Name:

Enrolment No:

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, May 2022

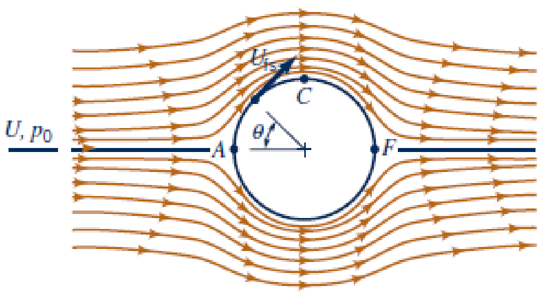
Programme Name: B. Tech Mechanical **Semester : IV**
Course Name : Fluid Mechanics and Machines **Time : 03 hrs**
Course Code : MECH 2026 **Max. Marks : 100**

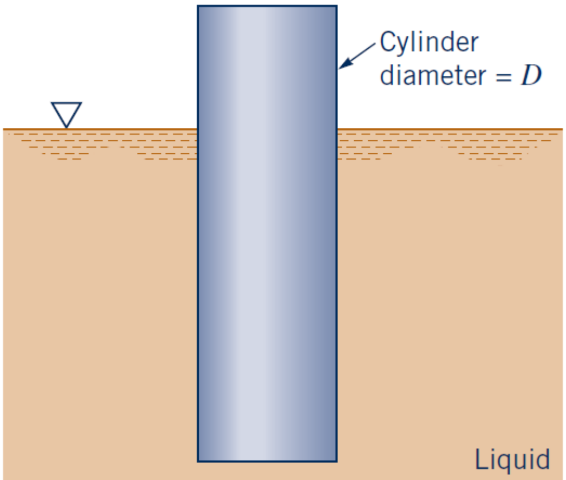
Instructions:

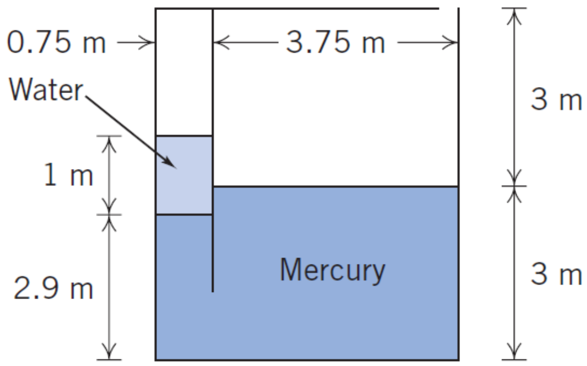
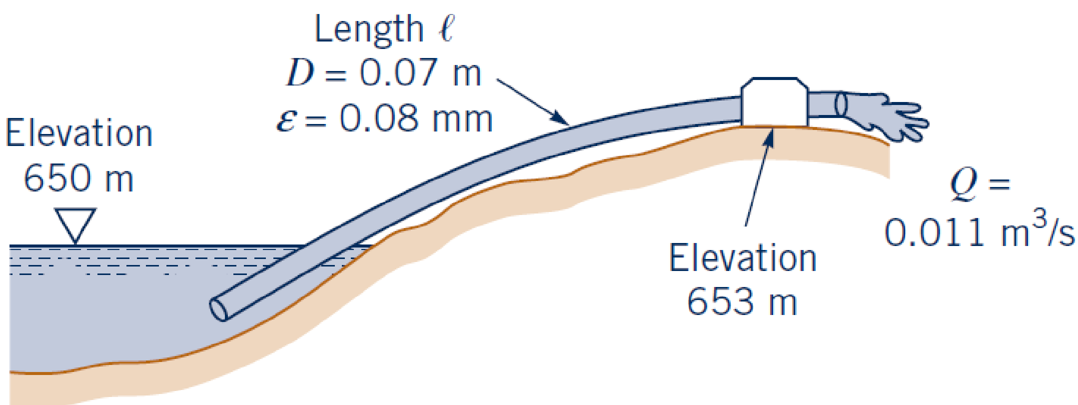
- Section A constitutes of 20 Marks (5 questions x 4 marks); Attempt All.
- Section B constitutes of 40 Marks (4 questions x 10 marks). Attempt All (One choice question).
- Section C constitutes of 40 Marks (2 questions x 20 marks). Attempt All (One choice question).

Please answer the sub-parts of a question together. Highlight the numerical answers**.**

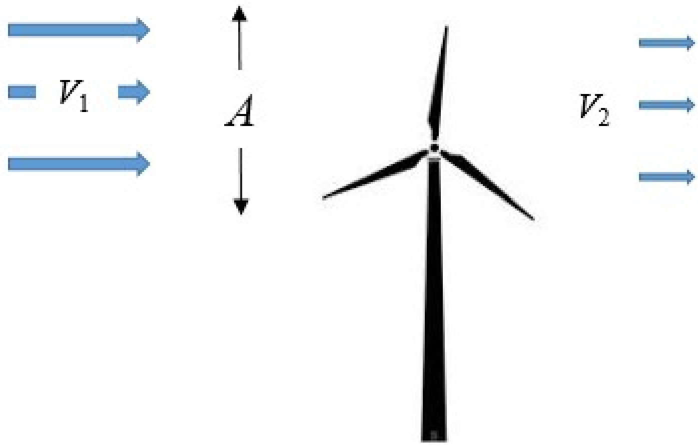
SECTION A

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. Raghuveer: All viscous flows are irrotational. Ram: 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	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	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.	**4**	**CO1**
Q 4	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	**4**	**CO1**

	extremely high speeds? Present only the Fluid Mechanics perspectives.		
Q 5	How does an Albatross undertake daily flights exceeding 1000 kms? Briefly explain.	**4**	**CO1**
	SECTION B		
Q 5	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 6	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 7	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** It is proposed to develop 2000 HP at a site where 150 m of head is available. What type of turbine would be employed if it had to run at 300 rpm? If the power requirements are stringent, but a compromise is possible to be made between N and H, Can you suggest alternative values of N, which are possible? How does the N-vs-H curves appear?		
Q 8	Water at 20 deg C is pumped from a lake as shown in the figure. If the flowrate is 0.011 m^3/s, what is the maximum length inlet pipe, *L*, that can be used without cavitation occurring?  	**10**	**CO4**
SECTION C			
Q 9	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**
Q 10	According to a recent report by National Renewable Energy Laboratory (NREL), there is an average wind speed below ~3m/s in Uttarakhand at heights of 80-100 m and a wind density of ρ kg/m^3. Assuming Uttarakhand Council of Science and Technology (UCOST) plans to install a single horizontal-axis wind turbine (shown) with the following	**20**	**CO4**

specifications:



a) Let the total incident power in the wind over the span area of the turbine be denoted by P_1 (dependent upon V_1). **Express P_1** as a function of V_1.

b) Express mass flow rate through the span area of wind turbine, **using the velocity obtained by taking the mean** of the incident (V_1) and exit velocities (V_2).

c) The total power extracted by the turbine, P can be described as the change in rate of kinetic energy before and after it has passed through blades. Use the mass flow rate obtained in part (b).

d) Get an expression for P/P_1 as a function of V_2/V_1 .

e) What is the maximum possible value of P/P_1 ?

OR

Consider these cases of external flow situations and answer the questions:

a) A plate of length 500 mm and width 250 mm has been placed longitudinally in a stream of crude oil which flows with a velocity of 6 m/s. if the oil has specific gravity 0.9 and viscosity 1 stoke calculate 1) Boundary layer thickness at the middle of the plate. 2) Shear stress and the middle of the plate 3) Friction drag on one side of the plate.

b) Experiment were conducted in a wind tunnel with wind speed of 50 km/hr on a flat plate 2 m long and 1 m wide. The mass density of air is 1.15 kg/m^3, and plate is kept at such an angle that the coefficients of lift and drag are 0.75 and 0.15 respectively. Determine the lift force, drag force, resultant force and power exerted by the air stream on the plate.

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)

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