum Equations in Cartesian Coordinates:

$$\rho\left(\frac{\partial U}{\partial t}+U\frac{\partial U}{\partial x}+V\frac{\partial U}{\partial y}+W\frac{\partial U}{\partial z}\right)=-\frac{\partial P}{\partial x}+\rho g_x+\mu\left(\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}+\frac{\partial^2 U}{\partial z^2}\right)$$

$$\rho\left(\frac{\partial V}{\partial t}+U\frac{\partial V}{\partial x}+V\frac{\partial V}{\partial y}+W\frac{\partial V}{\partial z}\right)=-\frac{\partial P}{\partial y}+\rho g_y+\mu\left(\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial y^2}+\frac{\partial^2 V}{\partial z^2}\right)$$

$$\rho\left(\frac{\partial W}{\partial t}+U\frac{\partial W}{\partial x}+V\frac{\partial W}{\partial y}+W\frac{\partial W}{\partial z}\right)=-\frac{\partial P}{\partial z}+\rho g_z+\mu\left(\frac{\partial^2 W}{\partial x^2}+\frac{\partial^2 W}{\partial y^2}+\frac{\partial^2 W}{\partial z^2}\right)$$