2019

RANK IMPROVEMENT WORKBOOK

Mechanical Engineering

Fluid Mechanics

Answer Key of Objective & Conventional Questions

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1 Fluid Properties

LEVEL 1 Objective Questions

1. (c)
2. (b)
3. (c)
4. (576)
5. (3.61)(3.50 to 3.75)
6. (0.0258)(0.025 to 0.026)
7. (b)
8. (d)
9. (c)
10. (a)
11. (b)

LEVEL 2 Objective Questions

12. (d)
13. (c)
14. (c)
15. (c)
16. (c)
17. (c)
18. (c)
19. (b)
20. (b)
21. (d)

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LEVEL 3 Conventional Questions

Solution : 22

Frictional resistance = 1553.33 N

Solution : 23

Depth of the sea = **8950 m**

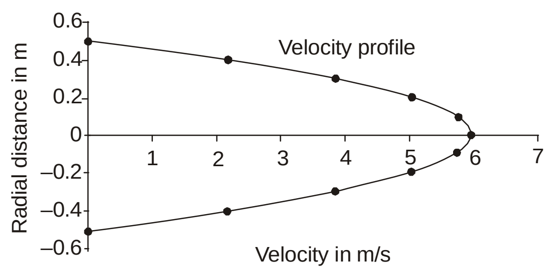
Solution : 24

$$\tau|_{y=0} = 0.9 \times 12 = 10.8 \text{ N/m}^2$$

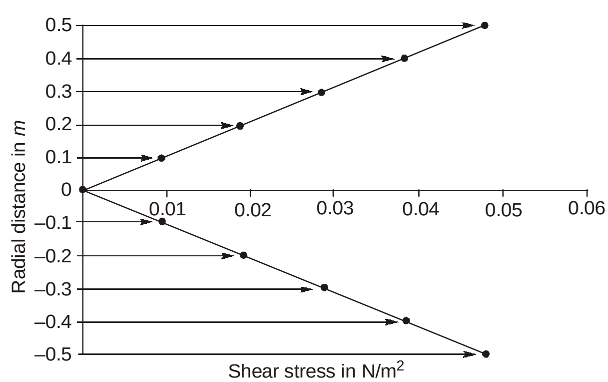
$$\tau|_{y=0.15} = 0.9 \times 6 = 5.4 \text{ N/m}^2$$

$$\tau|_{y=0.3} = 0.9 \times 0 = 0$$

Solution : 25



Velocity profile



Shear stress distribution

Solution : 26

$$y = 0, \tau = 0.0474 \text{ N/m}^2$$
$$y = 3 \text{ mm}, \tau = 0.0335 \text{ N/m}^2$$
$$y = 6 \text{ mm}, \tau = 0$$

Solution : 27

$$\mu = 0.397 \text{ Pa.s}$$

Solution : 28

$$R_0 = 54.6 \text{ mm}$$

Force required to separate the bubble into two identical halves is given by

$$\Delta P = 5.86 \text{ N/m}^2$$

Solution : 29

$$p_i = 292.15 \text{ N/m}^2 = 292.15 \text{ Pa}$$

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2 Fluid Statics

LEVEL 1 Objective Questions

1. (b)
2. (c)
3. (b)
4. (b)
5. (c)
6. (b)
7. (c)
8. (c)
9. (d)
10. (a)
11. (a)
12. (d)

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LEVEL 2 Objective Questions

13. (109.9)(109 to 110.5)
14. (a)
15. (c)
16. (d)
17. (a)
18. (a)
19. (0.338)(0.325 to 0.340)
20. (33.5)(33 to 34)
21. (a)

■■■■

LEVEL 3 Conventional Questions

Solution : 22

$$F_1 = 138814.95 \text{ N}$$

Solution : 23

$$V = 5590.9 \text{ m}^3 \text{ i.e. total volume}$$

$$\therefore \quad \text{weight of iceberg} = \rho_i \times V \times g$$
$$= 915 \times 5590.9 \times 9.81$$
$$= 50.184 \times 10^6 \text{ N.}$$

Solution : 24

The metacentric height is negative. Hence cylinder will not float with vertical axis.

Solution : 25

$$h_A = 4 \text{ m of water}$$

Solution : 26

$$H = x + 0.3 = 2.87 \text{ m}$$

Solution : 27

$$\frac{p_M}{\gamma} - \frac{p_N}{\gamma} = 13.86 \text{ m}$$

$$\frac{p_N}{\gamma} - \frac{p_R}{\gamma} = 5.04 \text{ m}$$

$$\frac{p_M}{\gamma} - \frac{p_R}{\gamma} = 18.9 \text{ m}$$

Solution : 28

Resultant water pressure in the dam

$$F = \sqrt{F_x^2 + F_y^2} = 790.907 \text{ kN}$$

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right) = 51°40'$$

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3 Fluid Kinematics

LEVEL 1 Objective Questions

1.	(b)
2.	(c)
3.	(b)
4.	(c)
5.	(d)
6.	(d)
7.	(c)
8.	(b)
9.	(c)
10.	(d)
11.	(b)
12.	(b)
13.	(c)

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LEVEL 2 Objective Questions

14.	(b)
15.	(8)
16.	(8)
17.	(c)
18.	(8)(7.9 to 8.1)
19.	(d)
20.	(b)
21.	(c)
22.	(a)
23.	(a)
24.	(0)

LEVEL 3 Conventional Questions

Solution : 25

(i)
$$V_1 = \frac{Q}{\frac{\pi}{4}(d_1)^2} = \frac{4Q}{\pi d_1^2}$$

Similarly,
$$V_2 = \frac{Q}{\frac{\pi}{4}d_2^2} = \frac{4Q}{\pi d_2^2} \text{ and } V_3 = \frac{Q}{\frac{\pi}{4}d_3^2}$$

(ii)
$$V_1 = 2.39 \text{ m/s}$$
$$V_2 = 9.55 \text{ m/s and } V_3 = 0.679 \text{ m/s}$$

(iii)
$$V_1 = 2.39 \text{ m/s}$$
$$V_2 = 19.10 \text{ m/s}$$

$\therefore$
$$V_3 = 0.52 \text{ m/s}$$

Solution : 26

(i) Local Acceleration is defined as the rate of increase of velocity with respect to time at a given point in a flow field. In the equations

$$a_x = \frac{du}{dt} = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t}$$
$$a_y = \frac{dv}{dt} = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + \frac{\partial v}{\partial t}$$
$$a_z = \frac{dw}{dt} = u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} + \frac{\partial w}{\partial t}$$

$\frac{\partial u}{\partial t}, \frac{\partial v}{\partial t}, \frac{\partial w}{\partial t}$ are known as local accelerations

Convective acceleration is defined as the rate of change of velocity due to the changed position of fluid particles in fluid flow. The expressions other than $\frac{\partial u}{\partial t}, \frac{\partial v}{\partial t}, \frac{\partial w}{\partial t}$ in the above equations are known as convective accelerations.

(ii)
$$\vec{\omega} = 1\hat{i} + 0\hat{k} + (-4)\hat{k} = \hat{i} - 4\hat{k}$$

Solution : 27

$$P_a - P = \rho\left[2x^2y^2 + \frac{x^4}{2} + \frac{y^4}{2} - x^2y^2\right] = \rho\left[\frac{x^4}{2} + \frac{y^4}{2} + x^2y^2\right]$$

Solution : 28

$$N = 567.22 \text{ rpm}$$

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Solution : 29

$$\frac{\rho}{\rho_0} = \exp[(1-y^2)\cos\omega t]/\omega$$

Solution : 30

If u, v and w satisfy the equation of continuity, then it will be possible liquid motion.

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z} = 0$$

$$2yz.\frac{3x^2-y^2}{(x^2+y^2)^3}+2yz.\frac{y^2-3x^2}{(x^2+y^2)^3}+0=0$$

This shows that the liquid motion is possible.

For irrotational motion, we have

$$\frac{\partial v}{\partial z}-\frac{\partial w}{\partial y} = 0$$

$$\frac{\partial w}{\partial x}-\frac{\partial u}{\partial z} = 0$$

and $$\frac{\partial u}{\partial y}-\frac{\partial v}{\partial x} = 0$$

So, $$\frac{\partial v}{\partial z}-\frac{\partial w}{\partial y} = \frac{x^2-y^2}{(x^2+y^2)^2}-\frac{x^2-y^2}{(x^2+y^2)^2}=0$$

Also, $$\frac{\partial w}{\partial x}-\frac{\partial u}{\partial z} = \frac{-2xy}{(x^2+y^2)^2}+\frac{2xy}{(x^2+y^2)^2}=0$$

and $$\frac{\partial u}{\partial y}-\frac{\partial v}{\partial x} = \frac{2xz(3y^2-x^2)}{(x^2+y^2)^3}-\frac{2xz(3y^2-x^2)}{(x^2+y^2)^3}=0$$

which satisfy the condition. Hence the motion is irrotational.

Solution : 31

The continuity equation becomes,

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 6x^2 - 6x^2 = 0$$

Hence, the flow is physically possible.

To find rotational or irrotational:

Because $\frac{\partial u}{\partial y} \neq \frac{\partial v}{\partial x}$, the flow is rotational.

To find angular velocity;

$$\omega_z = -6xy$$

Note at the origin (0, 0), because $\omega_z = 0$, the flow is rotational except at the origin.

To find vorticity :

vorticity, $\xi = -12xy$

To find shear strain:

$$\gamma_{xy} = -6xy$$

Note: The negative sign for angular velocity and shear strain indicates clockwise motion.

To find dilatancy (linear strain):

$$\in_x = \frac{\partial u}{\partial x} = 6x^2$$

$$\in_y = \frac{\partial v}{\partial y} = -6x^2$$

To find the circulation:

Circulation $\Gamma = -12xy(\pi a^2)$ m^2/s

where a is the radius of circle $x^2 + y^2 - 2ay = 0$

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4 Fluid Dynamics & Flow Measurement

LEVEL 1 Objective Questions

1.	(c)
2.	(d)
3.	(12.11)(12 to 12.15)
4.	(d)
5.	(c)
6.	(d)
7.	(c)
8.	(b)
9.	(34.90) (34.85 to 35.25)
10.	(a)
11.	(d)
12.	(c)

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LEVEL 2 Objective Questions

13.	(2.47)(2.40 to 2.50)
14.	(80.79)(80 to 81)
15.	(137500)
16.	(d)
17.	(a)
18.	(d)
19.	(d)
20.	(25.56)(25.0 to 26.0)
21.	(55.45)(55.20 to 55.90)
22.	(0.9848)(0.980 to 0.987)
23.	(135)(134.50 to 135.50)
24.	(b)
25.	(b)
26.	(8.76)

■■■■

LEVEL 3 Conventional Questions

Solution : 27

(i)
$$h = \frac{2500}{2\times 9.81}\frac{1}{\left(\frac{13600}{1.1807}-1\right)}\ \text{m} = 127.42\times\frac{1}{11517.6} = 0.011\ \text{m}$$

$\therefore$ $h = 11$ mm

(ii)
$$h = \frac{(420)^2}{2\times 9.81}\frac{1}{\left(\frac{13600}{1.1807}-1\right)}\text{m} = \frac{176400}{2\times 9.81\times 11517.6} = \mathbf{0.78\ m\ or\ 780\ mm}$$

Solution : 28

$$\therefore \quad h = \frac{2.203}{12.6} = 0.175\ \text{m} = \mathbf{17.5\ cm}$$

Deflection : As the value of *'h'* comes positive, hence our assumed direction is correct i.e. the manometer limb connected to section 1 will be having a smaller column of mercury than the other limb.

Solution : 29

Discharge: $Q = AV_1 = 0.009734\ \text{m}^3/\text{s} = \mathbf{9.734\ litre/s}$

Solution : 30

$$H = z + \frac{V^2}{2g} + \frac{p}{\gamma} = -3.058\ \text{m}$$

Solution : 31

$$Q = A_3V_3 = 3.28\times 10^{-3}\ \text{cumecs}$$
$$p_2 = -40.61\ \text{kN/m}^2$$

Solution : 32

Hence,
$$h = 4.5 + \frac{2.426^2}{2\times 9.81} = 4.7999\ \text{m}$$

Solution : 33

Equation of trajectory

$$= 1.73x - 0.7848x^2$$

Maximum elevation of the jet

$$s = \frac{U_0^2\sin^2\theta}{2g} = \frac{25\times(\sin 60)^2}{2\times 9.81} = 0.955\ \text{m}$$

Maximum horizontal distance

$$0 = 1.73x - 0.7848x^2$$

or $x(1.73 - 0.7848x) = 0$

That is, $x = 0$ or $x = 2.2$ m

So maximum horizontal distance = 2.2 m.

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Solution : 34

stagnation pressure = 161.109 kPa gauge

Solution : 35

Velocity = 214.37 kmph

Solution : 36

F = –2810 N [In this problem, p_2 = 0 has been assumed as if p_1 = 200 kPa = above p_2]

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5 Dimensional Analysis

LEVEL 1 Objective Questions

1.	(d)
2.	(a)
3.	(c)
4.	(c)
5.	(b)
6.	(c)
7.	(a)
8.	(c)
9.	(c)
10.	(c)
11.	(c)
12.	(a)

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LEVEL 2 Objective Questions

13.	(c)
14.	(d)
15.	(a)
16.	(b)
17.	(d)
18.	(a)
19.	(d)

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LEVEL 3 Conventional Questions

Solution : 20

Buckingham's π-theorem states that "If there are n-variable (Independent and dependent) in a physical phenomenon and if these variable contain m fundamental dimensions then the variables are arranged into $(n-m)$ dimensionless terms which are called π-terms".

Let $X_1, X_2, X_3 \ldots\ldots X_n$ are the variables involved in a physical problem. Let X_1 be the dependent variable and $X_2, X_3, X_4 \ldots X_n$ are the independent variables on which X_1 depends. Mathematically it can be written as

$$X_1 = f(X_2, X_3, X_4, \ldots. X_n)$$

and, $\quad f(X_1, X_2, X_3, X_4 \ldots X_n) = 0$

Hence, $\quad f(\pi_1, \pi_2, \pi_3 \ldots. \pi_{n-m}) = 0$

$$\text{Drag force, } F = f(V, L, K, \rho, g)$$

$$\therefore \quad F\,(\text{Drag force}) = \rho L^2 V^2 \phi\left(\frac{K}{L}, \frac{gL}{V^2}\right)$$

Solution:21

Total discharge, $\quad Q_p = 377.54 \text{ m}^3/\text{sec}$

Discharge through each turbine

$$Q_p' = \frac{377.54}{4} = 94.385 \text{ m}^3/\text{sec}$$

For Model

Power developed by each model

$$P_m = 17.06 \text{ kW}$$

$$\left(\frac{N_p}{N_m}\right) \times L_r = \sqrt{\frac{H_p}{H_m}} = \sqrt{\frac{60}{5}} = 3.46$$

From equation (i) and (ii),

$$N_m = 238.5 \text{ rpm}$$

Specific speed, $\quad (N_s)_m = 131.754 \text{ rpm}$

$$(N_s)_p = 133.90 \text{ rpm}$$

Type of turbine runner is Francis.

Solution : 22

Importance of Dimensional Analysis: Dimensional analysis is an important tool in designing fluid machines, structures and various aspects of fluid flow on them.

(i) In dimensional analysis, model of actual structure is analysed under various flow conditions in order to see various effects of flow on actual structure.

(ii) Dimensional analysis predicts the performance of actual structure with the help of model.

(iii) The model of actual structure made with the help of dimensionless analysis is the replica of actual structure. So it eliminates the chances of error, redesign and reduces the cost.

Rayleigh's Method: This method is used only for simple problems involving 3 to 4 variables only and there is no calculation for dimension less groups. The dimensionless groups are formed directly.

The power to maintain the rotation of cylinder is directly proportional to density ρ, kinematic viscosity v, and diameter D of cylinder.

Solution : 23

$$V_m = \frac{L_p}{L_m} \cdot \frac{\rho_p}{\rho_m} V_p = 4512.89 \text{ m/ s}$$

Drag force $F \propto \rho V^2 L^2$

Drag on prototype $F_p = 1.095 \times 400 = 437.86 \text{ N}$

Solution : 24

The specific speed of a turbine is defined as the speed of operation of a geometrically similar model of the turbine which produces 1 kW power when operating under 1 m head. The expression for specific speed is derived as follows:

We have $N = f(\rho, gH, P, D)$

Wherein 'gH' called shaft work is considered to be one variable only.

Thus in all there are 5 variables involved in the phenomenon which can be completely described by 3 fundamental dimensions. As such the above functional relationship may be replaced by another one involving only 2 dimensionless π-terms.

Choosing ρ, 'gH' and P as repeating variables,

Thus substituting $P = 1$, $H = 1$ and $N = N_s$ for the model and assuming g and ρ to be same for the model and the prototype, we get

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

Solution : 25

Given: η is a function of ρ, μ, ω, D, Q

$$\eta = f(\rho, \mu, \omega, D, Q)$$

or $$\eta = f\left[\frac{\mu}{D^2\omega\rho}, \frac{Q}{D^3\omega}\right]$$

Solution : 26

Distorted Models: A model is said to be distorted if it is not geometrically similar to its prototype. For a distorted model different scale ratios for the linear dimensions are adopted. The models of river and harbours are made as distorted models as two different scale ratios, one for the horizontal dimensions and other for vertical dimensions are taken. If for the river and harbours, the horizontal and vertical scale ratios are taken to be same so that the model is undistorted, then the depth of water in the model of the river will be very-very small which may not be measured accurately. Therefore these are made as distorted models.

Advantages:

1. The vertical dimensions of the model can be measured accurately.
2. The cost of the model can be reduced.
3. Turbulent flow in the model can be maintained.

Disadvantages:

1. Due to different scales in the different directions, the velocity and pressure distribution in the model is not same as that in the prototype.
2. Waves are not simulated in distorted models.
3. The results of the distorted model cannot be directly transferred to its prototype.

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6 Flow Through Pipes

LEVEL 1 Objective Questions

1.	(d)
2.	(b)
3.	(b)
4.	(c)
5.	(6.035)(6 to 6.10)
6.	(0.151)(0.14 to 0.16)
7.	(c)
8.	(a)
9.	(d)
10.	(c)
11.	(a)
12.	(c)
13.	(c)

LEVEL 2 Objective Questions

14.	(c)
15.	(4)
16.	(4.8)(4.7 to 4.9)
17.	(12.788)(12 to 13)
18.	(0.32768)(0.31 to 0.33)
19.	(d)
20.	(b)
21.	(c)
22.	(d)
23.	(1.82)(1.81 to 1.83)

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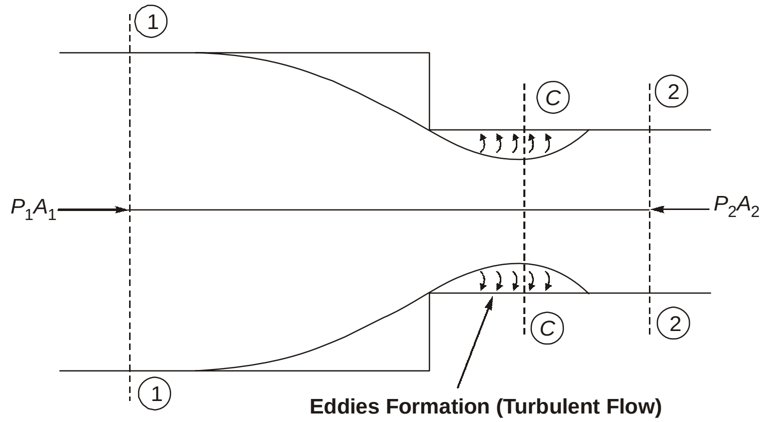
LEVEL 3 Conventional Questions

Solution : 24

$$h_s = 2.073 \text{ m}$$

Solution: 25

Consider a fluid (air) flowing in a pipe which has a sudden contraction in area



Let the dynamic loss coefficient be K and coefficient of contraction be C_C.

$$K = \left[\frac{1}{0.62} - 1\right]^2 = 0.3756 = 0.3756$$

Solution : 26

$\therefore$ For maximum differential pressure, the ratio of the diameters is $\dfrac{D_1}{D_2} = \dfrac{1}{\sqrt{2}}$

corresponding loss of head, $h_e = 0.25\dfrac{V_1^2}{2g}$

and corresponding differential pressure head:

$$\frac{\Delta P}{\rho g} = 0.5\frac{V_1^2}{2g}$$

Solution : 27

$$p_2 = 110.68 \text{ kPa}$$

$$\tau = \frac{\rho g h_f r_0}{2L} = 183.486 \text{ N/m}^2$$

Solution : 28

$$Q = \frac{\pi}{4}D_1^2 \times V_1 = \frac{\pi}{4}(0.06)^2 \times 2.422 = 6.848 \text{ lit/s}$$

Solution : 29

$$Q = \frac{\pi}{4}d^2 V = 0.215 \text{ m}^3/\text{s}$$

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Solution : 30

$$(h_L)_{1-2} = 0.051 \text{ m};$$
$$(h_L)_{1\text{-}3} = 7.95 \text{ m}$$

Solution : 31

$$p_1 = 1902.65 \text{ kPa}$$

Solution : 32

$$Q_2 = 6.788 \text{ cumecs}$$
$$Q_3 = 18.70 \text{ cumecs}$$

■■■■

7 Laminar & Turbulent Flow

LEVEL 1 Objective Questions

1.	(c)
2.	(a)
3.	(b)
4.	(d)
5.	(d)
6.	(c)
7.	(b)
8.	(d)
9.	(a)
10.	(c)
11.	(26.4)
12.	(2.66)

LEVEL 2 Objective Questions

13.	(c)
14.	(d)
15.	(a)
16.	(16)
17.	(0.00784)(0.00780 to 0.00785)
18.	(1)
19.	(d)
20.	(c)
21	(c)
22.	(a)
23.	(c)

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LEVEL 3 Conventional Questions

Solution : 24

Since ρ and Q are the same for both the pipes, the ratio of

$$\frac{\text{Cost of pumping 150 mm diameter pipe}}{\text{Cost of pumping 210 mm diameter pipe}} = \frac{h_{f1}}{h_{f2}} = \frac{f_1 d_2^5}{f_2 d_1^5} = \frac{0.0234 \times (210)^5}{0.021448 \times (150)^5} = \mathbf{5.8677}$$

Solution : 25

Since $Re < 2000$, flow is laminar.

Pressure loss, $\Delta p = 7019 \times 10^5 \text{ N/m}^2$

Maximum flow rate for laminar flow will be obtained for Re = 2000,

$$V = \frac{\nu \times \text{Re}}{d} = \frac{0.7 \times 10^{-3} \times 2000}{0.01} = 140 \text{ m/s}$$

$$Q_{max} = 0.01099 \text{ m}^3\text{/s} = 10.99 \text{ } l\text{/s}$$

$$= 659.4 \text{ litres/minute}$$

Solution : 26

(i) Flow rate: $Q = A\bar{u} = \frac{\pi}{4}D^2\bar{u} = 0.003679 \text{ m}^3\text{/s}$

The maximum velocity occurs at centre line of the pipe and it equals twice the average flow velocity.

$$U_{max} = 2\bar{u} = 2 \times 1.875 = 3.75 \text{ m/s}$$

(ii) Power required to maintain the flow in 100 m length of pipe: P

$$P = 6622.2 \text{ W}$$

(iii) Velocity at radius r is = 2.01 m/s

and shear stress; $\tau = 153 \text{ N/m}^2$

Solution : 27

$$\mu = 0.11094 \text{ Ns/m}^2$$

Solution : 28

$$f = 0.0217$$

Shear stress at the pipe surface is given by

$$\tau_0 = 110.065 \text{ N/m}^2$$

Shear velocity $V^* = 0.332 \text{ m/s}$

$$v_{max} = 7.64 \text{ m/s.}$$

Solution : 29

Distance from the boundary $y = 0.293\text{R}$

Solution : 30

$$\alpha = 2$$

$$\beta = \frac{4}{3} = 1.33$$

Solution : 31

The shear stress at the upper plate,

$$\tau = \mu \left.\frac{du}{dy}\right)_{y=b} = -108.72 \text{ N/m}^2$$

and it must be resisting the plate motion. The discharge through the channel is given by

$$Q = \int_0^b u\,dy$$

for no discharge,

$$\frac{Ub}{2} = \frac{1}{12\mu}\frac{d}{dx}(p+\rho gh)b^3$$

$$\therefore \quad U = \frac{b^2}{6\mu}\frac{d}{dx}(p+\rho gh) = -0.183 \text{ m/s}$$

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8 Boundary Layer Theory, Drag & Lift

LEVEL 1 Objective Questions

1.	(c)
2.	(b)
3.	(c)
4.	(d)
5.	(c)
6.	(c)
7.	(a)
8.	(d)
9.	(c)
10.	(b)
11.	(b)
12.	(c)

LEVEL 2 Objective Questions

13.	(a)
14.	(b)
15.	(d)
16.	(c)
17.	(b)
18.	(a)
19.	(c)
20.	(a)
21.	(c)
22.	(b)

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LEVEL 3 Conventional Questions

Solution : 23

$$x = 0.03576 \text{ m or } 35.76 \text{ mm}$$

To find maximum thickness of the boundary layer

$$\delta_{max} = 4.37 \times 10^{-4} \text{ m}$$

Solution : 24

When 0.3 m side is parallel to flow

$$C_D = 5.51 \times 10^{-3}$$

Total drag due to both sides

$$F_D = 0.024 \text{ N}$$

When 1.0 m side is parallel to flow

$$C_D = 3.022 \times 10^{-3}$$
$$F_D = 0.0133\text{N}$$

Solution : 25

1. Blasius solution

$$\delta = 0.011376 \text{ m}$$
$$C_D = 1.511 \times 10^{-3}$$

2. Approximate solution with assumption of cubic velocity profile

$$\delta = 0.010557 \text{ m}$$
$$C_D = 1.469 \times 10^{-3}$$

Approximate solution deviate from the exact solution by = 7.2%

Boundary layer thickness = 2.78%

Solution : 26

Therefore, $$\frac{F_{D_1}}{F_{D_2}} = 2.61$$

Solution : 27

$$\delta = 0.26 \text{ cm}$$
$$\delta^* = 0.0975 \text{ cm}$$
$$\theta = 0.1393\delta = 0.0362 \text{ cm}$$

Solution : 28

$$F = 0.766 \text{ N}$$

Solution : 29

$$\delta = \sqrt{\frac{2\mu x}{\rho U_\infty} \frac{\pi^2}{4-\pi}}$$

and $$\frac{\delta}{x} = \left[\frac{2\mu\pi^2}{(4-\pi)\rho U_\infty x}\right]^{1/2} = \frac{4.795}{\text{Re}_x^{1/2}}$$

The displacement thickness,

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$$\delta^* = \delta\left[1-\frac{2}{\pi}\right] = 0.363\delta$$

$$\theta = \frac{2\delta}{\pi}-\frac{\delta}{2} = 0.1366\delta$$

Shear stress,

$$\tau_w = 0.3276\frac{\mu U_\infty}{x}\mathrm{Re}_x^{1/2}$$

Solution : 30

$$\frac{L_1}{L} = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$$

■■■■

9 Hydraulic Machines

LEVEL 1 Objective Questions

1. (d)
2. (d)
3. (d)
4. (1.41)(1.30 to 1.50)
5. (662.57)(662 to 663)
6. (a)
7. (a)
8. (b)
9. (b)
10. (b)
11. (b)
12. (a)
13. (52.80)
14. (b)

LEVEL 2 Objective Questions

15. (109.52) (109 to 110)
16. (d)
17. (c)
18. (b)
19. (a)
20. (d)
21. (c)
22. (c)
23. (d)
24. (b)
25. (d)
26. (d)

■■■■

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LEVEL 3 Conventional Questions

Solution : 27

The maximum length of the draft tube = $H_s + h = 4.48 + 1 = 5.48$ m

Solution : 28

(a) Flow rate: $Q = 0.4157 \text{ m}^3/\text{s}$

(b) Shaft power:

Power developed by the runner = 1321919.64 W = 1321.919 kW

or Shaft power: P = 1189.71 kW

Solution : 29

(i) Guide vane angle at inlet: α_1

$$\alpha_i = \mathbf{28.796°}$$

(ii) Runner vane angle at inlet: β_i

$$\beta_i = 180° - 31.5° = \mathbf{148.5°}$$

Solution: 30

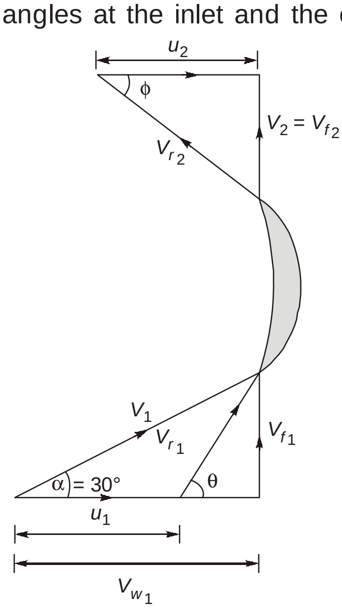
$$N = 303.5 \text{ rpm}$$
$$\phi = 28.19°$$

Solution : 31

$$p_A = 9810 \times 0.841 = 8250.21 \text{ N/m}^2.$$
$$p_B = 9810 \times 2.335 = 22906.35 \text{ N/m}^2 = 22.906 \text{ kN/m}^2 = 22.90 \text{ kPa}$$

Solution : 32

Refer to figure to find the vane angles at the inlet and the outlet.



(i) Vane angle at the inlet:

Vane angle at the inlet, $\theta = 48.06°$

Relative velocity is given by

$$V_{r_1} = 40.42 \text{ m/s}$$

(ii) Vane angle at the outlet:

Relative velocity of the jet and the vane at the outlet is

$$V_{r_2} = 34.357 \text{ m/s}$$

Vane angle at the outlet, $\phi = 43°18'$

Solutin : 33

To find diameter of wheel (D) $D = 1.56$ m

To find diameter of the jet (d) $d = 0.156$ m

To find the width of the bucket

width = 0.78 m

Depth of buckets = 0.187 m

For number of buckets = 20

Solution : 34

(i) $N_m = 1469.69$ r.p.m.

(ii) $P_m = 35.272$ kW

(iii) $Q_p = 69.4$ m^3/s.

Solution : 35

$$\eta_m = 0.552 = 55.2\%$$

If $P_1 = P_{atm} = 1$ bar

Discharge pressure $P_2 = P_1 + \rho g H_m = 4.78$ bar

Solution : 36

$$Q_t = 4.4175 \times 10^{-3} \text{ cumecs or } 265.05 \ l\text{/m}$$

Coefficient of discharge,

$$C_d = 0.9432$$

Slip of the pump = 15.05 l/m

Slip of the pump in percentage = 5.68%

Solution : 37

Power required to drive the pump = 2.401 kW

Solution : 38

$$Q_t = 0.0044175 \text{ cumecs}$$

The percentage slip = 4.92%

Theoretical power, $P_t = 1.083$ kW

Therefore,

$$h_{ad} = 20.75 \text{ m}$$

At the middle of the delivery stroke:

Therefore, $h_{ad} = 0$

Solution : 39

Speed of the pump without separation during suction stroke:

$$N = 87.66 \text{ rpm}$$

Speed of the pump without separation during delivery stroke:

But, $N = 55.58$ rpm

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