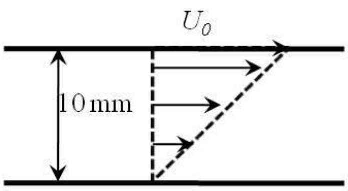
B : FLUID MECHANICS

Q. 1 – Q. 9 carry one mark each.

Q.1 In the parallel-plate configuration shown, steady-flow of an incompressible Newtonian fluid is established by moving the top plate with a constant speed, U_0 = 1m/s. If the force required on the top plate to support this motion is 0.5 N per unit area (in m^2) of the plate then the viscosity of the fluid between the plates is __________ N-s/m^2



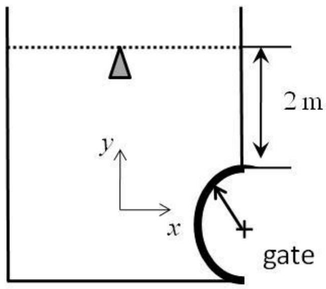
Q.2 For a newly designed vehicle by some students, volume of fuel consumed per unit distance travelled (q_f in m^3/m) depends upon the viscosity (μ) and density (ρ) of the fuel and, speed (U) and size (L) of the vehicle as

$$q_f = C\frac{\rho U^2 L}{\mu^3}$$

where C is a constant. The dimensions of the constant C are

(A) $M^0L^0T^0$ (B) $M^2L^{-1}T^{-1}$ (C) $M^2L^{-5}T^{-1}$ (D) $M^{-2}L^1T^1$

Q.3 A semi-circular gate of radius 1m is placed at the bottom of a water reservoir as shown in figure below. The hydrostatic force per unit width of the cylindrical gate in y-direction is _______ kN. The gravitational acceleration, g = 9.8 m/s^2 and density of water = 1000 kg/m^3.



Q.4 Velocity vector in m/s for a 2-D flow is given in Cartesian coordinate (x, y) as $\vec{V} = \left(\frac{x^2}{4}\hat{\imath} - \frac{xy}{2}\hat{\jmath}\right)$. Symbols bear usual meaning. At a point in the flow field, the x- and y-components of the acceleration vector are given as 1 m/s^2 and -0.5 m/s^2, respectively. The velocity magnitude at that point is ________ m/s.

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Q.5 If $\phi(x,y)$ is velocity potential and $\psi(x,y)$ is stream function for a 2-D, steady, incompressible and irrotational flow, which one of the followings is incorrect?

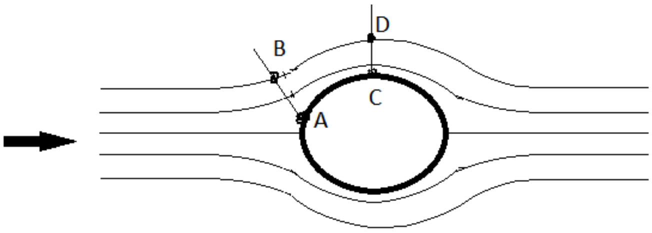
(A) $\left(\frac{dy}{dx}\right)_{\phi=const.} = -\frac{1}{\left(\frac{dy}{dx}\right)_{\psi=const.}}$

(B) $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2} = 0$

(C) $\left(\frac{dy}{dx}\right)_{\phi=const.} = \frac{1}{\left(\frac{dy}{dx}\right)_{\psi=const.}}$

(D) $\frac{\partial^2\phi}{\partial x^2}+\frac{\partial^2\phi}{\partial y^2} = 0$

Q.6 The flow field shown over a bluff body has considerably curved streamlines. A student measures pressures at points A, B, C, and D and denotes them as P_A, P_B, P_C, and P_D respectively. State which one of the following statements is true. The arrow indicates the freestream flow direction.



(A) $P_A = P_B$ and $P_C > P_D$
(B) $P_A > P_B$ and $P_C > P_D$
(C) $P_A = P_B$ and $P_C < P_D$
(D) $P_A > P_B$ and $P_C < P_D$

Q.7 A 2-D incompressible flow is defined by its velocity components in m/s as $u = -\frac{cy}{x^2+y^2}$ and $v = \frac{cx}{x^2+y^2}$. If the value of the constant c is equal to 0.1 m^2/s, the numerical value of vorticity at the point $x = 1$ m and $y = 2$ m is ________ s^{-1}.

Q.8 Two flow configurations are shown below for flow of incompressible, viscous flow. The inlet velocity for the diverging nozzle (Fig (i)) and free-stream velocity for flow past the bluff body (Fig(ii)) is constant. Points A and B are separation points and flow is laminar. The relation regarding velocity gradients at point A and B is (y is the direction normal to the surface at the point of separation)

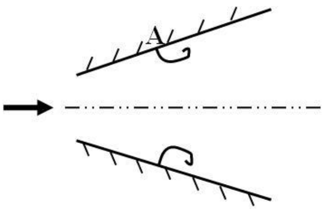


Fig (i)

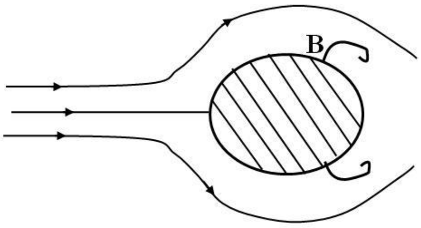
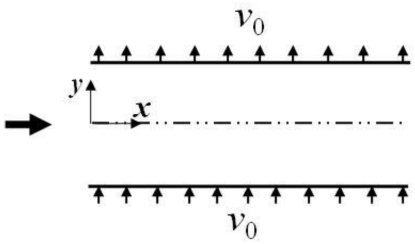


Fig (ii)

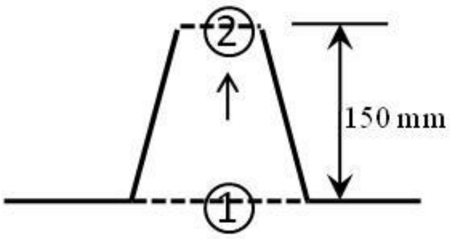
(A) $\left.\frac{\partial u}{\partial y}\right)_A = \left.\frac{\partial u}{\partial y}\right)_B$ (B) $\left.\frac{\partial u}{\partial y}\right)_A > \left.\frac{\partial u}{\partial y}\right)_B$ (C) $\left.\frac{\partial u}{\partial y}\right)_A < \left.\frac{\partial u}{\partial y}\right)_B$ (D) $\left.\frac{\partial^2 u}{\partial y^2}\right)_A = \left.\frac{\partial^2 u}{\partial y^2}\right)_B$

Q.9 Consider a fully developed, steady, incompressible, 2-D, viscous channel flow with uniform suction and blowing velocity v_0, as shown in the figure given below. The centerline velocity of the channel is 10 m/s along the *x*-direction. If the value of v_0 at both the walls is 1 m/s, the value of the *y*-component of velocity inside the flow field is __________ m/s.

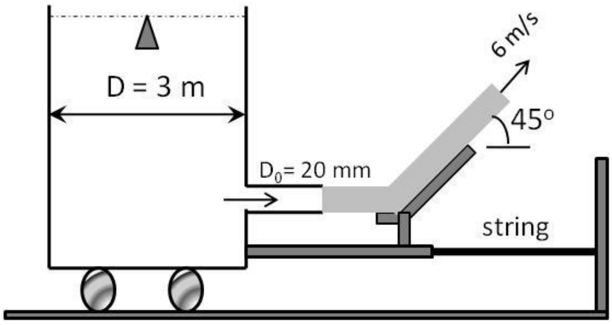


Q. 10 – Q. 22 carry two marks each.

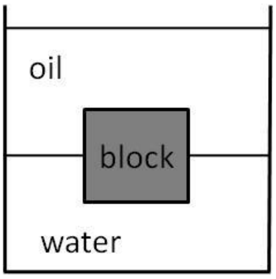
Q.10 Exhaust from a kitchen goes into the atmosphere through a tapered chimney as shown. The area of cross-section of chimney at location-1 is twice of that at location-2. The flow can be assumed to be inviscid with constant exhaust density of 1 kg/m^3 and acceleration due to gravity, g = 9.8 m/s^2. If the steady, uniform exhaust velocity at location-1 is U = 1m/s, the pressure drop across the chimney is ________ Pa.



Q.11 A jet of diameter 20 mm and velocity 6 m/s coming out of a water-tank standing on a frictionless cart hits a vane and gets deflected at an angle 45° as shown in the figure below. The density of water is 1000 kg/m^3. Neglect all minor and viscous losses. If the cart remains stationary, the magnitude of tension in the supporting string connected to the wall is ________ N.



Q.12 A block is floating at the oil-water interface as shown. The density of oil is two-thirds of that of water. Given that the density of the block is 800 kg/m^3 and that of water is 1000 kg/m^3, the fraction of the total height of block in oil is ________.



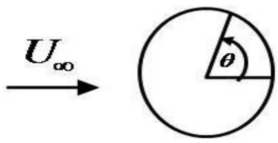
Q.13 A horizontal pipe is feeding water into a reservoir from the top with a time-dependent volumetric flow-rate, Q (m^3/h)= $1+0.1\times t$ where t is time in hours. The area of the base of the reservoir is 0.5 m^2. Assuming that initially the reservoir was empty, the height of the water level in the reservoir after 60 minutes is __________ m.

Q.14 Velocity field of a 2-D steady flow is provided as $\vec{V} = c(x^2 - y^2)\hat{\imath} - 2cxy\hat{\jmath}$. The equation of the streamlines of this flow is

(A) $x^2y - \frac{y^2}{3} = Constant$ (B) $xy^2 - \frac{y^2}{3} = Constant$

(C) $xy - \frac{y}{3} = Constant$ (D) $x^2y - \frac{y^3}{3} = Constant$

Q.15 Velocity potential and stream function in polar coordinates (r, θ) for a potential flow over a cylinder with radius R is given as $\emptyset = U_\infty\left(r + \frac{R^2}{r}\right)\cos\theta$ and $\psi = U_\infty\left(r - \frac{R^2}{r}\right)\sin\theta$, respectively. Here, U_∞ denotes uniform freestream velocity, and θ is measured counter clockwise as shown in the figure. How does the velocity magnitude, q, over the surface of the cylinder will vary?



(A) $q = 2U_\infty \cos\theta$ (B) $q = 2U_\infty \sin 2\theta$
(C) $q = U_\infty \cos 2\theta$ (D) $q = 2U_\infty \sin\theta$

Q.16 Consider a laminar flow over a flat plate of length L = 1m. The boundary layer thickness at the end of the plate is δ_w for water, and δ_a for air for the same freestream velocity. If the kinematic viscosities of water and air are $1\times 10^{-6}\ m^2/s$ and $1.6\times 10^{-5}\ m^2/s$, respectively, the numerical value of the ratio, $\frac{\delta_w}{\delta_a}$ is _________.

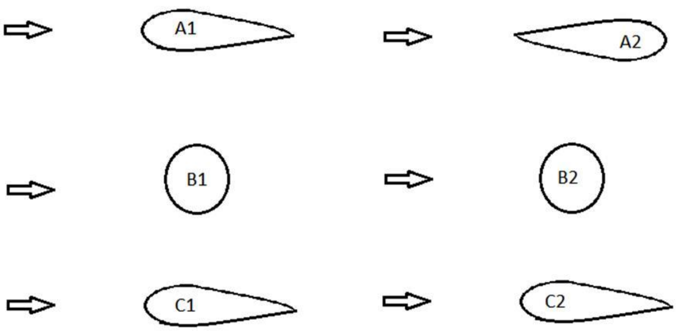
Q.17 Prototype of a dam spillway (a structure used for controlled release of water from the dam) has characteristic length of 20m and characteristic velocity of 2 m/s. A small model is constructed by keeping Froude number same for dynamic similarity between the prototype and the model. What is the minimum length-scale ratio between prototype and the model such that the minimum Reynolds' number for the model is 100? The density of water is 1000 kg/m^3 and viscosity is 10^{-3} Pa-s.

(A) 1.8×10^{-4} (B) 1×10^{-4} (C) 1.8×10^{-3} (D) 9.1×10^{-4}

Q.18 An orifice meter, having orifice diameter of $d = \frac{20}{\sqrt{\pi}} mm$ is placed in a water pipeline having flow rate, $Q_{act} = 3 \times 10^{-4}\, m^3/s$. The ratio of orifice diameter to pipe diameter is 0.6. The contraction coefficient is also 0.6. The density of water is 1000 *kg/m*^{3}. If the pressure drop across the orifice plate is 43.5kPa, the discharge co-efficient of the orifice meter at this flow Reynolds number is _________.

Q.19 Consider the following figures shown below. The objects are marked as A1, A2, B1, B2 and C1, C2 and the flow directions over these objects are shown by the respective arrow placed to the left of the object. Freestream velocities are same for all the cases. Amongst these objects, A1, A2, B1 and C1 are having smooth surfaces while B2 and C2 are having rough surfaces. Reynolds number is such that flow over rough surfaces become turbulent and flow over smooth surfaces can be considered laminar. All the airfoils can be considered as thin slender airfoil. Among the statements (i) to (vi) made about the drag of these objects which is/are correct?

(i) Drag of object A1 is less than drag of object A2.
(ii) Drag of Object A1 and A2 are same.
(iii) Drag of Object B1 is more than drag of object B2.
(iv) Drag of object B2 is more than drag of object B1.
(v) Drag of Object C1 is more than drag of object C2.
(vi) Drag of object C2 is more than drag of object C1.



(A) (i),(iii) & (vi) (B) (ii),(iii) & (vi) (C) (i),(iii) & (v) (D) (i),(iv) & (vi)

Q.20 Consider 2-D, steady, incompressible, fully developed flow of viscous, Newtonian fluid through two stationary parallel plates, in Cartesian co-ordinate (*x*,*y*,*z*) system. Assume plates are very long in *x*-direction, wide in *z*-direction (also there is no variation of velocity in *z* direction) and distance between them is 2*h*. The velocity in such a channel is given as $U = U_{max}\left(1 - \frac{y^2}{h^2}\right)$. The origin y = 0 is located at the center between the plates. If $h = 48\ mm$ and $U_{max} = 100\ mm/s$, difference between values of stream functions passing through $y = 0$ and $y = h/2$ is __________ mm^2/s.

Q.21 A pump is used to deliver water to an overhead tank at a flow rate of $Q = 4 \times 10^{-3} m^3/s$. The pump adds1.6 kW to water. If the density of water is 1000 kg/m^3 and acceleration due to gravity is 10 m/s^2, the pump head added to the flow is _________ m.

Q.22 Water is discharged at atmospheric pressure from a large reservoir through a long pipe of diameter *d* and length *L*. The height of the free surface of the reservoir from the discharge point is *h* meters. The Darcy's friction factor of the pipe is 0.002. Neglect the velocity inside the reservoir as the reservoir is very large. Given, *L* = 20m, *d* = 40mm, density of water = 1000kg/m^3 and flow rate is $Q = 4\pi \times 10^{-3} m^3/s$. Assume gravitational acceleration, *g* = 10 m/s^2. The value of *h* is _______m.

END OF THE QUESTION PAPER

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