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**UPSC IFS**  
**Previous Year Paper**  
**(Civil Engineering Paper - I)**  
**2020**



**CIVIL ENGINEERING**  
**Paper – I**

Time Allowed : **Three Hours**

Maximum Marks : **200**

**Question Paper Specific Instructions**

*Please read each of the following instructions carefully before attempting questions :*

*There are **EIGHT** questions in all, out of which **FIVE** are to be attempted.*

*Questions no. 1 and 5 are **compulsory**. Out of the remaining **SIX** questions, **THREE** are to be attempted selecting at least **ONE** question from each of the two Sections A and B.*

*Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off.*

*All questions carry equal marks. The number of marks carried by a question/part is indicated against it.*

*Unless otherwise mentioned, symbols and notations have their usual standard meanings.*

*Assume suitable data, if necessary and indicate the same clearly.*

*Neat sketches may be drawn, wherever required.*

*Answers must be written in **ENGLISH** only.*

## SECTION A

- Q1. (a) Determine the horizontal and vertical components of force which the pin at 'C' exerts on member BC of the frame in Figure 1(a). 8

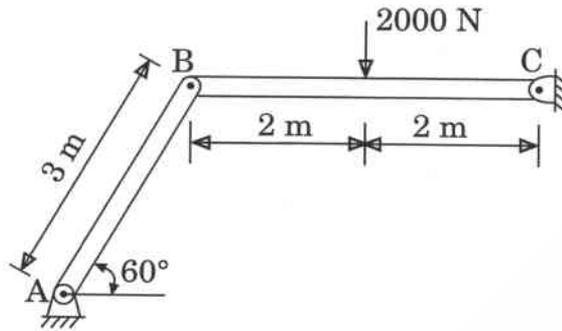


Figure 1(a)

- (b) A close-coiled helical spring is to have a stiffness of 900 N/m in compression, with a maximum load of 45 N and a maximum shearing stress of  $120 \text{ N/mm}^2$ . The solid length of the spring (i.e. coils touching) is 45 mm. Find the wire diameter, mean coil radius, and number of coils.  $G = 40,000 \text{ N/mm}^2$ . 8
- (c) A three hinged parabolic arch of 20 m span and 5 m rise is carrying a uniformly distributed load of 50 kN/m in the half portion as shown in Figure 1(c). Calculate the value of maximum horizontal thrust. 8

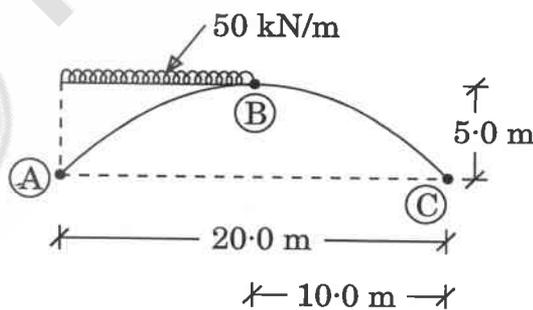


Figure 1(c)

- (d) Determine the design tensile strength of a plate (160 mm × 8 mm) connected to 10 mm thick gusset using 16 mm bolts as shown in Figure 1(d), if  $f_y = 250$  MPa,  $f_u = 410$  MPa,  $v_{m0} = 1.1$  and  $v_{m1} = 1.25$ .

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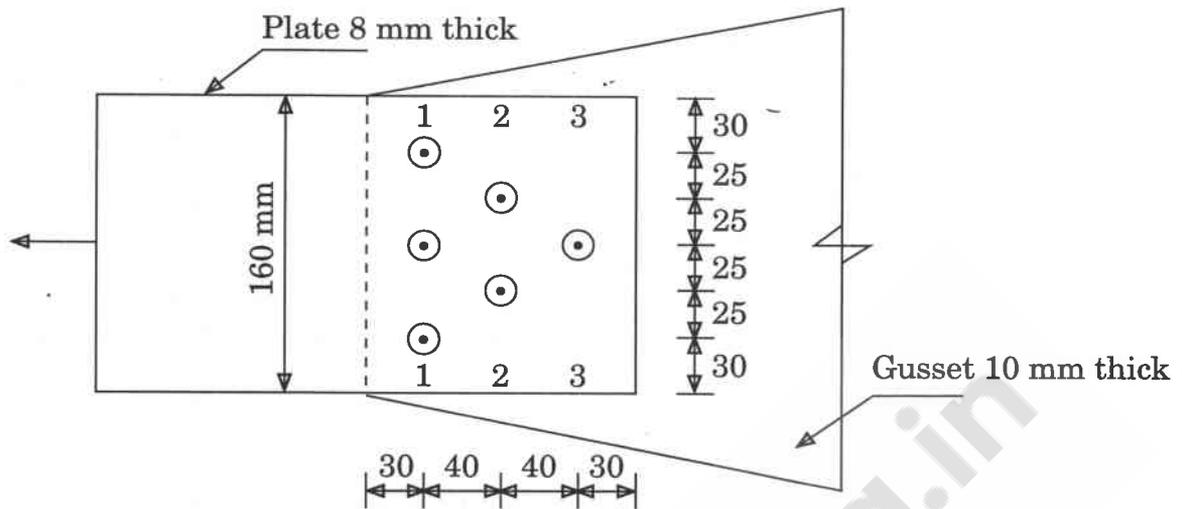


Figure 1(d)

- (e) An overhanging beam  $500 \times 2000$  mm in cross-section is effectively prestressed by 1000 kN prestressing force. Bending moment diagram has been shown in Figure 1(e). Calculate the eccentricities and sketch the prestressing cable profile.

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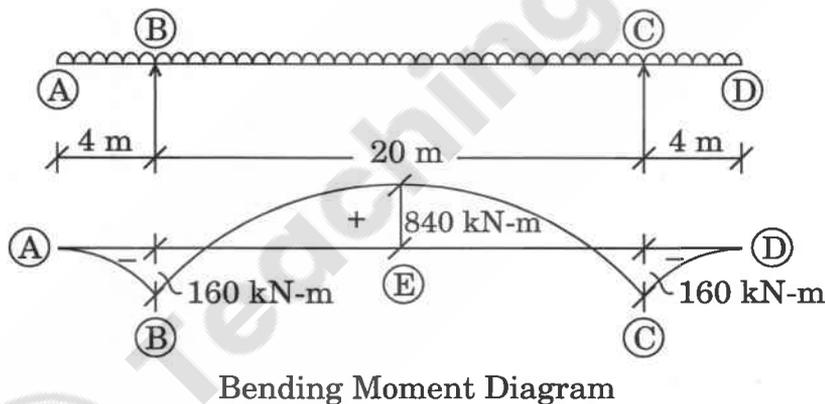


Figure 1(e)

- Q2. (a) (i) Explain the terms : Displacement, Velocity and Acceleration.
- (ii) During a test a rocket travels upward at 75 m/s, and when it is 40 m from the ground, its engine fails. Determine the maximum height reached by the rocket and its speed just before it hits the ground. While in motion the rocket is subjected to a constant downward acceleration of  $9.81 \text{ m/s}^2$  due to gravity. Neglect the effect of air resistance.

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(b) The load on a bolt consists of an axial pull of 10 kN together with a transverse shear force of 5 kN. Estimate the diameter of bolt required according to

- (i) Maximum Principle Stress theory
- (ii) Maximum Shear Stress theory
- (iii) Strain Energy theory
- (iv) Shear Strain Energy theory

Elastic limit in tension is  $270 \text{ N/mm}^2$  and a factor of safety of 3 is to be applied. Poisson's ratio = 0.3.

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(c) Develop the stiffness matrix for the cantilever beam shown in Figure 2(c). Length is 4.0 m and  $EI$  is constant. Neglect the axial deformation.

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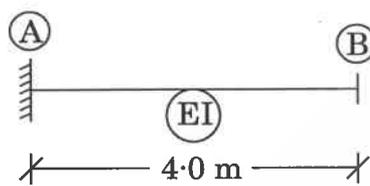


Figure 2(c)

Q3. (a) Draw the Bending moment diagram after analysing by moment distribution method for the open frame shown in Figure 3(a). Also draw the free body diagram for the frame. ( $EI$  constant)

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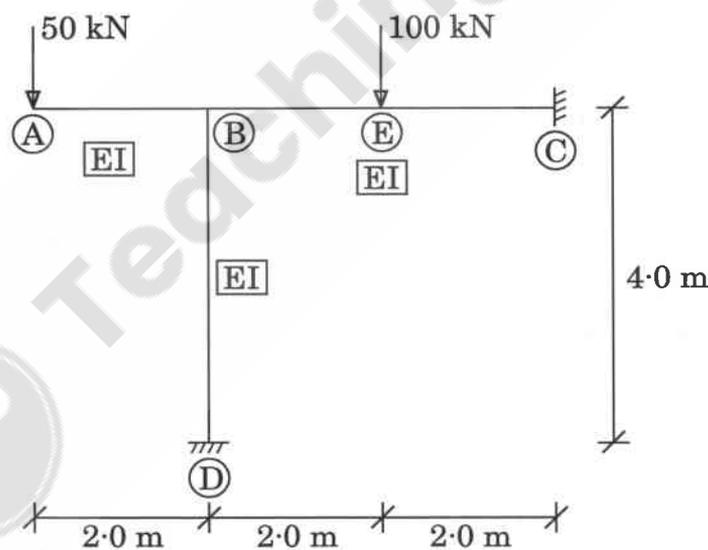


Figure 3(a)

- (b) (i) Mention the factors affecting strength of a steel column. 5
- (ii) Explain the possible failure modes of steel compression members. 10

(c) Design vertical wall of an RCC circular water tank for Hoop Tension only. Following parameters are to be considered :

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- (i) Tank resting on ground
- (ii) Fixed at base and free at top
- (iii) Internal diameter of tank = 11.30 m
- (iv) Depth of water in the tank = 4.0 m
- (v) Grade of concrete M 25
- (vi) Grade of reinforcing bar Fe 415
- (vii) Thickness of vertical wall = 170 mm
- (viii) Diameter of bar to be used = 8 mm
- (ix) Unit weight of water  $\gamma_w = 10 \text{ kN/m}^3$
- (x)  $\sigma_{cbc} = 8.5 \text{ N/mm}^2$ ,  $\sigma_{st} = 150 \text{ N/mm}^2$ ,  $\sigma_{ct} = 1.3 \text{ N/mm}^2$ ,  $m = 11.0$

#### Hoop Tension Coefficient in Cylindrical Wall

Coefficient at Points										
$\frac{H^2}{D.t}$	0.0H	0.1H	0.2H	0.3H	0.4H	0.5H	0.6H	0.7H	0.8H	0.9H
06	+ 0.018	+ 0.119	+ 0.234	+ 0.344	+ 0.441	+ 0.504	+ 0.514	+ 0.447	+ 0.301	+ 0.112
08	- 0.011	+ 0.104	+ 0.218	+ 0.335	+ 0.443	+ 0.534	+ 0.575	+ 0.530	+ 0.381	+ 0.151
10	- 0.005	+ 0.098	+ 0.208	+ 0.323	+ 0.437	+ 0.542	+ 0.608	+ 0.589	+ 0.440	+ 0.179

- Q4. (a) Design slab panel S-1 (by Limit State Method) for flexure only, as shown in Figure 4(a). All slab panels are supported and monolithic constructed with RCC frame structure. Following are the design considerations :

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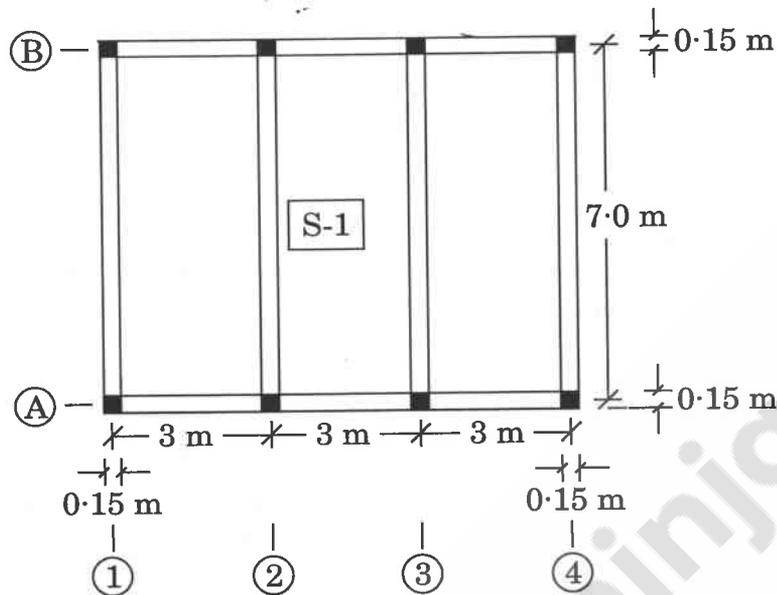


Figure 4(a)

- (i) Limit state of collapse : Flexure design only
- (ii) Live load (imposed load not fixed) :  $5.0 \text{ kN/m}^2$
- (iii) Grade of concrete : M 20
- (iv) Grade of Reinforcing bars : Fe 415
- (v) Unit weight of RCC :  $25 \text{ kN/m}^3$
- (vi) Unit weight of PCC :  $24 \text{ kN/m}^3$
- (vii) Ignore dead weight of ceiling plaster and floor finish.
- (viii) Nominal cover to reinforcement : 20 mm
- (ix) Value of partial safety factor for dead load/live load : 1.5.
- (x) Load combination : only (Dead load + Live load).
- (xi) Effective span to overall depth ratio : 26.
- (xii) Use 10 mm diameter bars for main reinforcement and 8 mm diameter bar for distribution reinforcement.
- (xiii) Total depth calculated shall be rounded off to next multiplier of 10 mm.

- (xiv) Largest calculated depth shall be used for reinforcement calculation.
- (xv) Spacing of reinforcement shall be rounded off to lower 10 mm multiplier.
- (xvi) B.M. shall be obtained from the table given below.
- (xvii)  $\frac{M_u, \text{lim}}{bd^2} = 0.1389 f_{ck}$  shall be used.
- (xviii) Percentage reinforcement  $p_t$  for M 20 and Fe 415 shall be used as

$\frac{M_u}{bd^2}$	0.9	1.0	1.1	1.2	1.25	1.3	1.35	1.4
$p_t$	0.264	0.295	0.327	0.359	0.376	0.392	0.409	0.426

IS 456 : 2000

**Table 12 Bending Moment Coefficients**  
(Clause 22.5.1)

Type of Load	Span Moments		Support Moments	
	Near Middle of End Span	At Middle of Interior Span	At Support Next to the End Support	At Other Interior Supports
(1)	(2)	(3)	(4)	(5)
Dead load and imposed load (fixed)	$+\frac{1}{12}$	$+\frac{1}{16}$	$-\frac{1}{10}$	$-\frac{1}{12}$
Imposed load (not fixed)	$+\frac{1}{10}$	$+\frac{1}{12}$	$-\frac{1}{9}$	$-\frac{1}{9}$

NOTE – For obtaining the bending moment, the coefficient shall be multiplied by the total design load and effective span.

- (b) A girder 30 m long carrying a uniformly distributed load of 'W' kN/m throughout is to be supported on two piers 18 m apart so that the greatest Bending Moment shall be as small as possible. Find the distance of the piers from the ends of the girder and the maximum Bending Moment.

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- (c) Design shear reinforcement (limit state of collapse : shear only) and apply all necessary checks for doubly reinforced beam shown below in Figure 4(c).

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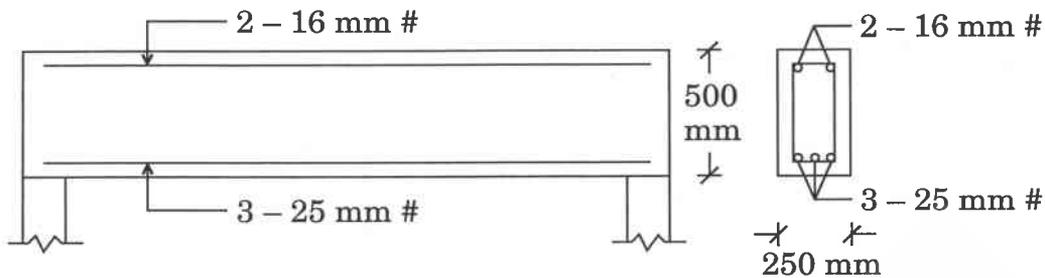


Figure 4(c)

Also sketch the shear reinforcement.

The following parameters may be used :

- (i) Effective simply support span : 5.0 m
- (ii) Total characteristic load (DL + LL) : 40 kN/m
- (iii) Partial safety factor for loads : 1.5
- (iv) Grade of concrete : M 20
- (v) Grade of Reinforcement : Fe 415
- (vi) Total effective cover : 50 mm
- (vii) Diameter of Shear Reinforcement : 8 mm
- (viii) Shear Reinforcement arrangement : vertical stirrups

$$(ix) \quad V_{us} = \frac{0.87 f_y \cdot A_{sv} \cdot d}{s_v}$$

(x)	$p_t$	1.22	1.26	1.30	1.34	1.38	1.42
	$\tau_c$ N/mm <sup>2</sup>	0.668	0.675	0.683	0.690	0.697	0.703

## SECTION B

- Q5.** (a) Water flows steadily through the piping junction, entering section ① at  $0.12 \text{ m}^3/\text{min}$ . The average velocity at the section ② is  $2.2 \text{ m/sec}$ . A portion of the flow is diverted through the showerhead, which contains 100 holes of  $1 \text{ mm}$  diameter. Assuming uniform shower flow, estimate the exit velocity from the showerhead jets. Take density of water =  $1000 \text{ kg/m}^3$ . (Please refer Figure 5(a))

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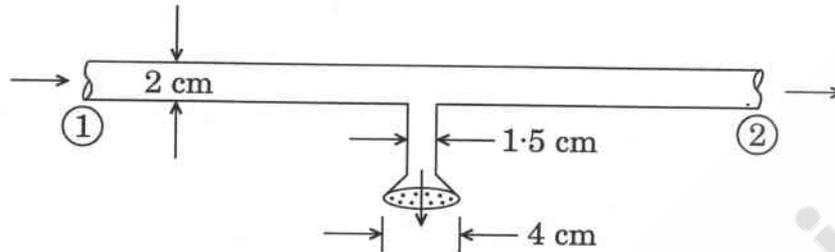


Figure 5(a)

- (b) A pump has a performance curve described by the relation
- $$h_p = 13 - 0.15 Q^2$$
- where  $h_p$  is in m and  $Q$  is in L/s. Answer the following :
- (i) What is the performance curve relation for a system having three of these pumps in series ?
  - (ii) What is the performance curve relation for a system having three of these pumps in parallel ?
- (c) A falling head permeameter test was conducted with a soil sample of  $20.0 \text{ cm}$  length and of  $6.0 \text{ cm}$  diameter in the laboratory. The soil sample was made of four layers, each having the same depth of  $5.0 \text{ cm}$  but of varying hydraulic conductivity. The hydraulic conductivity ( $K$ ) of first, second, third and fourth layers were observed as  $1.5 \times 10^{-4} \text{ cm/s}$ ,  $3 \times 10^{-4} \text{ cm/s}$ ,  $4.5 \times 10^{-4} \text{ cm/s}$  and  $6.0 \times 10^{-4} \text{ cm/s}$  respectively. If the flow is taking place perpendicular to the layers of the soil sample and the cross-sectional area of the standpipe is  $2.0 \text{ cm}^2$ , determine the time required for a drop of head from  $30 \text{ cm}$  to  $15 \text{ cm}$ .
- (d) The void ratio of clay "A" decreased from  $0.572$  to  $0.505$  under a change in pressure from  $1.22$  to  $1.8 \text{ kg/cm}^2$  due to building construction. The void ratio of another clay "B" at a different site decreased from  $0.61$  to  $0.557$  under the same increment of pressure due to the same type of construction. The thickness of clay layer "A" was  $1.5$  times that of "B"; nevertheless the time taken for  $50\%$  consolidation was  $3$  times larger for "B" than for "A". What would be the ratio of hydraulic conductivity  $K_A / K_B$  ?

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- (e) A footing of 1.5 m diameter carries a safe load (including its self-weight) of 750 kN in cohesionless soil. The soil has an angle of shearing resistance  $\phi = 35^\circ$  and a unit weight of  $18 \text{ kN/m}^3$ . Determine the depth of foundation for a factor of safety ( $F_s$ ) of 2.5. Use Terzaghi theory and assume the water table is close to the ground surface.

[Take  $N_\gamma = 42.4$  and  $N_q = 41.4$  for  $\phi = 35^\circ$ ]

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- Q6. (a) A concrete retaining wall shown in Figure 6(a) is satisfying Rankine's condition. Check the stability of retaining wall with respect to (a) Overturning, (b) Sliding, and (c) Bearing Capacity. Neglect the passive earth pressure. Unit weight of concrete is  $24 \text{ kN/m}^3$ . Force resisting the horizontal movement of retaining wall can be determined from  $F_R = 0.55 (C)(B) + \sum V \tan \delta$ .

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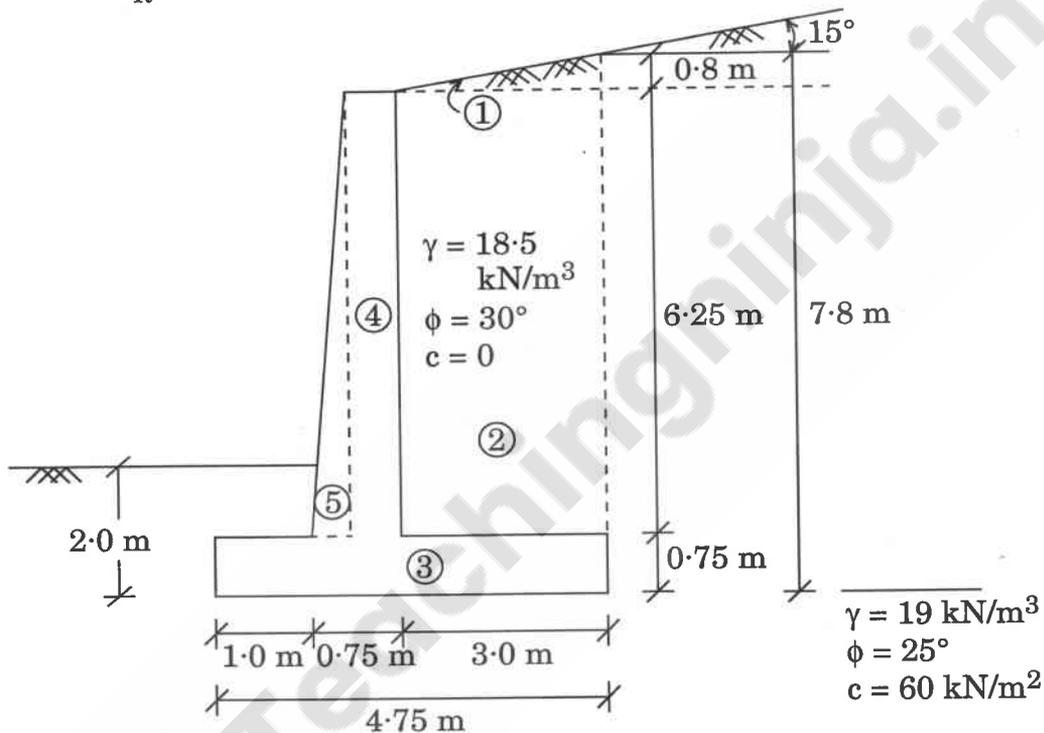


Figure 6(a)

Element	Area ( $\text{m}^2$ )	Lever Arm (m)
1	1.20	3.75
2	18.75	3.25
3	3.56	2.38
4	3.13	1.50
5	0.70	1.17

- (b) Water flows through a horizontal 60 mm diameter galvanized iron pipe at a rate of 20 l/s. If the pressure drop is 135 kPa per 10 m length of pipe, determine whether the pipe is new or is it an old pipe ? Justify your answer with appropriate calculations and necessary assumptions. Take average height of protrusions  $K = 0.15$  mm for a new galvanised iron pipe, kinematic viscosity  $\nu = 1.12 \times 10^{-6}$  m<sup>2</sup>/sec, and density of water  $\rho = 1000$  kg/m<sup>3</sup>. If required you can use Swamee-Jain explicit relationship for the friction factor ( $f$ ) as given below :

$$f = \frac{0.25}{\left[ \log_{10} \left( \frac{K}{3.7 D} + \frac{5.74}{(Re)^{0.9}} \right) \right]^2} \quad 15$$

- (c) A test is to be performed on a proposed design for a large pump that is to deliver 2.0 m<sup>3</sup>/sec of water from a 40 cm diameter impeller with a pressure rise of 400 kPa. A model with an 8 cm diameter impeller is to be used. What flow rate should be used and what pressure rise is to be expected in the model ? The model fluid is water at the same temperature as the water in the prototype. 10

- Q7.** (a) A 4 m deep sand layer (sp. gravity,  $G = 2.66$ , void ratio,  $e = 0.52$ ) overlies a thick bed of clay (specific gravity,  $G = 2.75$ , void ratio,  $e = 1.0$ ). Calculate the total stress, pore water pressure and effective stress at a depth of 8.0 m below the ground surface for the following cases :

- (i) If the water table is at the ground level.  
 (ii) If the water table is at 2.0 m below ground level and sand above water table has the degree of saturation as 50%. 15

- (b) For a highway embankment, soil is to be taken from a borrow pit having in-situ moist unit weight of a soil as 17 kN/m<sup>3</sup> at a moisture content of 16%. The specific gravity of soil is 2.67. This soil is to be excavated and transported to a construction site for use in a compacted fill. During excavation and dumping of soil in trucks, the soil increases in volume by 10%. If the specification calls for the soil to be compacted to a bulk unit weight of 18 kN/m<sup>3</sup> at the moisture content of 21%, how many cubic meters of soil from the excavation site are needed to produce 1000 m<sup>3</sup> of compacted fill ? Find the weight of additional water required to produce this 1000 m<sup>3</sup> of compacted fill. 10

- (c) A 4 m long quarter-circular gate of radius 3 m and negligible weight is hinged about its upper edge A as shown in Figure 7(c). The gate controls the flow of water over the edge at B, where the gate is pressed by a spring. Determine the minimum spring force required to keep the gate closed when the water level rises to A at the upper edge of the gate. Assume the density of water to be  $1000 \text{ kg/m}^3$  throughout.

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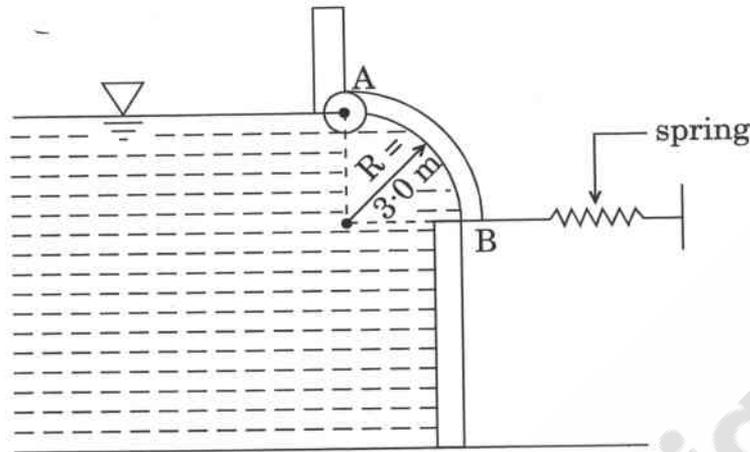


Figure 7(c)

- Q8. (a) A 600 mm diameter pile is to be installed at a site that is characterized by two sand layers. The top layer is 12 m thick, has a  $\gamma_t = 20 \text{ kN/m}^3$  and a  $\phi = 30^\circ$ . The bottom layer is 20 m thick, has a  $\gamma_t = 22 \text{ kN/m}^3$  and a  $\phi = 35^\circ$ . The ground water table is at the ground surface. Compute the Unit end bearing and the Unit skin friction at depths of 10, 15, 20 and 25 m below the ground surface. Use  $N_q = 20$  for  $\phi = 30^\circ$  and  $N_q = 50$  for  $\phi = 35^\circ$ . Take  $\delta = \phi$  and coefficient of earth pressure,  $K = 1.0$ , and unit weight of water,  $\gamma_w = 10 \text{ kN/m}^3$ .
- (b) A rectangular channel carries a discharge of  $1.20 \text{ m}^3/\text{sec}$  of water at a depth of  $0.80 \text{ m}$ . The width of the channel is  $1.25 \text{ m}$ . Answer the following :
- If a 25 cm wide pier is placed in the middle of the channel section, what would be the depth of flow at the constriction ?
  - What would be the minimum width of constriction that will not cause a rise in the upstream water surface ?
- (Assume that head loss between the constriction and the upstream section is neglected.)
- (c) Consider the two-dimensional incompressible velocity potential  $\phi = xy + x^2 - y^2$ . Answer the following :
- Is it true that  $\nabla^2\phi = 0$ , and, if so; what does this mean ? Explain.
  - If it exists, find the stream function  $\psi(x, y)$  of this flow.
  - Find the equation of the streamline which passes through a point  $(x, y) = (2, 1)$ .

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