DETAILED SOLUTIONS

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ESE 2026 : Prelims Exam
CLASSROOM TEST SERIES

CIVIL ENGINEERING

Test 16

Section A : Transportation Engineering + Building Materials [All Topics]

Section B : Flow of Fluids, Hydraulic Machines and Hydro Power [All Topics]

Section C : Design of concrete and Masonry Structures - II [Part Syllabus]

1.	(b)	16.	(d)	31.	(c)	46.	(a)	61.	(c)
2.	(c)	17.	(c)	32.	(b)	47.	(c)	62.	(c)
3.	(c)	18.	(a)	33.	(c)	48.	(d)	63.	(a)
4.	(d)	19.	(a)	34.	(a)	49.	(d)	64.	(c)
5.	(c)	20.	(c)	35.	(d)	50.	(d)	65.	(b)
6.	(d)	21.	(a)	36.	(d)	51.	(c)	66.	(c)
7.	(c)	22.	(d)	37.	(b)	52.	(a)	67.	(c)
8.	(c)	23.	(c)	38.	(b)	53.	(c)	68.	(b)
9.	(b)	24.	(d)	39.	(a)	54.	(d)	69.	(a)
10.	(a)	25.	(d)	40.	(d)	55.	(a)	70.	(c)
11.	(d)	26.	(a)	41.	(d)	56.	(b)	71.	(c)
12.	(b)	27.	(d)	42.	(b)	57.	(a)	72.	(b)
13.	(a)	28.	(c)	43.	(c)	58.	(a)	73.	(a)
14.	(c)	29.	(a)	44.	(b)	59.	(c)	74.	(b)
15.	(b)	30.	(b)	45.	(a)	60.	(c)	75.	(b)

DETAILED EXPLANATIONS

SECTION A : Transportation Engineering + Building Materials

1. (b)

Deviation angle,

$$N = 1.5 - (-4) = 5.5\%$$

Assuming $L > S$,

$$L = \frac{NS^2}{4.4} = \frac{0.055 \times 150^2}{4.4} = 281.25 \text{ m} \approx 281 \text{ m} > S (= 150 \text{ m}) \text{ (OK)}$$

2. (c)

IRC: 73-2023 (Table 4.1) specifies a standard right-of-way of 30 m for 2-lane National Highways in plain and rolling terrain under open area conditions, excluding additional land required for future expansion, utilities, or special site conditions.

S. No.	Road Classification	Minimum Right of Way
1	2- lane Highways	30 m
2	4- lane Highways	45 m
3	6- lane Highways	60 m
4	8- lane Highways	120 m
5	Expressways	90-120 m
6	2- lane Highways with Bypasses	45-60 m
7	2- lane Highways in Open Areas** (Mountainous and steep terrain)	24 m 18 m (Exceptional)
8	2- lane Highways in Built-up Areas** (Mountainous and steep terrain)	20 m 18 m (Exceptional)

Note: The *ROW* width must include the 2 m wide strip on either side reserved for placement of utilities outside the fencing.

3. (c)

$$\text{Crossing number, } N = \frac{\text{Spread at the leg of the crossing}}{\text{Length of crossing from theoretical nose of crossing}}$$

4. (d)

Refer IRC: 73-2023 Cl 7.5.1

5. (c)

In setback distance calculations on horizontal curves, sight distance is measured along the middle of the inner lane. This is because the inner lane governs the minimum available sight distance on a horizontal curve due to lateral obstructions on the inside of the curve. Accordingly, IRC: 73-2023 Cl 7.5.1,s specifies that setback distance is measured with respect to the center line of the inner lane, and for narrow single-lane roads this refinement may be neglected by assuming the inner lane center line to coincide with the road center line.

6. (d)

Airport reference temperature,

$$ART = T_a + \frac{T_m - T_a}{3}$$

$$\Rightarrow \quad T_R = 21 + \frac{30-21}{3} = 24°C$$

Standard temperature,

$$T_S = 15 - 0.0065\ E_L$$

$$\Rightarrow \quad T_S = 15 - 0.0065 \times 500 = 11.75°C$$

Length correction due to temperature effect,

$$L = \frac{L_R}{100}(T_R - T_S)$$

$$\Rightarrow \quad L = \frac{3700}{100}\ (24 - 11.75) = 453.25 \text{ m}$$

$\therefore$ Final corrected runway length = 3700 + 453.25 = 4153.25 m

7. (c)

Grade compensation allowed on *BG* curve is 0.04% per degree curve,

Compensation for 3° curve = 0.04 × 3 = 0.12%

Ruling gradient provided = 1 in 125 = 0.8%

Actual ruling gradient to be used = 0.8 – 0.12

= 0.68% = 1 in 147

8. (c)

$$n_a = 250 \text{ vehicles}$$

$$n_y = 24 \text{ vehicles}$$

$$t_a = t_w = \frac{6}{90} \text{ hours}$$

$$\therefore \quad q = \frac{n_a + n_y}{t_a + t_w} = \frac{24+250}{\frac{6}{90}+\frac{6}{90}} = 2055 \text{ vehicles per hour}$$

9. (b)

In the license plate or vehicle number method, observers record the vehicle numbers and corresponding times at the entry and exit of a test stretch, and travel times are later obtained through office computations. However, this method does not capture details such as the causes of delays or the duration and number of delays occurring within the test stretch. In addition, the post-processing involved is cumbersome and time-consuming, making this a key limitation of the method as stated in the literature.

10. (a)

Some features of harbours are:

(i) Approach channel: Dredged fairway through which ships proceed from the open sea towards the harbour entrance.

(ii) Inner channel: Portion of the channel between the harbour entrance and the harbour basin, generally protected from waves and storms by natural features or breakwaters.

(iii) Turning basin: Area provided within the harbour to enable ships to manoeuvre and turn safely, preferably allowing a vessel to leave the berth head-on.

(iv) Breakwaters: Structures constructed to protect the enclosed harbour waters from storm waves and to maintain calm conditions for safe navigation and berthing.

(v) Locked basin: Enclosed basin with an entrance controlled by lock gates, allowing the water level inside to remain independent of external tidal variations.

(vi) Wharves and quays: Structures built parallel to the shore or breakwaters to permit berthing of vessels alongside for cargo handling and operations.

11. (d)

Given, $R = 236$ m

$e = 12$ cm

As per Martin's formula,

$$V_{max} = 4.35\sqrt{R-67}$$

$\Rightarrow$ $$V_{max} = 4.35\sqrt{236-67} = 56.55 \text{ kmph}$$

Length of transition curve,

$$L = 0.08\,eV_{max} = 0.08 \times 12 \times 56.55 = 54.288 \text{ m} \simeq 54.29 \text{ m}$$

12. (b)

Narrow shoulders reduce the effective width of the adjacent traffic lane, especially when vehicles stop on the shoulder due to breakdowns or emergencies. This forces moving traffic towards the center of the carriageway, reducing lane efficiency and hence the practical capacity.

13. (a)

Cutback bitumen is produced by blending bitumen with suitable volatile solvents to reduce its viscosity for ease of application. After application, the solvent evaporates, causing the binder to harden and develop its binding properties. The rate of this curing process depends on the characteristics and proportion of the volatile diluent used, as well as atmospheric conditions such as temperature and humidity at the site. Cutback bitumen is therefore suitable for use without heating and is preferred in cold and high-altitude regions.

14. (c)

- In hard rock tunnelling, the full-face method involves excavation of the entire tunnel cross-section in a single operation. Vertical drill columns are used to drill a large number of holes over the full face, which are then charged and blasted together. This method is suitable for comparatively smaller diameter tunnels and causes minimum ground disturbance.

- In the heading and bench method, the top portion of the tunnel, known as the heading, is excavated first and is advanced ahead of the bottom portion, called the bench. This allows the roof to remain stable for a short length without support, after which the bench excavation is completed. This method is commonly adopted for railway tunnels in hard rock conditions.

15. (b)

In railway tracks, chairs are cast-iron fittings used to hold double-headed and bull-headed rails in position. They help in transferring and distributing the load from the rails to the sleepers and are fixed to the sleepers by means of spikes, while the rail is held in the chair by a key.

16. (d)

Angularity number is a laboratory index used to compare the shape characteristics of aggregates for mix design purposes. It reflects the degree of angularity of single-sized aggregates by indicating the excess voids present in a compacted aggregate sample compared to well-rounded aggregates. Rounded aggregates pack more efficiently and produce lower voids, whereas angular aggregates create higher void content due to interlocking of particles. Hence, a higher angularity number signifies a more angular aggregate, while lower values correspond to rounded particles.

17. (c)

Advantages of rigid pavements:

(i) Do not deteriorate under wet weather conditions or when exposed to stagnant water.
(ii) Designed and constructed for long service life, generally about 30 years or more.
(iii) Routine and periodic maintenance cost is very low; mainly joint maintenance is required.
(iv) Life cycle cost is much lower than that of flexible pavements.
(v) Total pavement thickness and quantity of hard aggregates required are lower, especially on weak soils and under heavy traffic loads.
(vi) Provide good night visibility, even under wet weather conditions.

Limitations of rigid pavements:

(i) Proper design requires a long design life of 30 years or more to reduce life cycle cost.
(ii) Fatigue-based design needs accurate assessment of axle load spectrum, growth rate, and design wheel load, which differs from standard wheel load.
(iii) It is not possible to restore a failed or badly cracked cement concrete pavement.
(iv) Surface may become too smooth and slippery during long service life; re-texturing is difficult or expensive.
(v) A long curing period of about 28 days is required before opening to traffic.
(vi) Cross cutting of cement concrete pavements is not desirable; service lines must be planned well in advance with suitable ducting provisions.

18. (a)

- In soft soils, excavation is usually carried out without the use of explosives.
- Due to instability and the tendency of soil to exert pressure on supports, the work has to be performed cautiously, resulting in slow progress compared to hard rock tunnelling.
- Excavation generally does not require heavy and costly mechanical equipment, but adequate timbering and strong supports are essential to prevent collapse.

19. (a)

Steel sleepers provide better lateral rigidity than wooden sleeper but not than concrete sleepers. They have long service life and high scrap value, but are liable to corrosion and are unsuitable for track-circuited areas. Concrete sleepers, being heavy, offer greater stability and higher elastic modulus to the track, are suitable for long welded rails, and are not affected by vermin, corrosion, or fire hazards, though they have no scrap value and require careful handling during laying.

20. (c)

Cleavability is the measure of the ease with which wood can be split. Most hardwoods split more readily along radial planes than along tangential planes. Since splitting is achieved by wedging apart the longitudinal elements, cleavability is closely related to tensile strength across the grain. Woods that are intended to be fastened by nails and screws should therefore possess high resistance to splitting. Among conifers, except for longleaf pine, the difference in cleavability strength in the two directions is generally small.

21. (a)

22. (d)

Shrinkage of wood during drying is non-uniform in different directions due to its anisotropic structure. The linear shrinkage along the fibres is very small, lying between about 0.1 and 0.3 per cent, whereas shrinkage across the grain is much larger. Radial shrinkage generally lies between 3 and 6 per cent and is generally about 60 per cent of the tangential shrinkage, which ranges from 7 to 12 per cent. As a result, the overall volumetric shrinkage of wood is practically about 1.6 times the tangential shrinkage.

23. (c)

Limes containing 3-5% of clay do not display any hydraulic property and do not set and harden under water. When clay is present as 20-30% of lime, it imparts excellent hydraulic properties.

24. (d)

Portland pozzolana cement is produced by blending Portland cement clinker with pozzolana, which has the ability to react with the calcium hydroxide released during hydration. This reaction forms additional calcium hydrosilicate, thereby reducing the amount of free lime present in the hardened cement paste. As a result, resistance to chemical attack is improved and the cement becomes suitable for marine and aggressive environments. Although the rate of strength development is slower compared to ordinary Portland cement, the ultimate compressive strength of Portland pozzolana cement is comparable.

25. (d)

Concrete is alkaline in nature with an initial pH value of about 12-13, due to the presence of calcium hydroxide in the cement paste, which protects embedded steel from corrosion. In the presence of moisture, carbon dioxide from the atmosphere reacts with calcium hydroxide to form calcium carbonate, a process known as carbonation. This reaction lowers the pH of concrete, and when the pH falls below about 10, the alkaline protection to steel reinforcement is lost, initiating corrosion in the steel reinforcement.

26. (a)

27. (d)

Some examples of accelerators are:

- Sulphates with an exception of calcium sulphate
- Alkali carbonates, aluminates and silicates
- Aluminium chloride, Calcium chloride, Sodium and Potassium hydroxides, Calcium formate, Formaldehyde, Para formaldehyde, etc.

28. (c)

Lime in brick clay has the following effects:

(i) It reduces the shrinkage on drying.
(ii) It causes silica in clay to melt on burning and thus helps to bind it.
(iii) In carbonated form, it lowers the fusion point.
(iv) If it is present in excess, it causes the brick to melt. The brick loses its shape.
(v) High lime content can result in buff-burning of bricks.

29. (a)

Constituents of glass:

- **Silica:** Used in the form of pure quartz, crushed sandstone or pulverised flint; forms the basic glass network and provides strength.
- **Lime:** Added in the form of limestone, chalk or marble; imparts durability and toughness to glass.
- **Soda:** Acts as an accelerator for fusion, excess is harmful.
- **Potash:** Renders glass infusible and makes it fire resistant.
- **Lead oxide:** Imparts colour, brightness and shine; lowers melting point and improves workability but reduces transparency.

30. (b)

Sea water contains a high amount of dissolved salts, mainly sodium chloride along with magnesium chlorides and sulphates. Its use in concrete has been found to reduce compressive strength by about 10-20 per cent and to slightly accelerate the setting time. Sea water increases the risk of corrosion of reinforcement due to the presence of chlorides and may also cause efflorescence, making it unsuitable for plastering works. Because of the danger of stress corrosion and failure of high-strength steel, sea water is not recommended for pre-stressed concrete, though it may be used in plain cement concrete where fresh water is unavailable.

31. (c)

Refer Cl. 9.3 of IS : 14315 – 1995.

32. (b)

Ransom stones are prepared by mixing soda silicate (sodium silicate) with cement to provide decorative flooring. These are also called as chemical stones and have compressive strength of about 32 N/mm^2.

33. (c)

34. (a)

Cl. 6.2 of IS : 2180 – 1988.

35. (d)

Mica, if present in sand, will reduce the strength of concrete.

36. (d)

An increase in the proportion of tricalcium aluminate (C_3A) in cement leads to very rapid hydration immediately after the addition of water, resulting in high early heat evolution and a tendency towards quick or flash setting. To regulate this rapid reaction, a higher gypsum content is required during grinding. However, increased C_3A content adversely affects durability, particularly by reducing resistance to sulphate attack, making such cement unsuitable for sulphate-rich or mass concrete applications

37. (b)

Mohs No.	Mineral	Scratch characteristic
1	Talc	Easily scratched with thumb-nail
2	Gypsum	Scratched by thumb-nail
3	Calcite	Not scratched by thumb-nail but easily cut by knife
4	Fluorite	Cut by knife with greater difficulty than calcite
5	Apatite	Cut only with difficulty by knife
6	Orthoclase	Cut with knife with great difficulty on thin edges
7	Quartz	Not scratched by steel; scratches glass
8	Topaz	Scratches quartz
9	Sapphire	Scratches topaz
10	Diamond	Scratches all other minerals

38. (b)

Quick lime is the lime obtained after the calcination of limestone or calcium carbonate.

39. (a)

At a constant water content, addition of a water-reducing admixture increases the consistency of concrete.

40. (d)

Wane is a defect that occurs during the conversion of timber when part of the bark or the rounded periphery of the trunk remains on one or more faces of the converted timber. It reduces the effective cross-sectional area of the member and consequently leads to reduction in strength of the affected portion of timber.

41. (d)

Sound-absorbing mortars are prepared by using Portland cement, slag cement, lime or gypsum as the binding material along with porous aggregates such as pumice, cinders or ceramsite. These porous materials create voids within the mortar, which help in absorbing sound energy and reducing noise levels.

42. (b)

43. (c)

Rapid hardening Portland cement is produced by increasing the C_3S content of the clinker and by finer grinding compared to ordinary Portland cement. Consequently, rapid hardening cement is able to attain compressive strength in about three days that is comparable to the seven days strength of ordinary Portland cement, making it suitable for works where early strength is required.

44. (b)

During the oxidation period of brick burning, the processes of carbon elimination, sulphur removal and oxidation of ferrous iron to ferric form take place in the presence of oxygen. To prevent the formation of black or spongy cores, oxidation is required to proceed at a controlled rate so that carbon and sulphur are completely removed before the clay softens and the pores begin to close. Sulphur, on account of its affinity for oxygen, holds back the oxidation of iron. Although oxidation of iron is an important chemical change in this stage, it is the timing of carbon and sulphur elimination relative to pore closure that governs the prevention of black cores.

45. (a)

As the speed of a vehicle increases, the duration for which a wheel load acts on the pavement reduces. This higher rate of stress application results in lower pavement deformation, and hence the stresses developed in the pavement layers due to moving loads are less than those produced by the same magnitude of static loads. However, on uneven pavements, the impact effects increase with speed, which can counteract this reduction in stress.

Section-B : Flow of Fluids, Hydraulic Machines and Hydro Power

46. (a)

At uniform velocity, the force causing the motion balances the fluid resistance offered by the oil filled in the gap,

$$\therefore \quad W \sin 30° = \mu \frac{du}{dy} \cdot A$$

$$\Rightarrow \quad 1000 \times \frac{1}{2} = \mu \frac{2-0}{2 \times 10^{-3}} \times 1 \times 0.4$$

$$\Rightarrow \quad \mu = 1.25 \text{ N-s/m}^2 = 12.5 \text{ poise}$$

47. (c)

Given, $B = 3$ m

$y = 1.5$ m

$S_o = 0.004$

Flow area, $A = By$

$\Rightarrow$ $A = 3 \times 1.5 = 4.5\ \text{m}^2$

Wetted perimeter, $P = B + 2y$

$\Rightarrow$ $P = 3 + 2 \times 1.5 = 6$ m

$\therefore$ Hydraulic radius, $R = \frac{A}{P}$

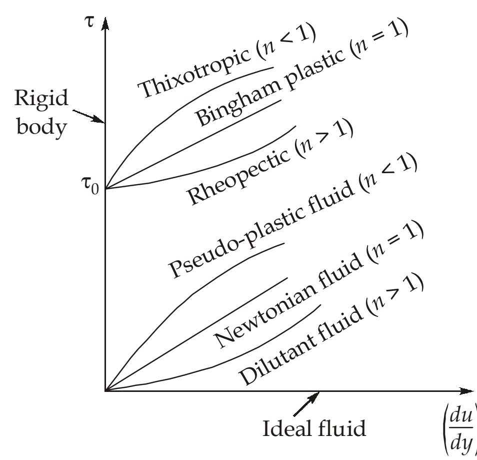
$\Rightarrow$ $R = \frac{4.5}{6} = 0.75$ m

Average boundary shear stress, $\tau_o = \gamma R S_o$

$\Rightarrow$ $\tau_o = 1000 \times 10 \times 0.75 \times 0.004$

$\Rightarrow$ $\tau_o = 30\ Pa$

48. (d)



49. (d)

Bernoulli's equation is applicable only for non-viscous flow. In actual flow situations, viscous forces are present within the boundary layer. Due to the presence of viscous effects inside the boundary layer, Bernoulli's equation cannot be applied there.

50. (d)

Impacts of cavitation on centrifugal pump:

- Reduces head and efficiency due to disturbed flow and poor energy transfer.
- Causes mechanical damage (pitting and erosion) from bubble collapse.
- Produces noise, often crackling or high-frequency sound.
- Creates pressure pulsations leading to vibration of casing and bearings.
- May cause vapour lock, resulting in complete loss of head and pump failure.

51. (c)

Given,
$$y_1 = 0.25 \text{ m}$$
$$y_2 = 1.25 \text{ m}$$

We know,
$$\frac{y_2}{y_1} = \frac{1}{2}\left[-1+\sqrt{1+8F_1^2}\right]$$
$$\Rightarrow \quad \frac{1.25}{0.25} = \frac{1}{2}\left[-1+\sqrt{1+8F_1^2}\right]$$
$$\Rightarrow \quad F_1{}^2 = \frac{120}{8} = 15$$
$$\Rightarrow \quad F_1 = \sqrt{15}$$

Now,
$$F_1 = \frac{v_1}{\sqrt{gy_1}}$$
$$\Rightarrow \quad \sqrt{15} = \frac{v_1}{\sqrt{10\times 0.25}}$$
$$\Rightarrow \quad v_1 = \sqrt{15}\times\sqrt{2.5} \text{ m/s}$$

Now,
$$q = v_1 y_1 = \sqrt{15}\times\sqrt{2.5}\times 0.25$$
$$\Rightarrow \quad q = \sqrt{5}\times\sqrt{3}\times\sqrt{5}\times\sqrt{0.5}\times 0.25$$
$$\Rightarrow \quad q = 5\sqrt{3}\times\frac{1}{\sqrt{2}}\times\frac{1}{4}$$
$$\Rightarrow \quad q = \frac{5\sqrt{3}}{4\sqrt{2}} \text{m}^3\text{/s/m}$$

52. (a)

For incompressible flow,
$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z} = 0$$

Here,
$$u = 3xy^2 + 2x + y^2$$
$$v = x^2 - 2y - y^3$$
$$\therefore \quad \frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 3y^2 + 2 - 2 - 3y^2$$
$$\Rightarrow \quad \frac{\partial u}{\partial x}+\frac{\partial v}{\partial y} = 0$$

$\therefore$ Flow is incompressible

Since there is no time component, it is steady flow.

53. (c)

Efficiency of draft tube, $\eta = \dfrac{\dfrac{V_i^2}{2g} - \dfrac{V_o^2}{2g} - h_{\text{loss}}}{\dfrac{V_i^2}{2g}}$

where V_i = Velocity of water at inlet

V_o = Velocity of water at outlet

$\therefore$ $\eta = \dfrac{\dfrac{8^2}{2g} - \dfrac{2^2}{2g} - 0.5}{\dfrac{8^2}{2g}}$

$\Rightarrow$ $\eta = 0.78421 = 78.42\%$

54. (d)

Here, $\Psi = 3x^2 y + (2 + t)y^2$

and $r = \hat{i} + 2\hat{j} - 3\hat{k}$

Now, at $t = 3$ units

$\Psi = 3x^2 y + 5y^2$

Now, $u = -\dfrac{\partial \psi}{\partial y} = -3x^2 - 10y$

and $v = \dfrac{\partial \psi}{\partial x} = 6xy$

From position vector, $r = \hat{i} + 2\hat{j} - 3\hat{k}$

$x = 1;\ y = 2;\ z = -3$

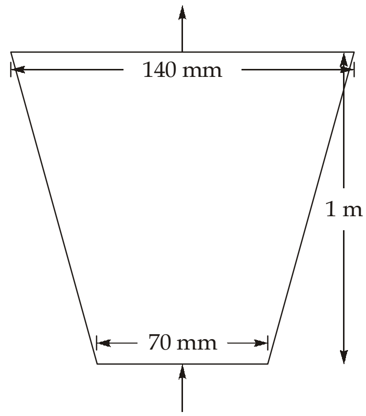
$\therefore$ $u = -23$ units and $v = 12$ units

Velocity vector is,

$\vec{V} = u\hat{i} + v\hat{j}$

$\Rightarrow$ $\vec{V} = -23\hat{i} + 12\hat{j}$

55. (a)



$$v_1 = \frac{Q}{\frac{\pi}{4}d_1^2} = \frac{77 \times 10^{-3}}{\frac{22}{7 \times 4} \times (0.07)^2} = 20 \text{ m/s}$$

$$v_2 = \frac{Q}{\frac{\pi}{4}d_2^2} = \frac{77 \times 10^{-3}}{\frac{22}{4 \times 7} \times (0.14)^2} = 5 \text{ m/s}$$

Now,
$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + Z_2$$

$$\Rightarrow \quad \frac{150 \times 10^3}{10^3 \times 10} + \frac{20^2}{2 \times 10} + 0 = \frac{P_2}{10^3 \times 10} + \frac{5^2}{2 \times 10} + 1$$

$$\Rightarrow \quad P_2 = 327.5 \text{ kN/m}^2$$

56. (b)

In a sudden expansion, the loss of head is,

$$h_L = \frac{(V_1 - V_2)^2}{2g}$$

Applying Bernoulli's equation,

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \frac{(V_1 - V_2)^2}{2g}$$

Here,
$$\frac{P_2}{\gamma} - \frac{P_1}{\gamma} = \frac{\Delta P}{\gamma}$$

$$\therefore \quad \frac{\Delta P}{\gamma} = \frac{V_1^2}{2g} - \frac{V_2^2}{2g} - \frac{(V_1 - V_2)^2}{2g}$$

By continuity,

$$V_1 D_1^2 = V_2 D_2^2$$

$$\Rightarrow \quad V_2 = V_1\left(\frac{D_1}{D_2}\right)^2 = V_1 x^2$$

where $$x = \frac{D_1}{D_2}$$

$$\therefore \quad \frac{\Delta P}{\gamma} = \frac{V_1^2}{2g}\left[1 - x^4 - \left(1 - x^2\right)^2\right]$$

For maximum pressure differential,

$$\frac{d}{dx}\left(\frac{\Delta P}{\gamma}\right) = 0$$

$$\therefore \quad -4x^3 - 2(1 - x^2)(-2x) = 0$$

$$\Rightarrow \quad 2x^2 - 1 = 0$$

$$\Rightarrow \quad x = \frac{1}{\sqrt{2}}$$

$$\Rightarrow \quad \frac{D_1}{D_2} = \frac{1}{\sqrt{2}}$$

57. (a)

The minimum cross-section region in a volute casing is the tongue, not the whirl chamber.

58. (a)

Discharge, $Q = 2\ l/s = 0.002\ m^3/s$

Now, $Q = C_d A\sqrt{2gH}$

$$\Rightarrow \quad H = \frac{\left(\frac{4Q}{\pi d^2 C_d}\right)^2}{2g} = \frac{\left(\frac{0.002 \times 4}{\frac{22}{7} \times (0.014)^2 \times 0.6}\right)^2}{2 \times 10} = 23.425\ \text{m}$$

Given depth of water is 1 m. The gauge pressure on top of the water column should, therefore, be

$$P = \rho g\ (23.425 - 1)$$

$$\Rightarrow \quad P = 1000 \times 10 \times (22.425)\ \text{N/m}^2$$

$$\Rightarrow \quad P = 224.25\ \text{kN/m}^2$$

59. (c)

A control section in open-channel flow is a location where a definite relationship exists between flow depth and discharge, allowing the depth at that point to uniquely determine the flow. Critical flow sections, sluice gates and abrupt changes in channel slope commonly act as control sections. For subcritical flow, the control lies in downstream direction, while for supercritical flow it lies in upstream direction. A transition from a mild slope to a steep slope also forms a natural control section by fixing the depth at the point of slope change.

60. (c)

From continuity equation, $A_1 v_1 = A_2 v_2$

Now, $$\frac{A_1}{A_2} = \frac{\frac{\pi}{4}(7)^2}{\frac{\pi}{4}(14)^2} = \frac{1}{4}$$

$$\therefore \quad v_2 = \frac{v_1}{4}$$

$$\therefore \quad \text{Head loss, } h_e = \frac{(v_1 - v_2)^2}{2g} = \frac{\left(v_1 - \frac{v_1}{4}\right)^2}{2g}$$

$$\Rightarrow \quad h_e = \frac{v_1^2}{2g} \times \left(\frac{3}{4}\right)^2 = \frac{9}{16}\left(\frac{v_1^2}{2g}\right) = \frac{9}{32}\left(\frac{v_1^2}{g}\right)$$

61. (c)

For centrifugal pump, minimum starting speed is,

$$\frac{u_1^2 - u_2^2}{2g} = H_m$$

Here $u = \frac{\pi DN}{60}$ = Tangential velocity of impeller

$$\therefore \quad \left(\frac{\pi D_1 N}{60}\right)^2 - \left(\frac{\pi D_2 N}{60}\right)^2 = 2gH_m$$

$$\Rightarrow \quad \left(\frac{\pi N}{60}\right)^2 \left(D_1^2 - D_2^2\right) = 2gH_m$$

$$\Rightarrow \quad N_{\text{minimum}} = \frac{60}{\pi} \times \sqrt{\frac{2gH_m}{D_1^2 - D_2^2}} = \frac{60}{\pi} \times \sqrt{\frac{2 \times 9.81 \times 20}{1.20^2 - 0.5^2}}$$

$$\Rightarrow \quad N_{\text{minimum}} = 346.81 \text{ rpm} \simeq 347 \text{ rpm}$$

62. (c)

Let velocity distribution be,

$$\frac{u}{U} = \frac{y}{\delta}$$

Displacement thickness,

$$\delta^* = \int_o^\delta \left(1 - \frac{u}{U}\right) dy$$

$$\Rightarrow \quad \delta^* = \int_o^\delta \left(1 - \frac{y}{\delta}\right) dy = \frac{\delta}{2}$$

Momentum thickness,

$$\theta = \int_o^\delta \left(1 - \frac{y}{\delta}\right)\left(\frac{y}{\delta}\right) dy = \frac{\delta}{6}$$

$$\therefore \quad \frac{\delta^*}{\theta} = \frac{\delta/2}{\delta/6} = 3$$

63. (a)

Kaplan turbines discharge water with high exit velocity, so a large amount of energy remains as kinetic energy. The draft tube must recover this energy, and any inefficiency in it results in major hydraulic losses.

Thus, the draft tube contributes the largest loss because exit velocity is high.

64. (c)

In a hydraulic press, the application of a small force on the plunger results in a large force on the piston due to pressure transmission through the confined liquid, in accordance with Pascal's law. The pressure remains the same throughout the fluid, and the increase in force is achieved because the piston has a larger cross-sectional area.

65. (b)

A rectangular duct has a larger wetted perimeter (contact area) than an equivalent circular duct. This results in higher boundary friction, leading to a greater pressure drop. Consequently, for the same discharge, the mean velocity in the rectangular duct is lower than that in the circular duct.

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66. (c)

As per IS 456:2000 (*Cl* 24.1)

For two-way slabs of shorter spans (up to 3.5 m) with mild steel reinforcernent, the span to overall depth ratios given below may generally be assumed to satisfy vertical deflection limits for loading class up to 3 kN/m^2.

Simply supported slabs	35
Continuous slabs	40

For high strength deformed bars of grade Fe 415, the values given above should be multiplied by 0.8.

67. (c)

As per IS 456 : 2000 (*Cl* 26.5.2.1),

the mild steel reinforcement in either direction in slabs shall not be less than 0.15 percent of the total cross-sectional area. However, this value can be reduced to 0.12 percent when high strength deformed bars or welded wire fabric are used.

68. (b)

Where splices are provided in the reinforcing bars, they shall as far as possible be away from the sections of maximum stress and be staggered. It is recommended that splices in flexural members should not be at sections where the bending moment is more than 50 percent of the moment of resistance; and not more than half the bars shall be spliced at a section.

69. (a)

Given $l = 20$ m, $\sigma_o = 1000\ \text{N/mm}^2$, $\Delta l = 2$ mm

Loss of prestress, $\Delta\sigma = 20\ \text{N/mm}^2$

$$\therefore \quad \text{Percent loss of prestress, } \Delta\sigma = \left(\frac{\Delta l}{l}\right)E_s = \frac{2}{20000}\times 200\times 10^3$$

$$\Delta\sigma = 20\ \text{N/mm}^2$$

$$\%\ \text{loss of prestress} = \frac{20}{1000}\times 100 = 2\%$$

70. (c)

Buttress retaining walls are structurally similar to counterfort retaining walls, but the direction of force in the web member differs

71. (c)

- Soft storey occurs due to sudden reduction in lateral stiffness.
- Increasing column size, providing shear walls, and adding infill walls increase stiffness and reduce soft storey effect.
- Avoiding columns worsens the soft storey problem.

72. (b)

- The sum of nodal forces at any yield line intersection in a slab is equal to zero, based on the principles of static equilibrium, not infinite. Nodal forces are internal forces that must balance at a junction.
- Yield lines are indeed assumed to be straight lines in yield line theory, representing the intersection of adjacent, inclined, rigid slab segments as they rotate.
- Yield lines must form a complete failure mechanism, and as such, they terminate at the boundary of the slab or at another yield line.

73. (a)

Length of footing = 5 m

Width of footing = 4 m

$$\text{Area of steel to be provided in central band} = A_{st}\times\frac{2}{\beta+1}$$

where, $$\beta = \frac{L}{B} = \frac{5}{4} = 1.25$$

$$\therefore \quad \text{Area of steel in central band} = 2250\times\frac{2}{1.25+1} = 2000\ \text{mm}^2$$

74. (b)

75. (b)

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