

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.

Question Nos. 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.

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.

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.

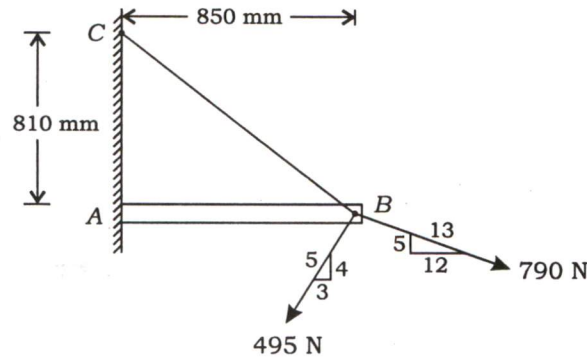
Answers must be written in ENGLISH only.

SECTION—A

1. (a) In a tension test, a steel rod of gauge length 255 mm and diameter 32 mm was used. The rod during the test was stretched 0.108 mm under a pull of 65 kN. In a torsion test, the same rod was twisted 0.018 radian over a length of 255 mm at the torque of 500×10^3 N-mm. Determine the modulus of elasticity, modulus of rigidity, Poisson's ratio and bulk modulus.

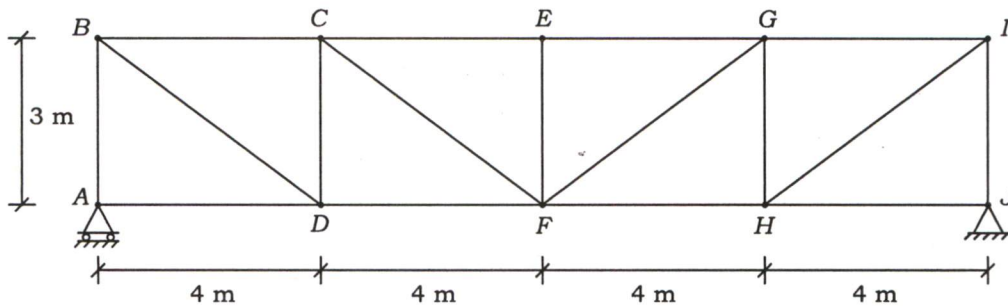
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- (b) The tension in cable BC is 750 N. Determine the resultant of the three forces exerted at point B of the beam AB :



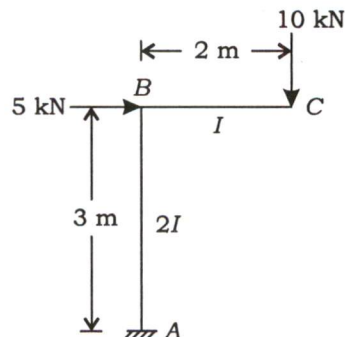
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- (c) Determine the vertical movements of joint C of the truss shown in the figure below, if the member FG is lengthened by 55 mm. Use the principle of virtual work :



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- (d) Using the unit load method, determine the vertical and horizontal deflection of the free end of the frame as shown in the figure below. Support A is fixed, B is rigid joint and point C is free. $BC = I$ and $BA = 2I$. Take $E = 210$ GPa and $I = 300 \times 10^{-6} \text{ m}^4$:



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- (e) With the help of neat sketches, explain the stress concept and load-balancing concept of prestressing.

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2. (a) Design a slab base for a column ISHB 300 @ 577 N/m carrying an axial factored load of 1200 kN and a factored bending moment of 30 kN-m about its major axis. M-20 grade concrete is used for the foundation. Provide welded connection between the column and base plate. Assume that the ends of the column are properly machined. Use Fe-410 grade steel. Take bearing strength of concrete = $0.45 f_{ck}$. The design bending strength of the base plate may be taken as $M_d = 1.2 Z_e \frac{f_y}{\gamma_{m0}}$, where Z_e is the elastic section modulus of the cross-section.

The properties of ISHB 300 @ 577 N/m are as under :

Depth = 300 mm

Width of flange = 250 mm

Thickness of flange = 10.6 mm

Thickness of web = 7.6 mm

Sectional area = 7484.95 mm²

$I_{zz} = 12545.2 \text{ cm}^4$

$I_{yy} = 2193.6 \text{ cm}^4$

$r_{zz} = 129.5 \text{ mm}$

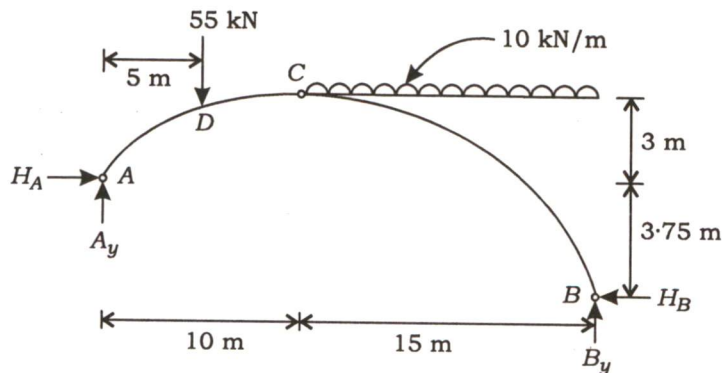
$r_{yy} = 54.1 \text{ mm}$

For Fe-410 grade steel : $f_u = 410 \text{ N/mm}^2$, $f_y = 250 \text{ N/mm}^2$

Take $\gamma_{m0} = 1.1$ and $\gamma_{mw} = 1.25$

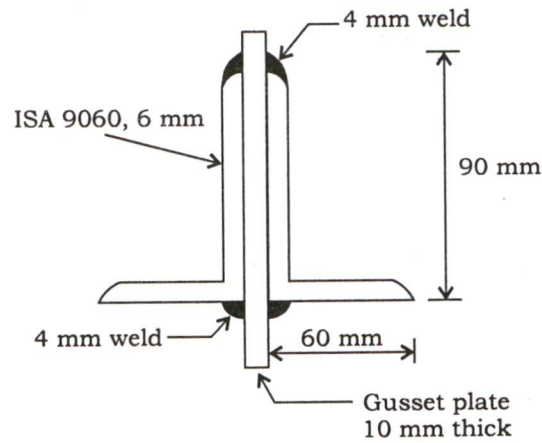
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- (b) A three-hinged parabolic arch of constant cross-section is subjected to uniformly distributed load over a part of its span and a concentrated load of 55 kN as shown in the figure below. Determine the horizontal thrust and the maximum bending moment in the arch :



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- (c) Determine the tensile strength of a roof truss member made of 2 ISA 9060, 6 mm and connected to the gusset plate of 10 mm thickness by 4 mm weld as shown in the figure below. The effective length of the weld is 250 mm. Steel used is of Fe-410 grade quality. Use the limit state method of design :



Given : $\gamma_{m0} = 1.1$ and $\gamma_{m1} = 1.25$

For ISA 9060, 6 mm : $A_g = 865 \text{ mm}^2$

For Fe-410 : $f_u = 410 \text{ N/mm}^2$, $f_y = 250 \text{ N/mm}^2$

Formulae :

$$T_{dg} = \frac{A_g f_y}{\gamma_{m0}}$$

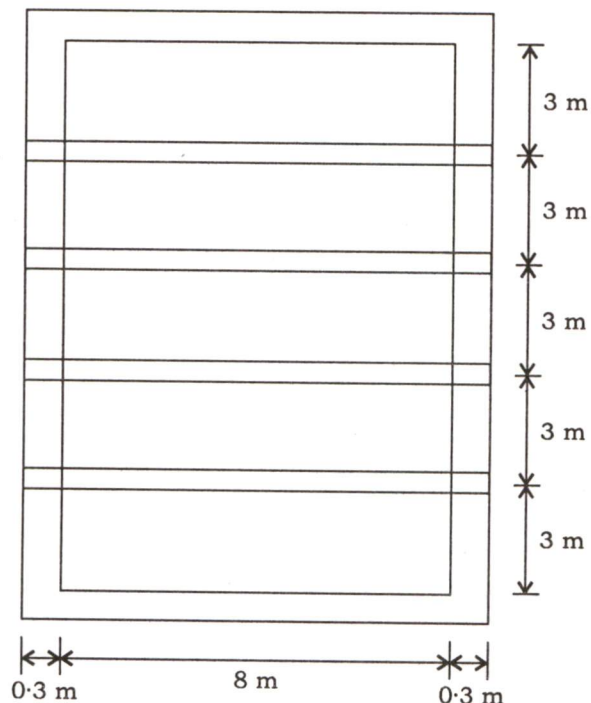
$$T_{dn} = \frac{0.9 f_u A_{nc}}{\gamma_{m1}} + \frac{\beta A_{g0} f_y}{\gamma_{m0}}$$

$$\text{where } \beta = 1.4 - 0.076 \left(\frac{w}{t} \right) \left(\frac{f_y}{f_u} \right) \left(\frac{b_s}{L_w} \right) < \left(\frac{f_u}{f_y} \frac{\gamma_{m0}}{\gamma_{m1}} \right) > 0.7$$

$$T_{db1} = \frac{A_{vg} f_y}{\sqrt{3} \gamma_{m0}} + \frac{0.9 A_{tn} f_u}{\gamma_{m1}}$$

$$T_{db2} = \frac{0.9 A_{vn} f_u}{\sqrt{3} \gamma_{m1}} + \frac{A_{tg} f_y}{\gamma_{m0}}$$

3. (a) The roof of a hall measuring $8\text{ m} \times 15\text{ m}$ consists of 100 mm thick reinforced concrete slab supported on steel I-beams spaced at 3 m apart as shown in the figure below. The finishing load is 1.5 kN/m^2 and live load is 1.5 kN/m^2 . ISMB 400 is readily available. Check the adequacy of the ISMB 400 for use as beam in the hall. The permissible deflection for the beam is $(l_e/300)$.



The properties of ISMB 400 are as under :

Depth of section, $h = 400\text{ mm}$

Width of flange, $b = 140\text{ mm}$

Sectional area, $A = 7845.58\text{ mm}^2$

Thickness of flange, $t_f = 16.0\text{ mm}$

Thickness of web, $t_w = 8.9\text{ mm}$

Depth of web, $d(=h_1) = 333.4\text{ mm}$

$I_{zz} = 20458.4 \times 10^4\text{ mm}^4$

$I_{yy} = 622.1 \times 10^4\text{ mm}^4$

$Z_p = 1176.163 \times 10^3\text{ mm}^3$

Weight of section = 0.604 kN/m

For steel : $f_y = 250\text{ N/mm}^2$, $f_u = 410\text{ N/mm}^2$, $\gamma_{m0} = 1.1$

Formulae :

$$\epsilon = \left(\frac{250}{f_y} \right)^{1/2} ; \quad V_d = \frac{A_v f_{yw}}{\sqrt{3}} \times \frac{1}{\gamma_{m0}}$$

For $\frac{d}{t_w} < 67\epsilon$ and $V \leq 0.6V_d$

$$M_d = \frac{\beta_b Z_p f_y}{\gamma_{m0}} < \frac{1.2 Z_e f_y}{\gamma_{m0}} \text{ (for simply supported beam)}$$

Ratio	Class of section		
	Plastic	Compact	Semi-compact
b/t_f	9.4ϵ	10.5ϵ	15.7ϵ
d/t_w	84ϵ	105ϵ	126ϵ

For plastic section, $\beta_b = 1.0$

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- (b) Design an RCC circular water tank with flexible base for a capacity of 500 kL. The depth of water is to be 4 m, including a freeboard of 0.2 m. The tank is resting on the ground and is open at the top. Use M-25 grade concrete and Fe-415 grade steel. The reinforcement bars of 20 mm ϕ , 10 mm ϕ and 8 mm ϕ are available.

Take unit weight of water = 10 kN/m³

For M-25 concrete : $\sigma_{cbc} = 8.5 \text{ N/mm}^2$, $\sigma_{ct} = 1.3 \text{ N/mm}^2$

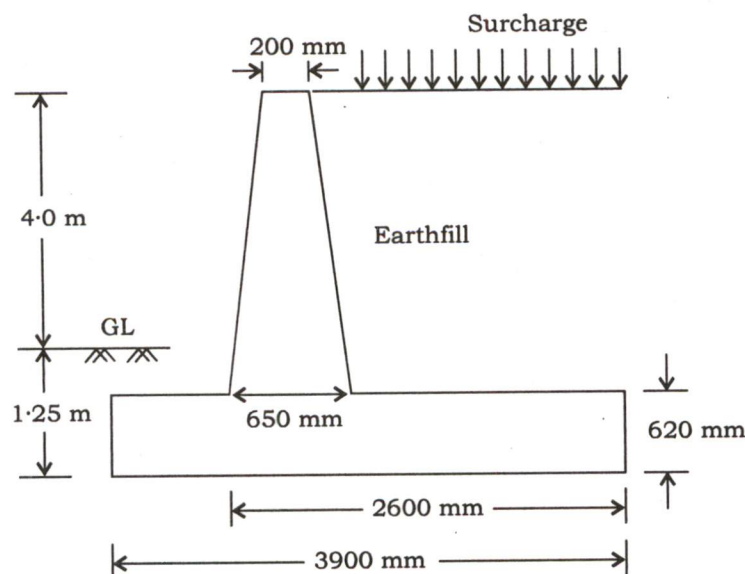
For Fe-415 steel : $\sigma_s = 150 \text{ N/mm}^2$

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- (c) A thick spherical shell having internal diameter of 150 mm is subjected to an internal fluid pressure of 25 N/mm². If the maximum hoop stress is 100 MPa, determine the thickness of the spherical shell.

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4. (a) An RCC cantilever retaining wall is used to retain a level earthfill of 4.0 m above the ground level. Due to construction of a building, there is a surcharge of 40 kN/m² on the earthfill. A good soil for foundation is at a depth of 1.25 m below the ground level with a safe bearing capacity of 160 kN/m². The unit weight and the angle of repose of the soil are 16 kN/m³ and 30° respectively. Assume the coefficient of friction between soil and concrete to be 0.50. The initial proportioning of the retaining wall is shown in the figure below :



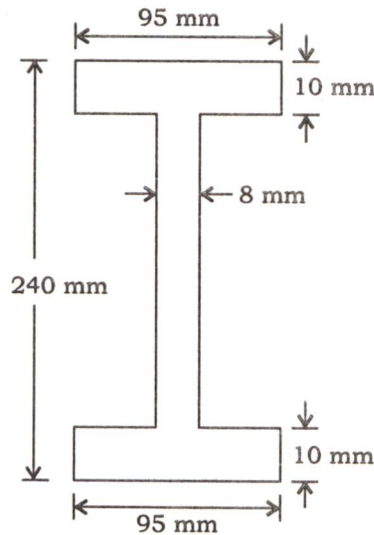
- (i) Check whether shear key is required. Ignore the passive pressure.
(ii) Design the stem of the retaining wall.

Use M-20 grade concrete and Fe-415 grade steel.

$\frac{100 A_s}{bd}$	τ_c for M-20 (N/mm ²)
0.25	0.36
0.50	0.48
0.75	0.56
1.00	0.62

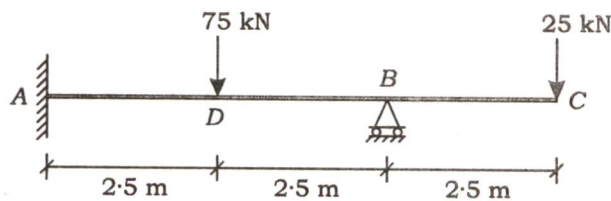
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- (b) Determine the plastic moment capacity and the shape factor of the I-section shown in the figure below, if the value of the yield stress is 300 MPa :



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- (c) Using the consistent deformation method, analyze the beam shown in the figure below. Take EI is constant throughout :



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SECTION—B

5. (a) A centrifugal pump is installed at a height of 3.0 m from water surface. The atmospheric pressure is 101 kPa, vapour pressure is 2.58 kPa, inlet and other losses in suction pipe are 1.96 m, manometric head of the pump is 49.2 m and Thomas cavitation parameter, $\sigma = 0.120$. Check whether cavitation develops in the pump or not. What is the preferable height of the pump above water surface in order to avoid cavitation?

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- (b) An aircraft is travelling at a speed of 350 kmph against a wind velocity of 25 kmph. A Pitot static tube is mounted on the aircraft to measure the pressure. If the specific weight of air is 12 N/m^3 and coefficient of velocity of the Pitot tube = 0.98, determine the pressure difference recorded in the instrument.

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- (c) At a particular site, the ground surface is at El. 0.0 m and the groundwater level is at El. (-)10.0 m. The degree of saturation, S , above the water table decreases towards the ground surface. The decrease in S is linear and continuous towards the surface. However for this problem, it can be treated as two zones of different average degree of saturation, S , as given below :

$$\text{El. } 0.0 - (-)5.0 \text{ m} \quad S = 25\%$$

$$\text{El. } (-)5.0 - (-)10.0 \text{ m} \quad S = 75\%$$

The soil has a void ratio, $e = 0.4$ and specific gravity, $G_s = 2.7$. Determine the total stress and effective stress at El. (-)20.0 m. Assume unit weight of water, $\gamma_w = 9.81 \text{ kN/m}^3$.

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- (d) Define major principal stress, minor principal stress and deviator stress. A sample of dry cohesionless soil has an angle of internal friction of approximately 35° . If the minor principal stress is 105 kPa, at what value of deviator stress and major principal stress is the sample likely to fail?

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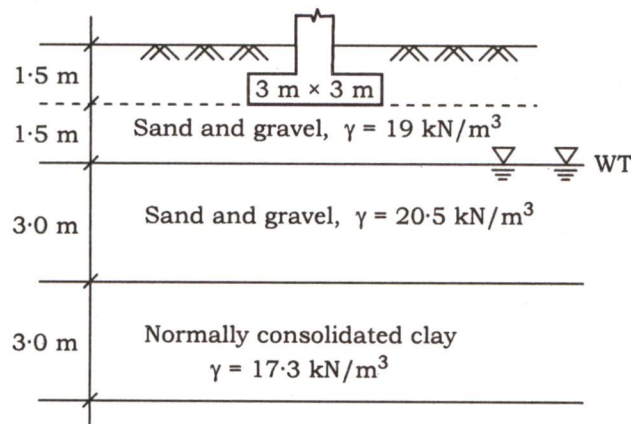
- (e) A precast concrete pile $300 \text{ mm} \times 300 \text{ mm}$ in cross-section is driven into a medium stiff clay and it is to carry a load of 300 kN. The unconfined compressive strength of the clay is 100 kN/m^2 . If the adhesion factor, $\alpha = 0.5$ and a factor of safety of 2 is desired for the safety of the structure, determine the depth of penetration required for the pile to carry the above load of 300 kN. Also determine the allowable load capacity of a circular pile of equivalent cross-sectional area and same length with the same factor of safety of 2. Finally comment on the result.

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6. (a) A sample of normally consolidated clay was obtained from the mid-height of a compressible clay layer as shown in the figure below. A consolidation test was conducted on a portion of this sample. The results of the consolidation test are as follows :

p (kPa)	80	160	320	640	1280
e	1.50	1.42	1.30	1.12	0.94

The natural void ratio (initial, e_0) of the clay existing in the field is 1.65. A footing is to be located at 1.5 m below the ground level as shown in the figure below. The base of the footing is 3 m $\times$ 3 m and it exerts a total load of 2500 kN. Plot a e -log p curve using the pressure void ratio data and determine the compression index, C_c . Also determine the total expected consolidation settlement of the clay layer. Assume unit weight of water, $\gamma_w = 9.81 \text{ kN/m}^3$:



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- (b) (i) A hemispherical bowl of radius 1.60 m is full of water and is rotated about its vertical axis at 25 r.p.m. Calculate the amount of water that will overflow due to rotation of the bowl with that speed.

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- (ii) If the velocity potential for a two-dimensional flow is given by $\phi = x(2y - 3)$, determine the velocity at point $N(2, 3)$ and find the stream function and check whether the flow is irrotational or not.

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- (c) A rectangular channel having 2.0 m width carries uniform flow of water at a depth of 1.6 m. The velocity of the flow is 0.80 m/s. If there is a bump of 34 cm raise in the bed and the bump is covering full width of the channel bed, find the change in upstream depth of flow. What is the maximum raise in the bump in the bed that will be permissible so that there is no change in the upstream depth of flow? Assume that the head loss between the bump and upstream section is neglected.

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7. (a) What are the differences between general shear failure and local shear failure in shallow footing? Where do they occur? A load test was made with a 300 mm square plate at a depth of 1.0 m below the ground level in a clayey soil. The water table was located at a depth of 1.5 m below the ground level. The failure occurred at a load of 52 kN. What would be the ultimate bearing capacity for a 1.5 m wide continuous footing with its base located at the same depth in the same soil? Assume unit weight of the soil, $\gamma = 18.6 \text{ kN/m}^3$ both above and below the water table. 15
- (b) What is 'negative skin friction'? What are the reasons that could lead to the development of 'negative skin friction' in a pile foundation? Explain with the help of neat sketches. How is 'negative skin friction' estimated for a single pile? 10
- (c) (i) A Pelton turbine works under a head of 260 m and develops a power of 5820 kW. Its revolving speed is 240 r.p.m. The overall efficiency of the turbine is 80%. Find the unit discharge, unit power and unit speed. Assume that the efficiency is constant under different heads. If the head on the same turbine falls down to 130 m, find the unit quantities for discharge, power and speed for this head. 10
- (ii) Explain the various functions of draft tube in reaction turbines and define the efficiency of the draft tube. Write the equation for draft tube efficiency. 5
8. (a) Four footings carrying an overhead tank are placed on the ground with the base of the footing close to the ground level. The centers of these footings form a square of 8 m sides and each of them carries a load of 600 kN. Calculate the vertical stress due to the footing loads by Boussinesq's point load equation at a depth 5 m (i) vertically below the center of any of the footings and (ii) vertically below the center of square joining the center of the footing. 15
- (b) (i) Explain boundary layer separation along with figure and also explain the methods of controlling the boundary layer. 5
- (ii) A notch is provided at the top of one of the sides of a steel tank. The horizontal area of cross-section of the tank is 2.20 m^2 . Water is flowing into the tank at a constant rate and is discharging over the notch steadily. The head over the crest of the notch at steady state is 0.35 m. When the supply of water into the tank was suddenly stopped, it was observed that the head over the crest started to fall at the rate of 4.80 mm/s. When the head over the notch had fallen to 0.19 m, it was observed that the head over the notch was falling at the rate of 2.1 mm/s. Estimate the rate of flow into the tank when there is steady head of 0.28 m over the notch. Assume the discharge equation of the notch as $Q = CH^n$. 10

- (c) Water is flowing through a pipe of 10 m length and 100 mm diameter. The velocity of the flow of water is 2.8 m/s. If the central 4.0 m length of the pipe is replaced by 150 mm diameter pipe, find the savings in loss of head and the corresponding power. The change of section is sudden. Take coefficient of friction, $f = 0.05$ for both the pipes.

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