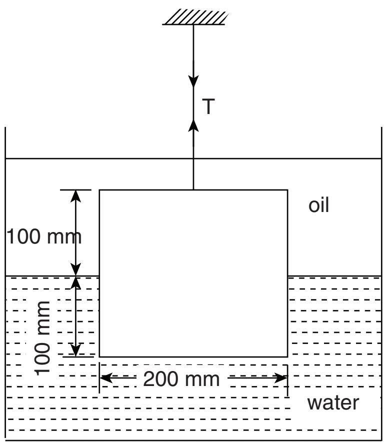
Fluid Mechanics Test 2

Number of Questions: 30 **Time: 75 min.**

Directions for questions 1 to 30: Select the correct alternative from the given choices.

1. A metallic cube of side 200 mm and specific weight 26 kN/m^3 is suspended by a string in oil and water as shown in the figure. Half of the cube is submerged in water and the remaining half is submerged in oil. If specific gravity of the oil is 0.8, determine the tension in the string



(A) 98.2 N (B) 176.6 N
(C) 156.7 N (D) 192.4 N

2. In a 3-dimensional incompressible fluid flow, velocity components in x and y directions are
$u = x^2 + y^2z^3$
$v = -(xy + yz + zx)$
Velocity component in the z direction is

(A) $-xz + \frac{z^2}{2} + f(x, y)$ (B) $-xz + \frac{z^2}{2}$

(C) $xz - \frac{z^2}{2} + C$ (D) $-x + z$

3. Match List – I (measuring devices) with List – II (measuring parameter) and select the correct answer using the codes given below

	List – I		**List – II**
a.	Pitot tube	1.	Rate of flow measurement
b.	Micro manometer	2.	Measurement of moderate pressure
c.	Venturimeter	3.	Velocity measurement
d.	Piezo meter	4.	Easier measurement of large pressures

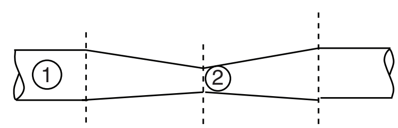
Codes:

	a	b	c	d		a	b	c	d
(A)	1	3	2	4	(B)	4	2	3	1
(C)	2	1	4	3	(D)	3	4	1	2

4. A curved surface is submerged in a fluid. Consider the following statements relating to it
I. Vertical component of the hydrostatic force acting on the surface is equal to the weight of the fluid vertically above the surface
II. Horizontal component of the force acting on the curved surface is the hydrostatic force acting on the vertical projection of the curved surface
III. Horizontal component of the force acts through the centre of gravity of the vertical projection of the curved surface.

(A) I and II are correct
(B) I and III are correct
(C) II and III are correct
(D) I, II and III are correct

5. In a horizontal pipeline as shown in figure, point 2 is a contraction with reduced area of cross section. At point 1 the pressure head and velocity head are 60 cm and 4 cm respectively. If pressure head at point 2 is zero, the ratio of velocity at point 2 to that at point 1 is



(A) 2 (B) 3
(C) 4 (D) 6

6. For a flow, velocity components in the x and y directions are given by $u = y^2$, $v = -3x$
Component of rotation about the z-axis is
(A) $-(3 + 2y)$ (B) $(3 + 2y)$
(C) $\frac{-1}{2}(3+2y)$ (D) $\frac{1}{2}(3+2y)$

7. The velocity along the centre line of a nozzle of length 1.5 m is given by

$v = 2t\left(1-\frac{x}{2\ell}\right)^2$ where ℓ = length in m

v = velocity in m/s,
t = time in seconds
from the commencement of flow and x = distance from inlet. The value of local acceleration at x = 1 m when t = 5 seconds is
(A) 0.67 m/s^2 (B) 0.89 m/s^2
(C) 1.33 m/s^2 (D) 1.67 m/s^2

8. Differential pressure head measured by a mercury oil differential manometer is 9.5 m of oil. If specific gravity of oil is 0.68, difference in level of mercury is
(A) 300 mm (B) 400 mm
(C) 500 mm (D) 600 mm

9. An orifice meter is calibrated with air in a geometrically similar model. Model to prototype scale ratio is $\frac{1}{4}$. The prototype has to carry water. Ratio of kinematic viscosity of air to water is 12.5. Dynamically similar flow will be obtained when the discharge ratio is

(A) 2.850 (B) 3.125
(C) 4.540 (D) 4.925

10. For a flow, the stream function is ψ. For the flow to be irrotational, the condition to be satisfied is

(A) $\frac{\partial\psi}{\partial x}-\frac{\partial\psi}{dy}=0$ (B) $\frac{\partial\psi}{\partial x}+\frac{\partial\psi}{\partial y}=0$

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

Common Data for Questions 11 and 12:

A liquid of viscosity 0.8 and sp. gravity 1.3 flows through a circular pipe of 100 mm diameter. Maximum shear stress at the pipe wall is 220 N/m^2

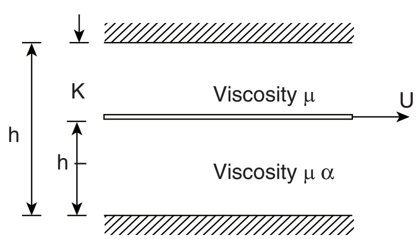
11. Pressure gradient of the flow in N/m^2 per m is

(A) – 6800 (B) – 8800
(C) 6800 (D) 8800

12. Average velocity of flow is

(A) 2.6 m/s (B) 2.9 m/s
(C) 3.2 m/s (D) 3.4 m/s

Statement for Linked Answer Questions 13 and 14:



A large thin plate is pulled at a constant velocity U through a narrow gap of height h. On one side of the plate is filled with oil of viscosity μ and the other side oil of viscosity $\alpha\mu$ where α is a constant

13. Total drag force on the plate is

(A) $A\mu U\left(\frac{1}{k}+\frac{\alpha}{h-k}\right)$ (B) $A\mu U\left(k+\frac{h-k}{\alpha}\right)$

(C) $\frac{\mu U}{A}\left(\frac{1}{k}+\frac{\alpha}{h-k}\right)$ (D) $\frac{\mu U}{A}\left(k+\frac{h-k}{\alpha}\right)$

14. Value of k such that the drag force is minimum is

(A) $\frac{\sqrt{h}}{1+\alpha}$ (B) $\frac{\sqrt{h}}{1-\alpha}$

(C) $\frac{h}{1-\sqrt{\alpha}}$ (D) $\frac{h}{1+\sqrt{\alpha}}$

Common Data for Questions 15 to 17:

An 80 mm diameter composite solid cylinder consists of a 20 mm thick metallic plate and 650 mm long wooden cylinder of specific gravity 4 and 0.8 respectively. The cylinder floats in water its axis vertical

15. The position of centre of gravity from bottom is

(A) 0.3 m (B) 0.35 m
(C) 0.4 m (D) 0.45 m

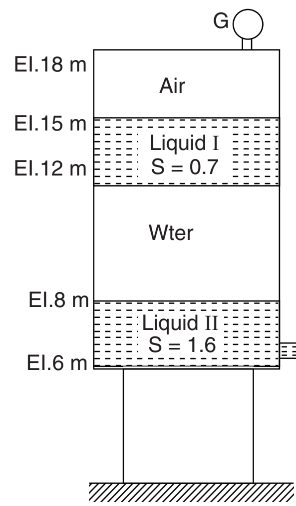
16. Position of centre of buoyancy from bottom is

(A) 0.2 m (B) 0.25 m
(C) 0.3 m (D) 0.35 m

17. Metacentric height is

(A) 0.667 mm (B) 6.67 mm
(C) 3.33 mm (D) 8.63 mm

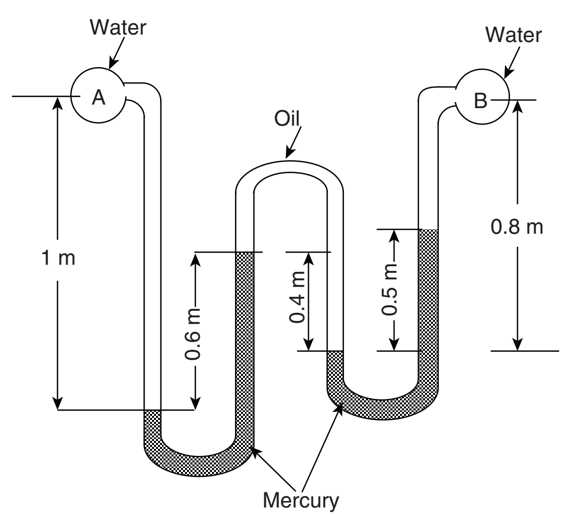
18.



A tank installed at an elevation of 6 m contains a liquid of specific gravity 1.6, water and another liquid of specific gravity 0.7 space over the liquids contain air. The gauge G show a pressure of -17 kN/m^2. The elevation of liquid level in the piezometer A is

(A) 4.73 m (B) 6.73 m
(C) 8.73 m (D) 10.73 m

19.



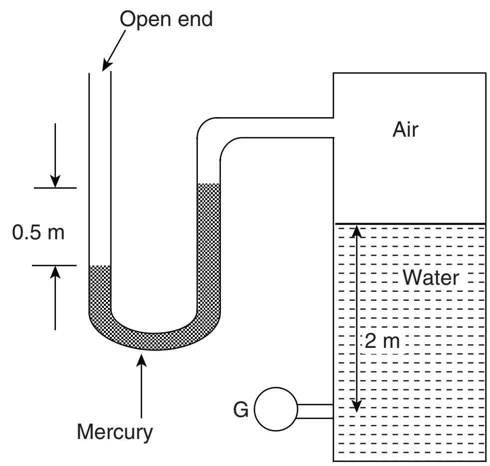
For the compound manometer shown in figure, the pressure difference between points A and B in kN/m^2 is ————

Given that specific gravity of mercury = 13.6 and specific gravity of oil = 0.85

(A) 115 (B) 125

(C) 135 (D) 150

Statement for Linked Answer Question 20:



Refer to the figure given above. The tank is filled with water upto 2 m from the gauge G. The manometer shows a level difference of 0.5 m as shown. Local atmospheric pressure is 750 mm of mercury.

20. Absolute pressure of air above the water surface in the tank is

(A) 21.68 kN/m^2 (B) 33.35 kN/m^2

(C) 38.72 kN/m^2 (D) 42.83 kN/m^2

Common Data for Questions 21 and 22:

A propeller turbine is to develop 6250 kW under a head of 5m, having given that speed ratio 'k_u' based on outer diameter = 2.10, flow ratio ψ = 0.65, diameter of boss = 0.35 times external diameter of the runner and overall efficiency is 85%.

21. The diameter of the runner in 'm' is

(A) 5.81 (B) 4.91

(C) 5.21 (D) 6.35

22. The speed of the turbine in RPM is

(A) 78.27 (B) 68.37

(C) 58.35 (D) 48.22

23. Draft tube is a pipe used in

(A) reaction turbine for discharge and it has gradually decreasing cross sectional area

(B) reaction turbine for discharge and it has gradually increasing cross sectional area

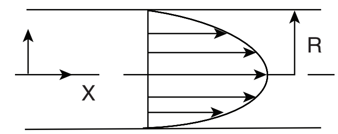
(C) Impulse turbine for discharge and it has gradually decreasing cross sectional area

(D) Impulse turbine for discharge and it has gradually increasing cross section area.

24. The velocity profile of a fully developed laminar flow in a straight circular pipe, as shown in the figure, is given by the expression

$$u(r) = \frac{-R^2}{4\mu}\left(\frac{\partial p}{\partial x}\right)\left(\frac{1-r^2}{R^2}\right)$$

Where $\frac{\partial p}{\partial x}$ is a constant

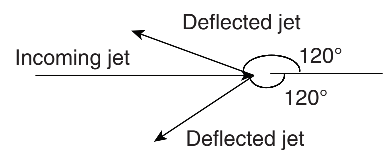


The average velocity of fluid in the pipe is

(A) $\frac{-R^2}{8\mu}\left(\frac{dp}{dx}\right)$ (B) $\frac{-R^2}{4\mu}\left(\frac{dp}{dx}\right)$

(C) $\frac{-R^2}{2\mu}\left(\frac{dp}{dx}\right)$ (D) $\frac{-R^2}{\mu}\left(\frac{dp}{dx}\right)$

25. Water having a density of 1000 kg/m^3, issues from a nozzle with a velocity of 10 m/s and the jet strikes a bucket mounted on a petton wheel. The wheel rotates at 10 rad/s. The mean diameter of the wheel is 1m. The jet is split into two equal streams by the bucket, such that each stream is deflected by 120°, as shown in the figure. Friction in the bucket may be neglected. Magnitude of the torque exerted by the water on the wheel, per unit mass flow rate of the incoming jet is.



(A) 0 (Nm) / (Kg/s) (B) 1.25 (Nm) / (Kg/s)

(C) 2.5 (Nm) / (Kg/s) (D) 3.75 (Nm) / (Kg/s)

26. Match the following:

	List – I		List – II
P.	Compressible flow	1.	Nusselt number
Q.	Boundary layer flow	2.	Reynold's number
R.	Pipe flow	3.	Skin friction coefficient
S.	Heat convection	4.	Mach number

Codes:

	P	Q	R	S
(A)	3	1	4	2
(B)	3	4	2	1
(C)	4	3	2	1
(D)	2	1	3	4

Common Data for Questions 27 and 28:

A pelton wheel has to be designed for the following data. Power to be developed = 6000 kW net head available = 300 m, speed = 550 RPM, ratio of jet diameter to wheel diameter = $\frac{1}{10}$ and overall efficiency = 85%

27. Find the no. of jets required

(A) 1 (B) 2
(C) 3 (D) 4

28. The diameter of jet is in mm

(A) 135.2
(B) 116.4
(C) 141.2
(D) 186.4

29. The maximum hydraulic efficiency for a pelton wheel is given by the expression (θ is the vane angle of outlet).

(A) $\frac{1-\cos\theta}{2}$ (B) $\frac{1+\cos\theta}{2}$
(C) $\frac{\cos\theta}{2}$ (D) None of these

30. Incase of Pelton turbine installed in a hydraulic power plant the gross head available is the vertical distance between

(A) forebay and tailrace
(B) reservoir level and turbine inlet
(C) forebay and turbine inlet
(D) reservior level and tail race

Answer Keys

1. B	**2.** A	**3.** D	**4.** A	**5.** C	**6.** C	**7.** B	**8.** C	**9.** B	**10.** D
11. B	**12.** D	**13.** A	**14.** D	**15.** A	**16.** C	**17.** A	**18.** D	**19.** C	**20.** B
21. A	**22.** B	**23.** B	**24.** A	**25.** D	**26.** C	**27.** C	**28.** B	**29.** B	**30.** B

Hints and Explanations

1. Tension in the string $T = W - F_B$

where W = weight of the cube

F_B = Buoyant forces

$\therefore \quad T = (0.2)^3 \times 26 \times 10^3 - [(0.2)^3 \times 0.5 \times 9810 \times 0.8]$

$= 26 \times 8 - 4 \times 9.81 \times 0.8 = 176.6$ N. Choice (B)

2. For a three dimensional, incompressible fluid flow the continuity equation must be satisfied

i.e., $\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$

$u = x^2 + y^2z^3$

$\frac{\partial u}{\partial x} = 2x$

$v = -(xy + yz + zx)$

$\frac{\partial v}{\partial y} = -(x+z)$

$\therefore \quad 2x - (x+z) + \frac{\partial w}{\partial z} = 0$

$\Rightarrow \quad \frac{\partial w}{\partial z} = -2x + x + z = -x + z$

Integrating with respect to z

$w = -xz + \frac{z^2}{2} + C$ where $C = f(x, y)$

or $w = -xz + \frac{z^2}{2} + f(x,y)$. Choice (A)

4. Statements I and II are correct

The horizontal component acts at a distance from top surface $= \bar{x} + \frac{I_G}{A\bar{x}}$ where $\bar{x}$ = the vertical distance of centre of gravity from surface Choice (A)

5. Applying Bernoullis theorem,

velocity head + pressure head = constant

i.e., $\frac{V_1^2}{2g} + \frac{p_1}{\rho g} = \frac{V_2^2}{2g} + \frac{p_2}{\rho g}$

$\therefore \quad 0.04 + 0.6 = \frac{V_2^2}{2g} + 0$

$\Rightarrow \quad \frac{V_2^2}{2g} = 0.64$

$$\frac{\frac{V_2^2}{2g}}{\frac{V_1^2}{2g}} = \left(\frac{V_2}{V_1}\right)^2 = \frac{0.64}{0.04} = 16$$

$\Rightarrow \quad \frac{V_2}{V_1} = 4$. Choice (C)

6. $u = y^2$, $v = -3x$

Rotation component about z-axis is

$$\omega_z = \frac{1}{2}\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = \frac{1}{2}(-3-2y) = -\frac{1}{2}(3+2y)$$

Choice (C)

7. $V = 2t\left(1 - \frac{x}{2\ell}\right)^2$

Local acceleration $\frac{\partial V}{\partial t} = \left(1 - \frac{x}{2\ell}\right)^2 \times 2$

$= \left(1 - \frac{1}{2\times 1.5}\right)^2 \times 2 = \left(1 - \frac{1}{3}\right)^2 \times 2$

$= \left(\frac{2}{3}\right)^2 \times 2 = \frac{8}{9} = 0.89$ m/s^2 Choice (B)

8. $h = y\left(\frac{S_m}{S_o} - 1\right)$

$9.5 = y\left(\frac{13.6}{0.68} - 1\right) = y \times 19$

$\Rightarrow \quad y = \frac{9.5}{19} = 0.5 \text{ m} = 500 \text{ mm.}$ Choice (C)

9. Scale ratio $\frac{L_m}{L_p} = \frac{1}{4}$

Ratio of kinematic viscosity

$\frac{\upsilon_{air}}{\upsilon_{water}} = \frac{\upsilon_m}{\upsilon_p} = 12.5$

For dynamically similar flow, Reynold number will be same

i.e., $(\text{Re})_m = (\text{Re})_p$

$\text{Re} = \frac{\rho VL}{\mu} = \frac{VL}{\upsilon}$

$\therefore \quad \frac{V_m L_m}{\vartheta_m} = \frac{V_p L_p}{\vartheta_p}$

$\Rightarrow \quad \frac{V_m}{V_p} = \frac{L_p}{L_m} \cdot \frac{\upsilon_m}{\upsilon_p} = 4 \times 12.5 = 50$

Discharge ratio $\frac{Q_m}{Q_p} = \left(\frac{L_m}{L_p}\right)^2 \times \frac{V_m}{V_p}$

$= \left(\frac{1}{4}\right)^2 \times 50 = 3.125$ Choice (B)

10. If Ψ is stream function

$\frac{\partial \psi}{\partial x} = v$ and $\frac{\partial \psi}{\partial y} = -u$

For irrotational flow, $\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y} = 0$

i.e., $\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 0$ Choice (D)

11. $\mu = 8$ poise $= 0.8$ Ns/m^2, sp. gravity $= 1.3$
$D = 100$ mm $= 0.1$ m, $\tau_o = 220$ N/m^2

$\tau_o = \frac{-\partial p}{\partial x} \times \frac{R}{2}$

$220 = \frac{-\partial p}{\partial x} \times \frac{0.1}{2 \times 2}$

$\therefore$ pressure gradient

$\frac{\partial p}{\partial x} = -\ 8800$ N/m^2 per m. Choice (B)

12. Average velocity

$\bar{u} = \frac{1}{2} u_{\max} = \frac{1}{2}\left[\frac{-1}{4\mu} \cdot \frac{\partial p}{\partial x} \cdot R^2\right] = \frac{1}{8 \times 0.8} \times 8800 \times \left(\frac{0.1}{2}\right)^2$

$= 3.4375$ m/s. Choice (D)

13. $\tau_1 = \mu_1 \frac{du}{dy} = \mu \frac{U}{k}$

$\tau_2 = \mu_2 \frac{du}{dy} = \alpha\mu \frac{U}{h-k}$

Total drag force $F = A(\tau_1 + \tau_2) = A\, \mu\, U \left(\frac{1}{k} + \frac{\alpha}{h-k}\right)$.

Choice (A)

14. Drag force is minimum when $\frac{dF}{dk} = 0$

$\frac{-1}{k^2} + \frac{\alpha}{(h-k)^2} = 0$

$\frac{\alpha}{(h-k)^2} = \frac{1}{k^2}$

$\frac{\sqrt{\alpha}}{h-k} = \frac{1}{k}$

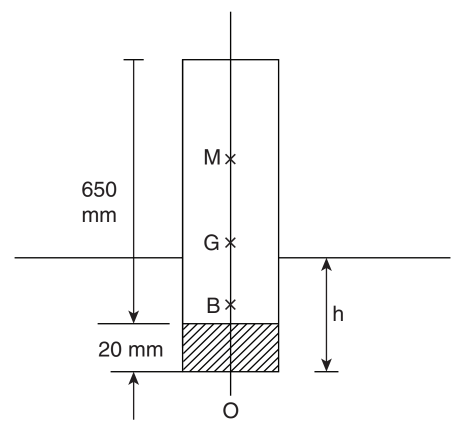
$k\sqrt{\alpha} = h - k$

$k + k\sqrt{\alpha} = h$

$k\left(1 + \sqrt{\alpha}\right) = h$

$k = h/(1 + \sqrt{\alpha}\ )$. Choice (D)

15.



Position of centre of gravity

$OG = \frac{A\left[0.02 \times 4 \times 0.01 + 0.65 \times 0.8\left(0.02 + \frac{0.65}{2}\right)\right]}{A(0.02 \times 4 + 0.65 \times 0.8)}$

where A = area of cross section

$= \frac{8 \times 10^{-4} + 0.1794}{0.6} = 0.3$ m Choice (A)

16. Weight of cylinder = buoyancy force
$A\ (0.02 \times 4 + 0.65 \times 0.8) = A \times h \times 1$
$h = 0.6$ m

Position of centre of buoyancy $OB = \frac{h}{2} = 0.3$ m

Choice (C)

17. BM $= \dfrac{I}{V} = \dfrac{\pi}{64}\dfrac{(0.08)^4 \times 4}{\pi \times (0.08)^2 \times 0.6} = \dfrac{(0.08)^2}{16 \times 0.6} =$

6.67×10^{-4} m

$BG = OG - OB = 0.3 - 0.3 = 0$

$MG = BM - BG = 6.67 \times 10^{-4}$ m

$= 0.667$ mm Choice (A)

18. Air pressure $= -17$ kN/m^2

$= -17000$ N/m^2 $= \dfrac{-17000}{9810} = -1.733$ m of water

Pressure at the bottom of tank in metres of water

$= -1.733 + (15 - 12) \times 0.7 + (12 - 8) \times 1 + (8 - 6) \times 1.6$

$= 7.567$ m of water

In metres of liquid II, pressure $= \dfrac{7.567}{1.6} = 4.73\,\text{m}$

Elevation of level in piezometer $= 4.73 + 6$

$= 10.73$ m. Choice (D)

19. Starting from point A and forming the manometric equation, in metres of water

$$\frac{p_A}{w} + 1 - 0.6\,S_m + 0.4\,S_o - 0.5\,S_m - (0.8 - 0.5) = \frac{p_B}{w}$$

Where w = sp. weight of water

S_m = sp. gravity of mercury

S_o = sp. gravity of oil

i.e., $\dfrac{p_A - p_B}{w} = (0.6 + 0.5)\,13.6 - 0.4 \times 0.85 - 1 + 0.3$

$= 13.92$

$p_A - p_B = 13.92 \times 9810$ N/m^2 $= 136.56$ kN/m^2

Choice (C)

20. Atmospheric pressure

$p_{\text{atm}} = \dfrac{1}{2}\rho A U^2 \times 13.6 \times 9810 = 100062$ N/m^2

$p_{\text{air}} = 0 - 0.5 \times 13.6 \times 9810 = -66708$ N/m^2

Absolute pressure of air

$p_{\text{air}}\,(\text{abs}) = p_{\text{atm}} + p_{\text{air}} = 100062 - 66708$

$= 33354$ N/m^2 $= 33.354$ kN/m^2. Choice (B)

21. $\eta_0 = 0.85 = \dfrac{6250 \times 10^3}{9810 \times Q \times 5}$

$Q = 149.91$ m^3/sec

$0.65 = \dfrac{v_f}{\sqrt{2 \times 9.81 \times 5}}$

$V_f = 6.44$ m/s

$Q = 149.91 = \dfrac{\pi}{4}\left[D^2 - (0.35D)^2\right] \times 6.44$

$D = 5.81$ m Choice (A)

22. $K_u = 2.1 = \dfrac{u}{\sqrt{2 \times 9.81 \times 5}}$

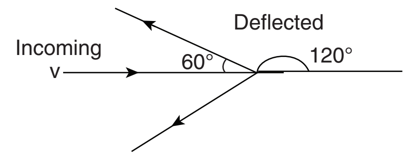
$u = 20.8$ m/s

$u = \dfrac{\pi D N}{60}$

$20.8 = \dfrac{\pi \times 5.81 \times N}{60}$

$N = 68.37$ RPM Choice (B)

25.



$\phi = 60°$, $K = 1$ (No friction)

$V = 10$ m/s

Wheel speed $= u = 10 \times \dfrac{1}{2} = 5$ m/s

Work done per sec by wheel $= \dfrac{w}{g}\,(v - u)\,(1 + k\cos\phi)\,u$

Power $= \dfrac{mg}{g}\,(v - u)\,(1 + k\cos\phi)\,u$

$P = T\omega$

$\dfrac{T}{m} = \dfrac{(v-u)(1 + k\cos\phi)u}{\omega} = \dfrac{(10-5)(1+\cos 60°)5}{10}$

$= 3.75$ Nm / (kg/s) Choice (D)

27. $K_v = 0.98$, $K_u = 0.46$

$V = k_v\sqrt{2gh} = 0.98\sqrt{2 \times 9.8 \times 300} = 75.19$ m/sec

$u = k_u\sqrt{2gh} = 0.46\sqrt{2 \times 9.8 \times 300} = 35.29$ m/s

$\eta_0 = \dfrac{p}{WQH}$

$0.85 = \dfrac{6000 \times 10^3}{9810 \times Q \times 300}$

$Q = 2.39$ m^3/s

$u = \dfrac{\pi D N}{60} = \dfrac{\pi \times D \times 550}{60}$

$D = 122.5$ m

$\dfrac{d}{D} = \dfrac{1}{10}$

$d = 0.1225$ m $= 122.5$ m

$A = \dfrac{\pi}{4}(0.1225)^2 = 0.0118$ m^2

Total jet area required $= \dfrac{Q}{V} = \dfrac{2.399}{75.19} = 0.0319$ m^2

No. of jets required $= \dfrac{0.0319}{0.0118} = 2.7 = 3$ Choice (C)

28. $d = \left[\dfrac{0.0319}{3\left(\dfrac{\pi}{4}\right)}\right]^{\frac{1}{2}} = 0.1164$ m $= 116.4$ mm Choice (B)