

Fluid Mechanics (XE-B)

Q.1 - Q.8 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	The general relationship between shear stress, τ, and the velocity gradient $\left(\frac{du}{dy}\right)$ for a fluid is given by $\tau = k \left(\frac{du}{dy}\right)^n$, where k is a constant with appropriate units. The fluid is Newtonian if
(A)	$n > 1$
(B)	$n < 1$
(C)	$n = 1$
(D)	$n = 0$

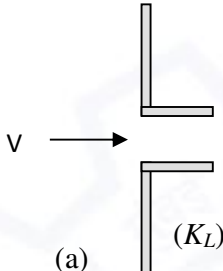
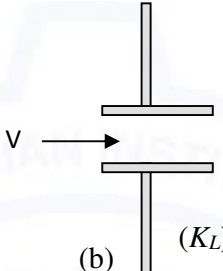
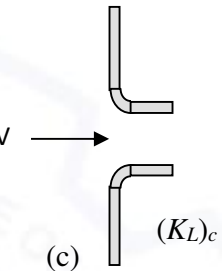
Q.2	Which one of the following options is TRUE?
(A)	Pathlines and streaklines are the same in an unsteady flow, and streamlines are tangential to the local fluid velocity at a point.
(B)	Streamlines are perpendicular to the local fluid velocity at a point, and streamlines and streaklines are the same in a steady flow.
(C)	Pathlines and streaklines are the same in an unsteady flow, and streamlines and streaklines are the same in a steady flow.
(D)	Streamlines are tangential to the local fluid velocity at a point, and streamlines and streaklines are the same in a steady flow.

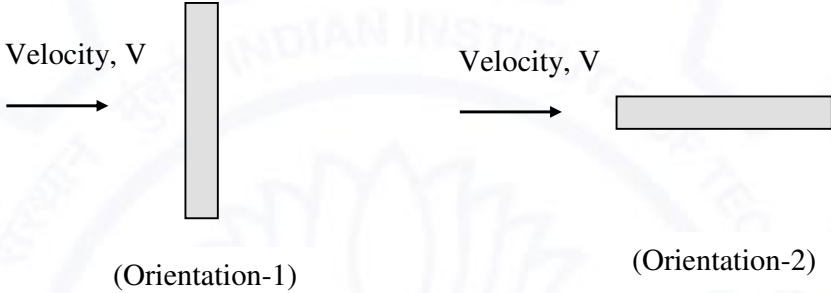
Q.3	If $P_{in} = 1.2$ Pa and $P_{out} = 1.0$ Pa are the average pressures at inlet and outlet respectively for a fully-developed flow inside a channel having a height of 50 cm, then the absolute value of average shear stress (in Pa) acting on the walls of the channel of length 5 m is
(A)	0.005
(B)	0.02
(C)	0.01
(D)	0.05

Q.4	Consider the fully-developed flow of a Newtonian fluid (density ρ ; viscosity μ) through a smooth pipe of diameter D and length L . The average velocity of the flow is V . If the length of the pipe is doubled, keeping V, D, ρ, μ constant, the friction factor
(A)	increases by two times
(B)	remains the same
(C)	decreases by two times
(D)	increases by four times

Q.5	The absolute value of pressure difference between the inside and outside of a spherical soap bubble of radius, R , and surface tension, γ , is:
(A)	$\frac{2\gamma}{R}$
(B)	$\frac{\gamma}{R}$
(C)	$\frac{\gamma}{2R}$
(D)	$\frac{4\gamma}{R}$

Q.6	Which one of the following statements is TRUE about the continuity equation $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$ (where u, v, w are the velocity components along the x, y, and z coordinates respectively):
(A)	The equation is valid only for steady incompressible flows.
(B)	The equation is valid for both steady and unsteady incompressible flows.
(C)	The equation is valid only for steady compressible flows.
(D)	The equation is valid only for unsteady compressible flows.

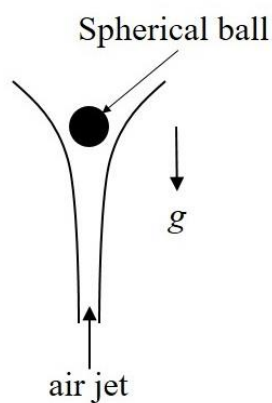
Q.7	The head loss (K_L) associated with the flow entry of water to an internal passage depends on the shape of the entry. The following figure shows three different types of flow entry into a pipe. Which one of the following relationships correctly represents the head loss associated with the three different flow entries?  (a) $(K_L)_a$  (b) $(K_L)_b$  (c) $(K_L)_c$
(A)	$(K_L)_a > (K_L)_b > (K_L)_c$
(B)	$(K_L)_b > (K_L)_a > (K_L)_c$
(C)	$(K_L)_b \leq (K_L)_a = (K_L)_c$
(D)	$(K_L)_b < (K_L)_a < (K_L)_c$

Q.8	The form and friction drags together contribute to the total drag when flow of air occurs past any object. Two orientations of a finite flat plate are shown in the figure. In Orientation-1, the plate is placed perpendicular to the flow while in Orientation-2, the plate is placed parallel to the flow. If the velocity (V) of air in both orientations is the same, which one of the following options is TRUE?  (Orientation-1) (Orientation-2)
(A)	Orientation-1 has higher form drag and lower friction drag and Orientation-2 has lower form drag and higher friction drag
(B)	Orientation-1 has lower form drag and lower friction drag and Orientation-2 has higher form drag and higher friction drag
(C)	Orientation-1 has lower form drag and higher friction drag and Orientation-2 has higher form drag and lower friction drag
(D)	Orientation-1 has higher form drag and higher friction drag and Orientation-2 has lower form drag and lower friction drag

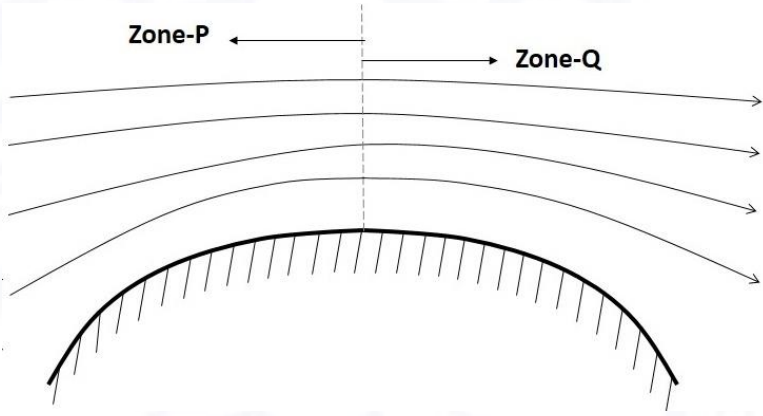
Q.9 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

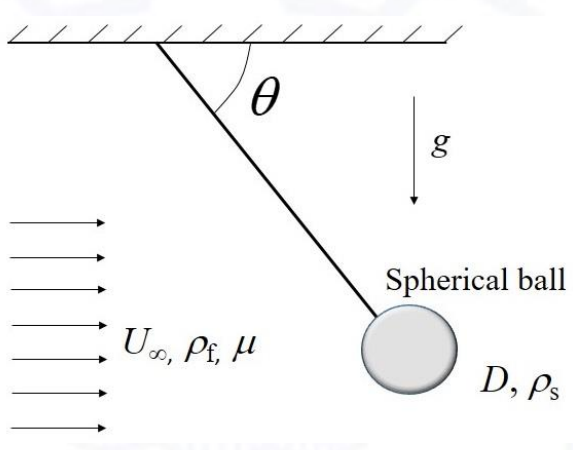
Q.9

A spherical ball is steadily supported against gravity by an upward air jet as shown in the figure. Take acceleration due to gravity to be $g = 10 \text{ m/s}^2$. The mass flow rate of air, reaching the ball, is 0.01 kg/s and the air reaches the ball at an upward velocity of 3 m/s . Neglecting the buoyancy force, and using the principle of integral momentum balance, the mass (in grams, up to one decimal place) of the ball is ____.



Q. 10 – Q. 12 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

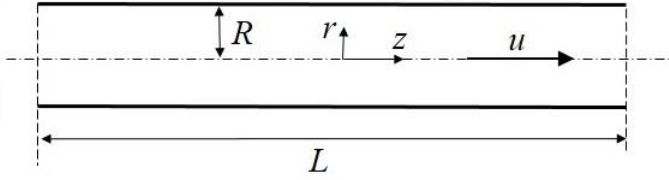
Q. 10	The incompressible flow of air over a curved surface having possible flow separation is schematically shown in the figure. Two zones P and Q are indicated in the figure. Which one of the following combinations is TRUE for zones P and Q?  (a) Acceleration of flow, (b) Deceleration of flow, (c) Adverse pressure gradient, (d) Favorable pressure gradient, (e) No flow separation (f) Possible flow separation.
(A)	<u>P: (a), (d), (e) and Q: (b), (c), (f)</u>
(B)	<u>P: (a), (d), (f) and Q: (b), (d), (f)</u>
(C)	<u>P: (a), (c), (f) and Q: (a), (d), (e)</u>
(D)	<u>P: (a), (c), (e) and Q: (a), (d), (f)</u>

Q. 11	A spherical metal ball (of density ρ_s and diameter D), attached to a string, is exposed to a crossflow (of velocity U_∞) of a viscous fluid (of viscosity μ and density ρ_f). Due to the crossflow, the string makes an angle of inclination, θ, with the top surface as shown in the figure. The acceleration due to gravity is denoted by g. For this flow, Reynolds number, $Re = \frac{\rho_f U_\infty D}{\mu} \ll 1$ and buoyancy force in the fluid is negligible compared to viscous force. Assuming the string to be weightless and offering negligible drag, the expression for θ is 
(A)	$\tan^{-1} \left[\frac{1}{18} \frac{D^2 \rho_s^2 g}{\mu U_\infty \rho_f} \right]$
(B)	$\tan^{-1} \left[\frac{1}{18} \frac{D^2 \rho_f g}{\mu U_\infty} \right]$
(C)	$\sin^{-1} \left[\frac{2}{9} \frac{D^2 \rho_s g}{\mu U_\infty} \right]$
(D)	$\tan^{-1} \left[\frac{1}{18} \frac{D^2 \rho_s g}{\mu U_\infty} \right]$

Q. 12	In a Cartesian coordinate system, a steady, incompressible velocity field of a Newtonian fluid is given by $\mathbf{V} = u_0(1 - ay^2) \mathbf{i}$ Here, $\mathbf{V}$ is the velocity vector in m/s, $\mathbf{i}$ is the unit vector in the x-direction, u_0 is a positive, real constant (in m/s), and a is a positive, real constant (in m^{-2}). The viscosity of the fluid is μ (in Pa-s). The absolute value of the pressure gradient (in Pa/m) is
(A)	$a\mu u_0$
(B)	$2a\mu u_0$
(C)	$3a\mu u_0$
(D)	$4a\mu u_0$



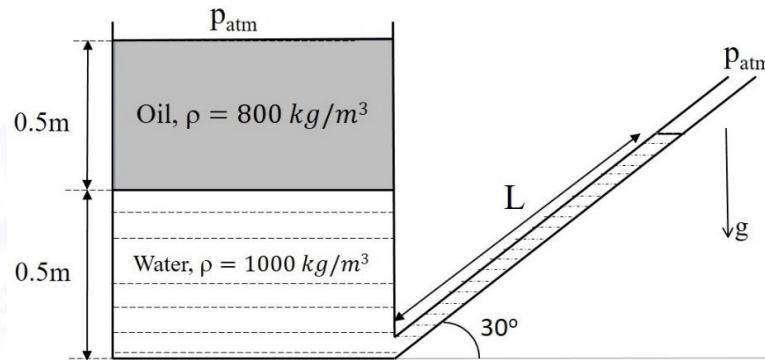
Q. 13 – Q. 22 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

Q. 13	In a laminar, incompressible, fully-developed pipe flow of a Newtonian fluid, as shown in the figure, the velocity profile over a cross-section is given by $u = U \left(1 - \frac{r^2}{R^2} \right)$, where U is a constant. The pipe length is L and the fluid viscosity is μ. The power P required to sustain the flow is expressed as $P = c\mu LU^2$, where c is a dimensionless constant. The value of the constant c (up to one decimal place) is _____. Laminar, fully-developed pipe flow 
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Q. 14	The two-dimensional velocity field $\mathbf{V}$ of a flow in a Cartesian coordinate system is given in dimensionless form by $\mathbf{V} = (x^2 - axy) \mathbf{i} + \left(bxy - \frac{y^2}{2} \right) \mathbf{j}$. Here, $\mathbf{i}$ and $\mathbf{j}$ are the unit vectors along the x and y directions respectively, a and b are independent of x, y and time. If the flow is incompressible, then the value of $(a - b)$, up to one decimal place, is _____.
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Q. 15

For the configuration shown in the figure, oil of density 800 kg/m^3 lies above water of density 1000 kg/m^3 . Assuming hydrostatic conditions and acceleration due to gravity $g = 10 \text{ m/s}^2$, the length L (in meters, up to one decimal place) of water in the inclined tube is ____.



Q. 16

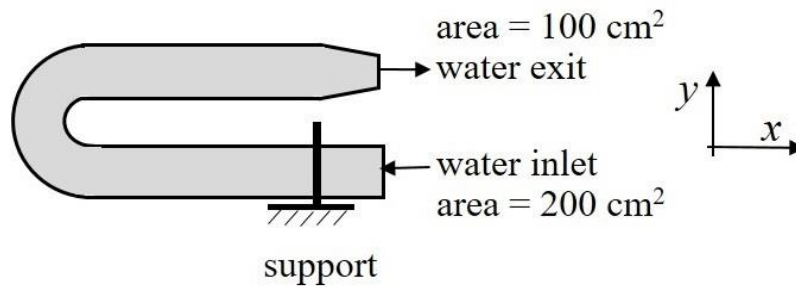
A two-dimensional Eulerian velocity field is given (in m/s) by $\mathbf{V} = [(\sqrt{5})x] \mathbf{i} - [(\sqrt{12})y] \mathbf{j}$, where x and y are the coordinates (in meters) in a Cartesian coordinate system. The magnitude of the acceleration (in m/s^2 , up to one decimal place) of a fluid particle at $x = 1 \text{ m}$ and $y = -1 \text{ m}$ is ____.

Q. 17

A large pump is to deliver oil at an average velocity (V) of 1.5 m/s . The pump has an impeller diameter (D) of 40 cm and the pressure rise across the pump is 400 kPa . To design this pump, a lab-scale model pump with an impeller diameter of 4 cm is to be used with water as the fluid. The viscosity (μ) of the oil is 100 times that of water, and the densities (ρ) of oil and water are identical. A complete geometric similarity is maintained between the model and prototype. If the pressure rise is a function only of V, D, ρ and μ , the pressure rise (in kPa , up to one decimal place) across the model pump is ____.

Q. 18

Water (density = 10^3 kg/m^3) enters steadily into a horizontal pipe bend, which is part of a larger piping system, as shown in the figure. The volumetric flow rate of water is $0.1 \text{ m}^3/\text{s}$. The gage pressure at the inlet is 500 kPa , while the exit is open to atmosphere. The x -component of the force on the support is F_x . The absolute value of F_x (in kN , up to one decimal place) is ____.

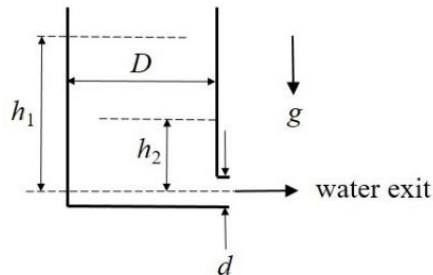


Q. 19

Air (of density 0.5 kg/m^3) enters horizontally into a jet engine at a steady speed of 200 m/s through an inlet area of 1.0 m^2 . Upon entering the engine, the air passes through the combustion chamber and the exhaust gas exits the jet engine horizontally at a constant speed of 700 m/s . The fuel mass flow rate added in the combustion chamber is negligible compared to the air mass flow rate. Also neglect the pressure difference between the inlet air and the exhaust gas. The absolute value of the horizontal force (in kN , up to one decimal place) on the jet engine is _____.

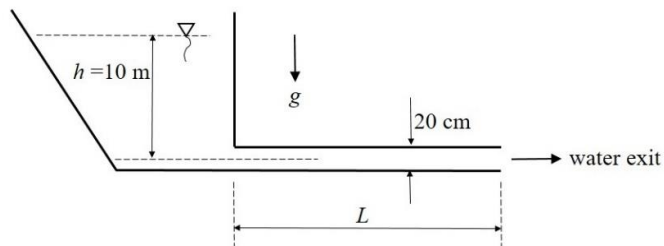
Q. 20

Water discharges from a cylindrical tank through an orifice, as shown in the figure. The flow is considered frictionless. Initially, the water level in the tank was $h_1 = 2$ m. The diameter of the tank is $D = 1$ m, while the diameter of the jet is $d = 10$ cm, and the acceleration due to gravity is $g = 10 \text{ m/s}^2$. The time taken (in seconds, up to one decimal place) for the water level in the tank to come down to $h_2 = 1$ m is _____.



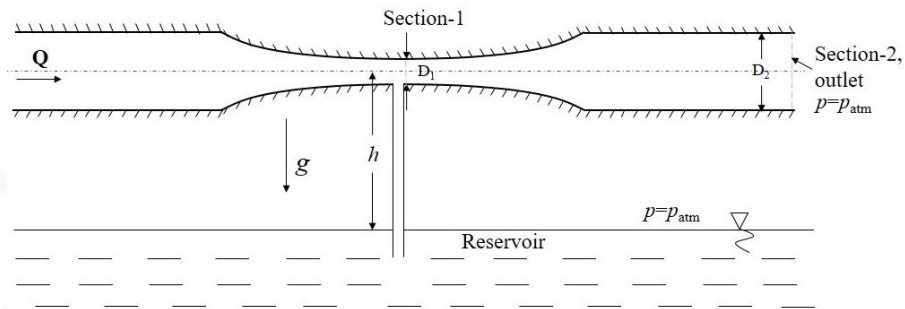
Q. 21

Water discharges steadily from a large reservoir through a long pipeline, as shown in the figure. The Darcy friction factor in the pipe is 0.02. The pipe diameter is 20 cm and the discharge of water is $360 \text{ m}^3/\text{h}$. Water level in the reservoir is 10 m and acceleration due to gravity $g = 10 \text{ m/s}^2$. If minor losses are negligible, the length L (in meters, up to one decimal place) of the pipeline is _____.



Q. 22

Water is flowing with a flow rate Q in a horizontal circular pipe. Due to the low pressure created at the venturi section (Section-1 in the figure), water from a reservoir is drawn upward using a connecting pipe as shown in the figure. Take acceleration due to gravity $g = 10 \text{ m/s}^2$. The flow rate $Q = 0.1 \text{ m}^3/\text{s}$, $D_1 = 8 \text{ cm}$, and $D_2 = 20 \text{ cm}$. The maximum height (h , in meters, up to one decimal place) of the venturi from the reservoir just sufficient to raise the liquid upto Section-1 is _____.



END OF THE QUESTION PAPER