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Important Questions *for* GATE 2022

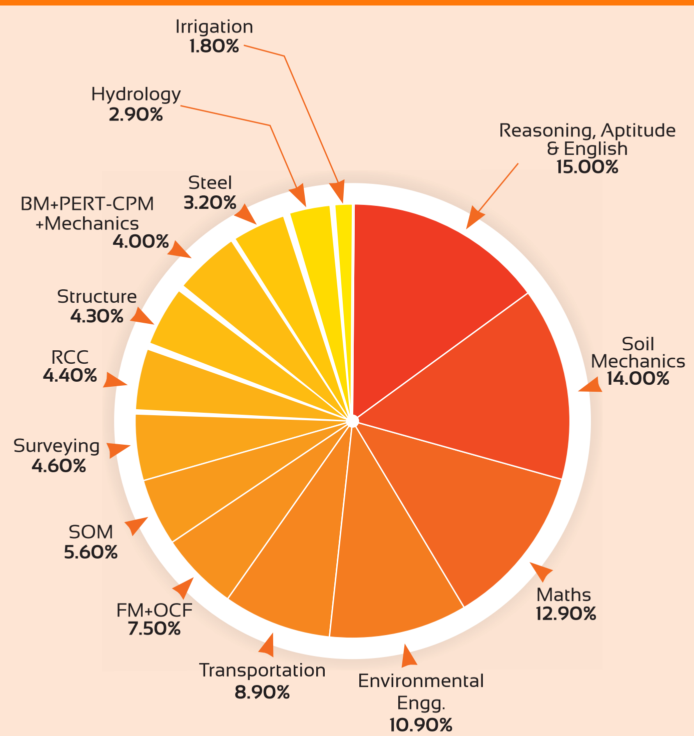
CIVIL ENGINEERING

Day 6 of 8

Q.126 - Q.150 (Out of 200 Questions)

Fluid Mechanics + Structural Analysis

SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



Subject	Average % (last 5 yrs)
Reasoning, Aptitude and English	15.00%
Soil Mechanics	14.00%
Engineering Mathematics	12.90%
Environmental Engineering	10.90%
Transportation Engineering	8.90%
Fluid Mechanics + OCF	7.50%
Strength of Materials	5.60%
Surveying Engineering	4.60%
Reinforced Cement Concrete	4.40%
Structural Analysis	4.30%
Building Materials+PERT-CPM+Mechanics	4.00%
Steel Structures	3.20%
Engineering Hydrology	2.90%
Irrigation Engineering	1.80%
Total	**100%**

Fluid Mechanics + Structural Analysis

Q.126 A model of harbour has a length scale of $\frac{1}{100}$. Storm waves of velocity, 10 m/s strike against the break water of the prototype harbour. The velocity of wave in the model is __________ m/s.

Q.127 A smooth flat plate with a sharp leading edge is placed at zero incidence in a free stream of water flowing at 2.5 m/s. The thickness of boundary layer at transition from laminar to turbulent is [Take dynamic viscosity of water as 1 centipoise]

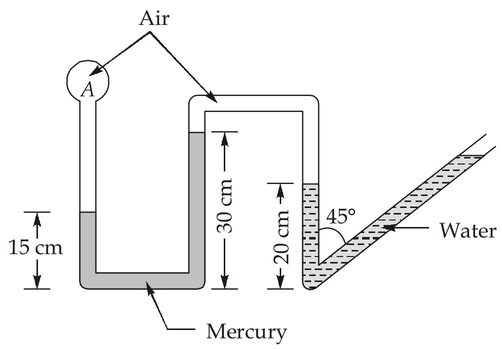
(a) 4.62 mm
(b) 1.414 mm
(c) 0.23 mm
(d) 1.328 mm

Q.128 A rectangular channel is carrying water which is provided with a hydraulic jump type of energy dissipator. It is desired to have an energy loss of 3 m in hydraulic jump when inlet Fraud number is 5.292. Sequent depth after jump is __________ m.

Q.129 A reducer bend having an outlet diameter of 15 cm discharge freely. The bend, connected to a pipe of 20 cm, has a deflection of 60° and lies in a vertical plane such that freely discharging end is 2 m above the centre line of pipe. Determine magnitude and direction of force with positive x-axis respectively on the anchor block supporting the pipe when a discharge of 0.3 m^3/s passes through the pipe.

(a) 5975.43 N, θ = 312.42°
(b) 5520.61 N, θ = 251.42°
(c) 5975.43 N, θ = 47.58°
(d) 5520.61 N, θ = 68.2°

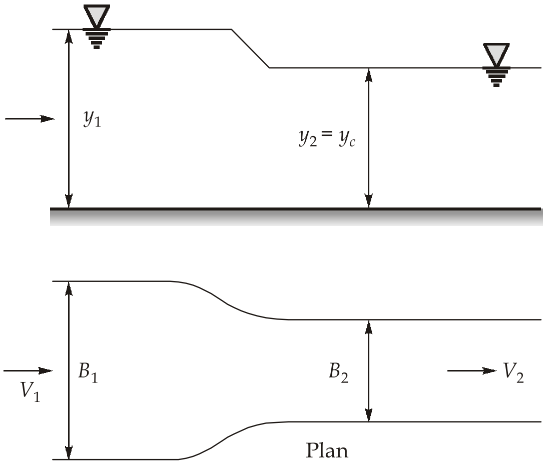
Q.130 In the shown figure, if pressure at A is, 125 kPa then length of limb is



[Take g = 10 m/s^2, and ρ_{air} = 0]

(a) 74.60 cm
(b) 17.67 cm
(c) 149.05 cm
(d) 48.58 cm

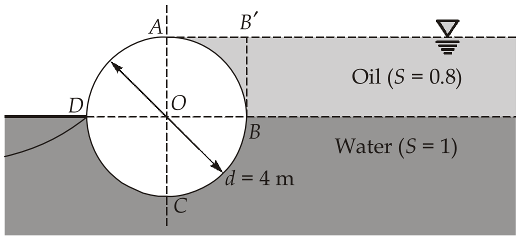
Q.131 A rectangular channel is 3 m wide and carries a flow of 3.25 m^3/s at a depth of 1 m. A contraction of the channel width is proposed at a certain section as shown in figure. The smallest allowable contracted width that will not affect the upstream flow condition is __________ m.



Q.132 A triangular channel of side slopes of 1.5 H : 1V has a longitudinal slope of 0.0004 and Manning's coefficient, n = 0.022. When the discharge through the section is 2 m^3/s, the water slope magnitude relative to the horizontal at the section of 1.2 m depth of flow is __________ $\times 10^{-3}$.

Q.133 In a rectangular channel 3.5 m wide laid at a slope of 0.0036, uniform flow occurs at a depth of 2 m. The hump can be raised maximum upto _________ (in m, upto two decimal places) without causing afflux.

Q.134 The figure shows a cylinder of 4 m diameter in equilibrium. Calculate the resultant pressure force acting on $ABCD$ [Take : γ_w = 10 kN/m^3]



Q.135 Water from a main canal is siphoned to a branch canal over an embankment by means of wrought iron pipes of 9 cm diameter. The length of pipe upto the summit is 25 m and the total length is 65 m. Water surface elevation in the branch canal is 10 m below the main canal. The number of pipes of 9 cm dia. are required to convey a total discharge of 90 l/sec. is

Q.136 The velocity along the centerline of a nozzle of length L is given by $V = t^2\left(1 - \frac{x}{L}\right)^2$

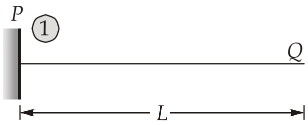
where, V = Velocity, t = time (in sec), L = 1 m

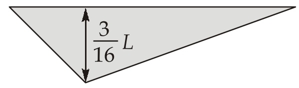
The convective acceleration at $x = \frac{L}{2}$, t = 4 sec is _________ m/s^2.

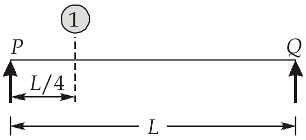
Q.137 A hydraulically most efficient transpezoidal section carries 2 m^3/s water at a depth of flow 1.2 m. If Manning's n is 0.015 then slope of the channel is __________ $\times 10^{-4}$.

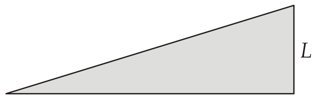
Q.138 Match **List-I** (Beam) with **List-II** (Influence line for BM) and select the correct answer using the codes given below the lists:

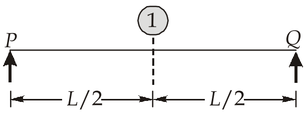
List-I | **List-II**

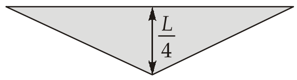
A.


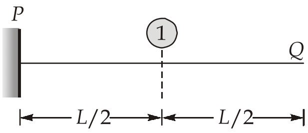
1.


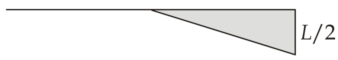
B.


2.


C.


3.


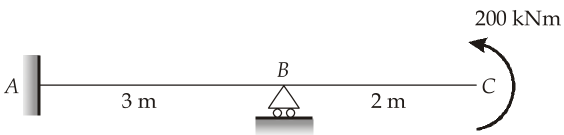
D.


4.


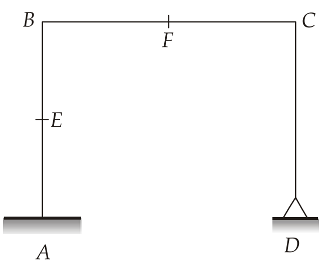
Codes:

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

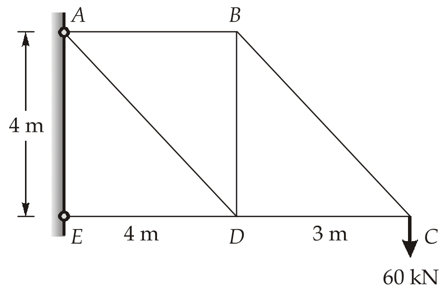
Q.139 A propped cantilever of uniform flexural rigidity is loaded as shown in figure below. The magnitude of bending moment at fixed end A is __________ kNm.



Q.140 A vertical downward load of 40 kN acting at F in the portal frame shown in figure below produces a horizontal deflection of 2 mm at E towards left and a clockwise rotation of 0.1 radian at D. The vertical deflection at F due to a horizontal load of 20 kN at E towards right and an anticlockwise moment of 1.6 kNm acting at D is __________ mm upward.

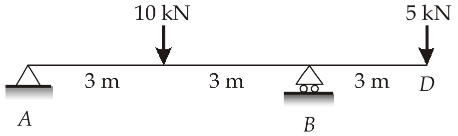


Q.141 The cross sectional area of member *DE* in the truss shown below is 1500 mm^2 and E = 200 kN/mm^2. The horizontal deflection of point *D* in the truss, due to the vertical load of 60 kN acting in the truss, is __________ mm in compression.

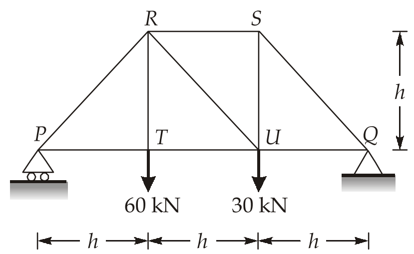


Q.142 A symmetrical semicircular three-hinged arch of span 20 m carries a udl of 60 kN/m on the left half of the span. The value of normal thrust at a section 4 m from the left support is ________ kN.

Q.143 For the overhanging beam as shown in figure below, the slope at *A* is $\frac{P}{EI}$ radian, where $|P|$ is ________. *EI* is constant throughout the beam having unit kNm^2.



Q.144 Consider a loaded truss shown in the given figure.



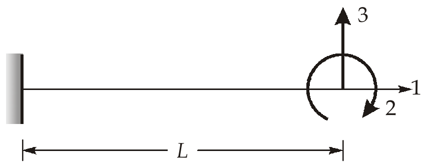
Match **List-I** (Member) with **List-II** (Force) and select the correct answer using the codes below the lists:

List-I	List-II
A. *PR*	**1.** 40 kN (Tension)
B. *RS*	**2.** 40 kN (Compression)
C. *SU*	**3.** 60 kN (Tension)
D. *RT*	**4.** $50\sqrt{2}$ kN (Compression)

Codes:

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

Q.145 What is the stiffness matrix for a prismatic cantilever with coordinates as shown in figure below?



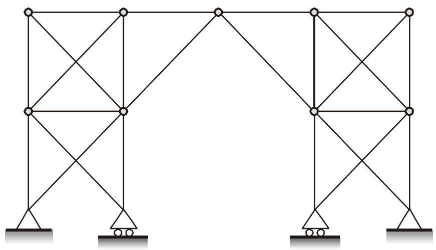
(a) $\begin{bmatrix} \frac{AE}{L} & 0 & 0 \\ 0 & \frac{4EI}{L} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{12EI}{L^3} \end{bmatrix}$

(b) $\begin{bmatrix} 0 & 0 & \frac{AE}{L} \\ 0 & \frac{4EI}{L} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{12EI}{L^3} \end{bmatrix}$

(c) $\begin{bmatrix} \frac{AE}{L} & \frac{4EI}{L} & 0 \\ 0 & 0 & 0 \\ 0 & \frac{6EI}{L^2} & \frac{4EI}{L} \end{bmatrix}$

(d) $\begin{bmatrix} \frac{AE}{L} & \frac{4EI}{L} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & 0 \\ 0 & \frac{6EI}{L^3} & \frac{12EI}{L^3} \end{bmatrix}$

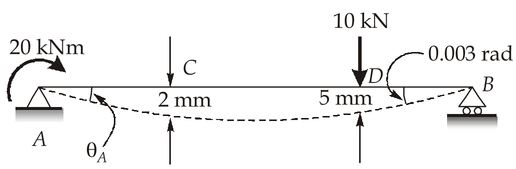
Q.146 The degree of static indeterminacy of the pin jointed compound frame shown in figure below is



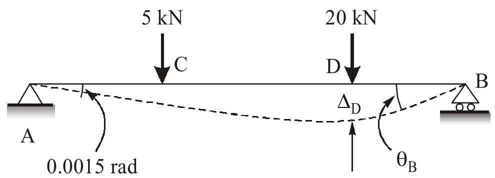
(a) 3
(b) 4
(c) 5
(d) 6

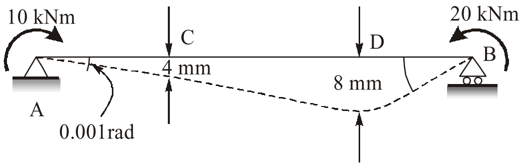
Q.147 Three system of forces and displacement for a simply supported beam are shown in figure below:

(I)



(II)

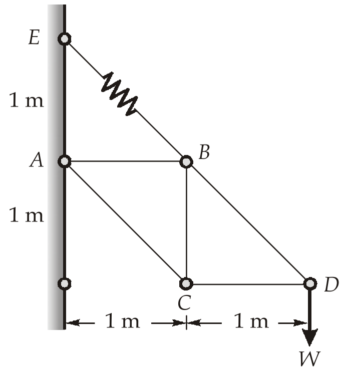


(III) 

The unknown displacements θ_A and Δ_D, respectively are

(a) 0.004 rad, 4 mm
(b) 0.008 rad, 2 mm
(c) 0.002 rad, 8 mm
(d) 0.004 rad, 8 mm

Q.148 In a truss with all the pin-connected rods there is a joint *B* attached to joint *E* by a spring whose unstretched length is 1 m and whose spring constant is 4 kN/m. Neglect the weight of all the bars and the spring. The magnitude of the load *W* applied at *D* that makes *CD* horizontal is ___________ N.



Multiple Select Questions (MSQ)

Q.149 Consider the following statements:

A horizontal pipe reduces from 10 cm to 5 cm in diameter. If the pressure head at 10 cm section is 10 metres and velocity head is 1 metre, then the (assume centreline as datum)

(a) total head at any point is 11 metres
(b) pressure head at the 5 cm section is negative
(c) discharge varies proportionate to the diameter
(d) datum head at all sections is constant

Q.150 Consider the following statements in respect of critical flow in a wide rectangular channel, identify the true statement.

(a) The specific energy is minimum for a given discharge.
(b) The discharge is maximum for a given specific energy.
(c) The specific force is minimum for a given discharge.
(d) The Froude number is equal to unity.

■■■■

Detailed Explanations

126. 1 (0.9 - 1.1)

Here dynamic similarity will be governed by Froude number between the model and prototype

So, $$\frac{V_p}{\sqrt{g_p l_p}} = \frac{V_m}{\sqrt{g_m l_m}}$$

$$\Rightarrow \quad \frac{V_p}{V_m} = \sqrt{\frac{l_p}{l_m}} \qquad [\because g_p = g_m]$$

$$\Rightarrow \quad V_m = \frac{V_p}{\sqrt{100}} = \frac{10}{10} \qquad \left[\frac{l_p}{l_m} = 100\right]$$

$$= 1 \text{ m/s}$$

127. (b)

Reynold's number at transition = 5×10^5

$$\mu = 1 \times 10^{-2} \text{ poise} = 1 \times 10^{-3} \text{ Nsec/m}^2$$

$$\Rightarrow \quad R = \frac{\rho v x}{\mu} = 5 \times 10^5$$

$$\Rightarrow \quad \frac{1000 \times 2.5 \times x}{1 \times 10^{-3}} = 5 \times 10^5$$

$$\Rightarrow \quad x = 0.2 \text{ m}$$

Thickness of boundary layer can be determined as

$$\frac{\delta}{x} = \frac{5}{\sqrt{\text{Re}_x}}$$

$$\Rightarrow \quad \frac{\delta}{0.2} = \frac{5}{\sqrt{5 \times 10^5}}$$

$$\Rightarrow \quad \delta = 1.414 \times 10^{-3} \text{ m} = 1.414 \text{ mm}$$

128. 2.72 (2.6 to 2.8)

We know,

$$\frac{y_2}{y_1} = \frac{-1 + \sqrt{8F_1^2 + 1}}{2}$$

$$\Rightarrow \quad \frac{y_2}{y_1} = \frac{-1 + \sqrt{8 \times 5.292^2 + 1}}{2} \qquad (F_1 = 5.292)$$

$$\frac{y_2}{y_1} = \frac{-1 + 15}{2} = 7$$

Also, $$E_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$

$$\Rightarrow \qquad 3 = \frac{y_1\left(\frac{y_2}{y_1}-1\right)^3}{4\left(\frac{y_2}{y_1}\right)}$$

$$\Rightarrow \qquad 3 = \frac{y_1(7-1)^3}{4\times 7}$$

$$y_1 = 0.389 \text{ m}$$

$$\therefore \qquad y_2 = 7 \times 0.389 = 2.72 \text{ m}$$

129. **(a)**

Consider the control volume as shown by the dotted line in the accompanying figure.

At section 2 : p_2 = 0 = atmospheric pressure.

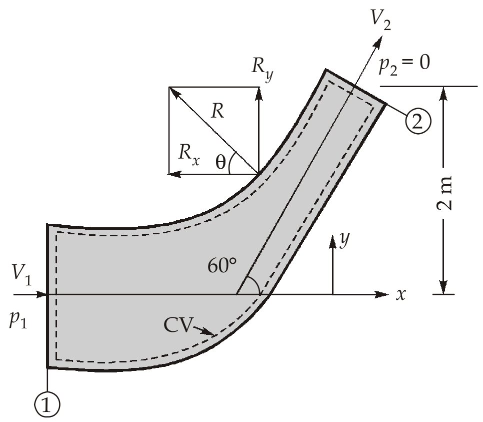
$$V_2 = \frac{0.3}{\frac{\pi}{4}\times(0.15)^2} = 16.98 \text{ m/s}$$

At section 1: $$V_1 = V_2\left(\frac{D_2}{D_1}\right)^2 = 16.98\times\left(\frac{15}{20}\right)^2 = 9.55 \text{ m/s}$$

By applying Bernoulli is equation to sections 2 and 1,

$$Z_2 + \frac{p_2}{\gamma} + \frac{V_2^2}{2g} = \frac{p_1}{\gamma} + \frac{V_1^2}{2g}$$

$$2 + \frac{(16.98)^2}{(2\times 9.81)} = \frac{p_1}{\gamma} + \frac{(9.55)^2}{(2\times 9.81)}$$



$$p_1 = 118.17 \text{ kPa}$$

Let R_x and R_y be the reaction of the pipe on the fluid in the control volume in ($-x$) and y-directions, respectively (figure). By applying momentum equation in x-direction)

$$p_1A_1 - R_x = \rho Q\,(V_2\cos 60° - V_1)$$

$$118.17\times 10^3 \times \frac{\pi}{4}\times(0.2)^2 - R_x = 1000 \times 0.3 \times (16.98 \cos 60° - 9.55)$$

$$R_x = 4030.42 \text{ N}$$

By momentum equation in y-direction,

$$0 + R_y = \rho Q (V_2 \sin 60° - 0)$$

$$R_y = 1000 \times 0.3 \times 16.98 \times 0.866 = 4411.53 \text{ N}$$

Resultant $R = \sqrt{R_x^2 + R_y^2} = \sqrt{(4030.42)^2 + (4411.53)^2} = 5975.43 \text{ N}$

Inclined at an angle θ such that $\tan\theta = \dfrac{R_y}{R_x}$

$$\theta = \tan^{-1}\left(\frac{4411.53}{4030.42}\right) = 47.58°$$

The force F on the pipe is equal and opposite to R and hence F = 5975.43 N inclined at (360° – θ) = 312.42° to positive x-axis.

130. (a)

For the given condition,

$$P_A + \rho_m g h_2 + \rho_w g h_3 + \rho_w g L \sin 45° = P_{atm}$$

As per question

$$\Rightarrow \quad 125 + 13.6 \times 10 \times 0.15 - 13.6 \times 10 \times 0.3 + 10 \times 0.2 - 10 \times L \times \frac{1}{\sqrt{2}} = 101.325$$

$$\Rightarrow \quad L = 0.7459 \text{ m} \simeq 74.60 \text{ cm}$$

131. 1.75 (1.65 to 1.85)

$$q_1 = \frac{Q}{B_1} = \frac{3.25}{3} = 1.083 \text{ m}^3/\text{s/m}$$

$$\therefore \quad E_1 = y_1 + \frac{q_1^2}{2gy_1^2} = 1.0 + \frac{(1.083)^2}{2 \times 9.81 \times (1)^2} = 1.0598 \text{ m}$$

For upstream condition not get affected

$$E_1 = E_{c2}$$

$$\Rightarrow \quad 1.0598 = \frac{3}{2} y_{c_2}$$

$$\therefore \quad y_{c_2} = 0.707 \text{ m}$$

$$\therefore \quad \left(\frac{q_2}{g}\right)^{1/3} = 0.707$$

$$\Rightarrow \quad q_2 = 1.86 \text{ m}^3/\text{s/m}$$

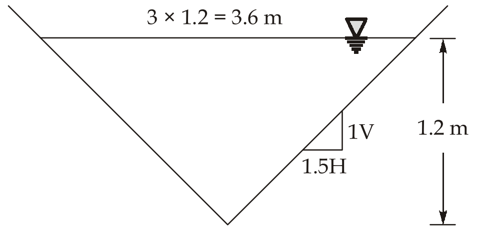
$$\Rightarrow \quad \frac{Q}{B_2} = q_2$$

$$\Rightarrow \quad B_2 = \frac{Q}{q_2} = \frac{3.25}{1.86} = 1.75 \text{ m}$$

132. 1.16 (1 to 1.3)

Given: $n = 0.022, S_0 = 0.0004, y = 1.2$ m

$Q = 2\ m^3/s$



$$A = \frac{1}{2} \times 3.6 \times 1.2 = 2.16\ m^2$$

$$P = 2\sqrt{1.2^2 + 1.8^2} = 4.327\ m$$

$$R = \frac{A}{P} = \frac{2.16}{4.327} \cong 0.5\ m$$

$$V = \frac{2}{2.16} = 0.93\ m/s$$

By Manning's formula,

$$V = \frac{1}{n} R^{2/3}\sqrt{S_f}$$

$$\Rightarrow \quad 0.93 = \frac{1}{0.022} \times (0.5)^{2/3} \times \sqrt{S_f}$$

$$\Rightarrow \quad S_f = 0.00105$$

$$\frac{dy}{dx} = \frac{S_0 - S_f}{1 - F^2} = \frac{0.0004 - 0.00105}{1 - 0.38^2} \cong -7.6 \times 10^{-4}$$

$$S_w = \frac{dy}{dx} - S_0$$

$$= -7.6 \times 10^{-4} - 0.0004$$

$$= -1.16 \times 10^{-3}$$

133. 0.255 (0.20 to 0.30)

The area of flow section at the upstream section is

$$A = (3.5 \times 2) = 7.0\ m^2$$

The wetted perimeter is $P = 3.5 + (2 \times 2) = 7.5$ m

Thus $$R = \frac{A}{P} = \frac{7.0}{7.5} = 0.93\ m$$

Using Manning's formula

$$V = \frac{1}{n}R^{2/3}S^{1/2} = \frac{1}{0.015}\times(0.93)^{2/3}(0.0036)^{1/2} = 3.81 \text{ m/s}$$

Discharge, $Q = (7.0 \times 3.81) = 26.67 \text{ m}^3/\text{s}$

Specific energy at upstream section is

$$E_1 = y_1 + \frac{V_1^2}{2g} = 2.0 + \frac{(3.81)^2}{2\times 9.81} = 2.74 \text{ m}$$

For the rectangular channels the critical depth is given by

$$y_c = \left(\frac{q^2}{g}\right)^{1/3}$$

$$q = \frac{Q}{B} = \frac{26.67}{3.5} = 7.62 \text{ m}^3/\text{s per metre}$$

Thus $$y_c = \left[\frac{(7.62)^2}{9.81}\right]^{1/3} = 1.81 \text{ m}$$

The corresponding minimum specific energy is

$$E_c = \frac{3}{2}y_c = \frac{3}{2}\times 1.81 = 2.715 \text{ m}$$

The maximum height of the hump without causing afflux is obtained as (i.e. there is no change in y_1)

$$\Delta z_{max} = (E_1 - E_c) = (2.74 - 2.715) = 0.025 \text{ m}$$

If the upstream depth of flow is raised to 2.5 m, the area of flow section becomes

$$A = (3.5 \times 2.5) = 8.75 \text{ m}^2$$

Then for the same discharge the velocity of flow will be

$$V = \frac{26.67}{8.75} = 3.05 \text{ m/s}$$

Specific energy at the upstream section will be

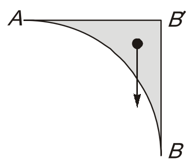
$$E_1 = 2.5 + \frac{(3.05)^2}{2\times 9.81} = 2.97 \text{ m}$$

$\therefore$ The required height of the hump is

$$\Delta z = (E_1 - E_c)$$
$$= (2.97 - 2.715) = 0.255 \text{ m}$$

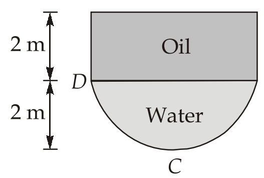
134. 121.02 (120 to 122)

Force on AB (downward) = [Volume of $AB'BA$ per meter length] × γ_w × S



$$\Rightarrow \quad F_{V(AB)} = \left[(2\times 2) - \frac{\pi}{4}(2)^2\right]\times 1\times(10\times 0.8)$$
$$= 6.87 \text{ kN}$$

Force on BCD (upward), $F_{V(BCD)} = (4 \times 2 \times 1 \times 0.8 \times 10) + \frac{\pi}{8}\times(4)^2\times 10\times 1$
$= 64 + 62.83$
$= 126.83 \text{ kN}$



$\therefore$ Net upward force = 126.83 – 6.87 = 119.96 kN

Total horizontal force on $ABCD$ is equal to (force on curve portion AB + force on BC + force on CD) but force on curved portion BC and CD will get compensated.

Hence, total horizontal force = Force on curve AB.

$$\therefore \quad F_H = \gamma_w SA\bar{h}$$

$$\Rightarrow \quad = 10 \times 0.8 \times 2 \times 1 \times 1$$

$$\Rightarrow \quad = 16 \text{ kN } (\leftarrow)$$

$$F_R = \sqrt{119.96^2 + 16^2} = 121.02$$

135. 5 (5 to 5)

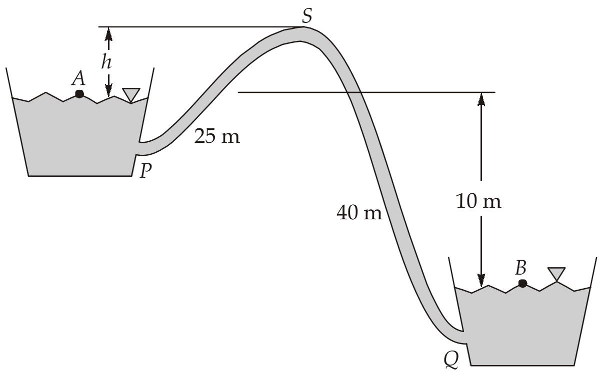
Given, $D = 9$ cm $= 0.09$ m, $l_s = 25$ m, $L = 65$ m

The difference in the level of water in the main and branch canals equal the sum of all head losses along the pipeline PSQ.

Therefore, 10 = entry loss + friction loss + exit loss

$$10 = \frac{0.5V^2}{2g} + \frac{4fLV^2}{2gD} + \frac{V^2}{2g}$$

$$\Rightarrow \quad 10 = \frac{V^2}{2g}\left[1.5 + \frac{4fL}{D}\right]$$



$$10 = \frac{V^2}{2g}\left[1.5 + \frac{4 \times 0.0075 \times 65}{0.09}\right]$$

$$\Rightarrow \quad V = 2.91 \text{ m/sec}$$

$\therefore$ Discharge through 9 cm diameter pipe is

$$Q = \frac{\pi}{4}d^2V = \frac{\pi}{4}(0.09)^2 \times 2.91$$

$$= 0.0185 \text{ m}^3/\text{sec} = 18.5 \, l/\text{sec}$$

No. of pipes required to convey 60 l/sec $= \left(\frac{90}{18.5}\right) = 4.86$

Thus 5 pipes of 9 cm dia are needed to convey a total discharge of 90 l/sec.

136. –64 (–66 to –62)

Convective acceleration is due to change in shape with length of nozzle at a point of time.

$$\text{Convective acceleration} = \left.\frac{VdV}{dx}\right|_{t=4} = t^2\left(1-\frac{x}{L}\right)^2 \times t^2 \times 2 \times \left(1-\frac{x}{L}\right)\times\left(-\frac{1}{L}\right)$$

$$= (4)^2\left(1-\frac{1}{2}\right)^2 \times (4)^2 \times 2 \times \left(1-\frac{1}{2}\right)\times\left(-\frac{1}{1}\right)$$

$$= 4 \times 16 \times (-1) = -64 \text{ m/s}^2$$

137. 2.87 (2.7 to 3)

Given, most efficient trapezodial channel with y = 1.2 m

$$Q = \frac{1}{n}\cdot A.R^{2/3} \times \sqrt{S} \qquad \text{(Manning's equation)}$$

$$A = \sqrt{3}\cdot y^2 = \sqrt{3} \times 1.2^2$$

$$= 2.49 \text{ m}^2$$

$$\left(\because m = \tan 60° = \sqrt{3} \text{ for hydraulized most efficient trapezoidal section}\right)$$

$$R = \frac{y}{2} = \frac{1.2}{2} = 0.6 \text{ m}$$

$$\therefore \quad 2 = \frac{1}{0.015} \times 2.49 \times (0.6)^{2/3} \times \sqrt{S}$$

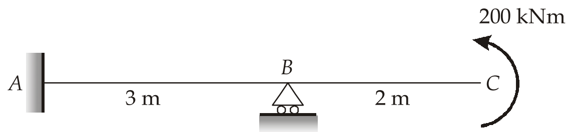
$$\Rightarrow \quad S = 2.87 \times 10^{-4}$$

138. (a)

Introduce pinned connection at given section and given unit rotation at the section to find the *ILD* for *BM*.

139. 100 (99.99 to 100.01)

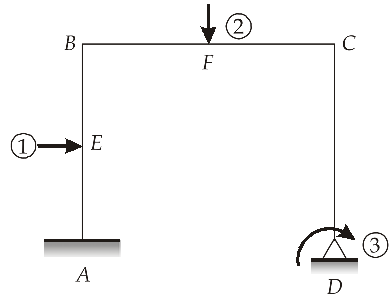
Using moment distribution method,



	A	B	B
DF		1	0
Fixed end moment (kNm)			+200
Balance of moment		–200	0
Carry over moment	–100		
Final moment (kNm)	–100	–200	200

$\therefore$ The magnitude of bending moment at fixed end A is 100 kNm.

140. **5 (4.99 to 5.01)**



With reference to the coordinates shown above:

$$\delta_{12} = \frac{\Delta_1}{P_2} = \frac{-0.002}{40}\text{m}$$

$$\delta_{32} = \frac{\Delta_3}{P_2} = \frac{0.1}{40}\text{rad}$$

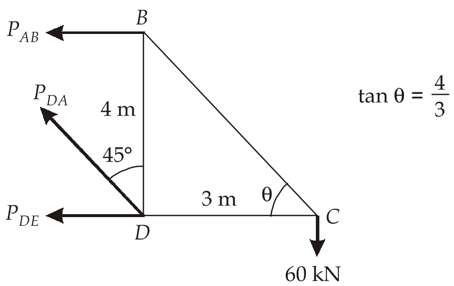
Hence,
$$\Delta_2 = \delta_{21} P_1 + \delta_{23} P_3$$
$$= \delta_{12} P_1 + \delta_{32} P_3$$
$$= \frac{-0.002}{40} \times 20 + \frac{0.1}{40} \times (-1.6)$$
$$= -0.005 \text{ m}$$
$$= -5 \text{ mm}$$

Minus sign shows that the vertical deflection at F is upwards.

141. **1.4 (1.35 to 1.45)**

By method of sections

P-force:



Joint D:

$$\Sigma F_y = 0 \quad \Rightarrow \quad P_{DA} \cos 45° = 60$$

$\Rightarrow$ $$P_{DA} = 60\sqrt{2} \text{ kN (Tensile)}$$

Joint C:

$$\Sigma F_y = 0 \quad \Rightarrow \quad P_{CB} \sin\theta = 60$$

$\Rightarrow$ $$P_{CB} = 60 \times \frac{5}{4} = 75 \text{ kN (T)}$$

$$\Sigma F_x = 0 \quad \Rightarrow \quad P_{CB} \cos\theta = P_{CD}$$

$\Rightarrow \quad P_{CD} = P_{CB} \times \frac{3}{5} = 45 \text{ kN(C)}$

Joint D:

$\Rightarrow \quad P_{DE} = P_{DA} \times \frac{1}{\sqrt{2}} + P_{DC} = 60 + 45 = 105 \text{ kN } (C)$

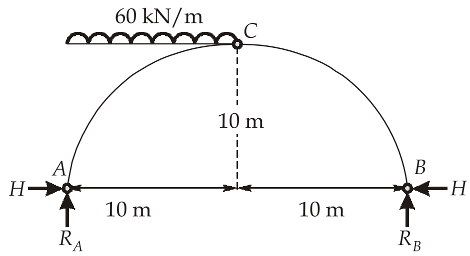
$\because \quad k_{DE} = 1 \text{ kN}$ (For rest of the members, $k = 0$)

$$\Rightarrow \quad \delta_H = \left(\frac{Pkl}{AE}\right)_{\text{of } DE}$$

$$= \frac{105 \times 1 \times 4}{1500 \times 200} \times 10^3$$

$= 1.4$ mm **(compression)**

142. 246 (245 to 247)



$\Sigma M_A = 0$

$\Rightarrow \quad R_B \times 20 = 60 \times 10 \times 5$

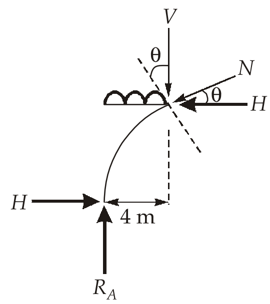
$\Rightarrow \quad R_B = 150$ kN

$\therefore \quad R_A = 60 \times 10 - 150 = 450$ kN

$\Sigma M_{C \text{ from right}} = 0$

$\Rightarrow \quad H \times 10 = 150 \times 10$

$\Rightarrow \quad H = 150$ kN



The equation of semicircular arch is

$y^2 = x(20 - x)$

At $x = 4$ m, $y = \sqrt{4 \times (20-4)} = 8$ m

Normal thrust, $N = H\cos\theta + V\sin\theta$

At $x = 4$ m

$V = 450 - 60 \times 4 = 210$ kN (↓)

Also, $y^2 = x(20 - x)$

$$\Rightarrow \quad 2y \cdot \frac{dy}{dx} = 20 - 2x$$

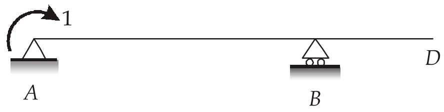
At $x = 4$ m, $\frac{dy}{dx} = \tan\theta = \frac{10-x}{y} = \frac{10-x}{\sqrt{x(20-x)}} = \frac{10-4}{\sqrt{4(20-4)}} = \frac{3}{4}$

$\therefore \quad \sin\theta = 0.6$ and $\cos\theta = 0.8$

$\therefore \quad N = 150 \times 0.8 + 210 \times 0.6$

$= 246$ kN

143. **7.5 (7.49 to 7.51)**



Solving by Unit load method.

$$\Sigma M_A = 0$$

$$\Rightarrow \quad 5 \times 9 + 10 \times 3 = R_B \times 6$$

$$\Rightarrow \quad R_B = 12.5 \text{ kN}$$

$$\Rightarrow \quad R_A = 2.5 \text{ kN}$$

$$\theta_A = \int \frac{Mmdx}{EI}$$

$$\Rightarrow \quad \theta_A = \int_0^3 \frac{2.5x\left(1-\frac{x}{6}\right)dx}{EI} + \int_3^6 \frac{(-7.5x+30)\left(1-\frac{x}{6}\right)dx}{EI} + \int_0^3 \frac{(-5x)\cdot 0\cdot dx}{EI}$$

$$= \frac{7.5}{EI} \text{ radians}$$

144. **(d)**

$$R_P = \frac{2}{3}\times 60 + \frac{1}{3}\times 30 = 50 \text{ kN}$$

$$R_Q = 40 \text{ kN}$$

The force in *PR* will be compressive and will be equal to $\sqrt{2}\,R_P = 50\sqrt{2}\,\text{kN}$.

Cutting a section through *RS*, *RU* and *TU* and taking moment of right part about *U*. The force in *RS* will be compressive and it will be

$$\frac{R_Q \times h}{h} = R_Q = 40 \text{ kN}$$

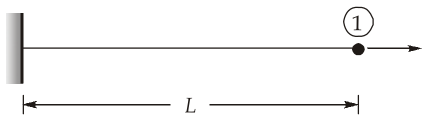
Considering joint equilibrium at *S*, the force in member *SU* will be tensile and equal to R_Q i.e. 40 kN.

Considering joint equilibrium at *T* in the vertical direction, the force in member *RT* will be 60 kN tension.

145. **(a)**

The stiffness matrix is symmetrical in nature so (a) should be the answer.

The elements of stiffness matrix can be found as follows:



EI is Flexural rigidity

For first column of matrix consider the axial displacement only i.e.,

$$D_1 = 1.0,\ D_2 = 0 \text{ and } D_3 = 0.$$

For one unit elongation of beam, the force needed $s_{11} = \frac{AE}{L}$

The moment due to axial elongation,

$$s_{21} = 0$$

The vertical force due to axial elongation,

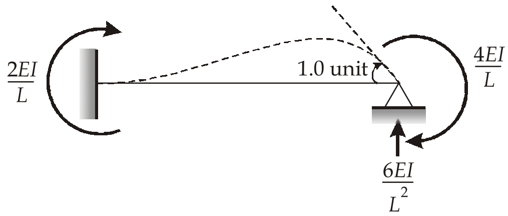
$$s_{31} = 0$$

For second column of matrix, give unit rotation at free end in the direction of displacement component (2) and calculate axial force, moment and vertical force due to the same. The other displacement components should be zero i.e.,

$$D_1 = 0, D_2 = 1.0 \text{ and } D_3 = 0.$$

Axial force induced,

$$s_{12} = 0$$



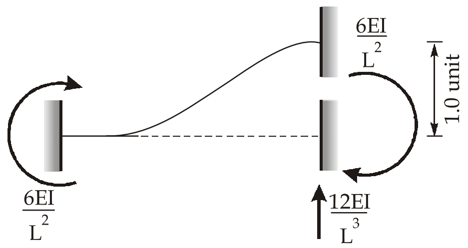
Moment required to produce unit rotation,

$$s_{22} = \frac{4EI}{L}$$

Vertical force produced,

$$s_{32} = \frac{6EI}{L^2}$$

For third column of matrix give unit deflection in the direction of displacement component (3). The other components being zero i.e. $D_1 = 0$, $D_2 = 0$ and $D_3 = 1$.



Axial force induced, $s_{13} = 0$

Moment induced, $s_{23} = \frac{6EI}{L^2}$

Vertical force required to cause unit deflection,

$$s_{33} = \frac{12EI}{L^3}$$

∴ The stiffness matrix is

$$\begin{bmatrix} s_{11} & s_{12} & s_{13} \\ s_{21} & s_{22} & s_{23} \\ s_{31} & s_{32} & s_{33} \end{bmatrix} = \begin{bmatrix} \frac{AE}{L} & 0 & 0 \\ 0 & \frac{4EI}{L} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{12EI}{L^3} \end{bmatrix}$$

146. (b)

$m = 24;\quad j = 13;\quad r_e = 2 + 1 + 1 + 2 = 6$

⇒ $D_s = m + r_e - 2j = 24 + 6 - 2 \times 13 = 4$

Alternatively, $D_{se} = 6 - 3 = 3$

$D_{si} = 24 - (2 \times 13 - 3) = 1$

$D_s = D_{se} + D_{si} = 3 + 1 = 4$

147. (d)

Applying Betti's theorem to system (I) and (II)

⇒ $20(0.0015) + 10\Delta_D = 5(0.002) + 20(0.005)$

⇒ $\Delta_D = 0.008$ m or 8 mm

Applying Betti's theorem to system (I) and (III)

⇒ $20(0.001) + 10(0.008) = 10\theta_A + 20(0.003)$

⇒ $\theta_A = 0.004$ rad

148. 585 (580 to 595)

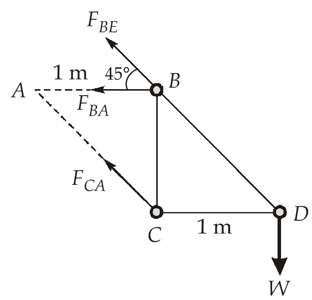
Unstretched length of spring = 1 m

Stretched length of spring = $\sqrt{2}$ m = 1.414 m

Thus change in length = 0.414 m

∴ $F_{BE} = k\Delta = 4 \times (0.414) = 1.656$ kN

By method of sections,

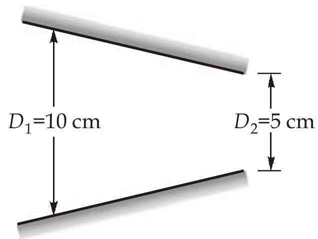


$\Sigma M_A = 0$

⇒ $W \times 2 - \left(\frac{F_{BE}}{\sqrt{2}} \times 1\right) = 0$

⇒ $W = \frac{F_{BE}}{2\sqrt{2}} = \frac{1.656}{2\sqrt{2}} = 0.585 \text{ kN} = 585 \text{ N}$

149. (a, b, d)



Given: $\frac{P_1}{\rho g} = 10$ m, $\frac{V_1^2}{2g} = 1$ m

Since the pipe is horizontal so datum is same for all the points.
Since centreline is datum.

So, $z = 0$

Total head at section 1

$$= \frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1$$
$$= 10 + 1 + 0$$
$$= 11 \text{ m}$$

So statement 1 is correct.

Apply energy equation between (i) and (ii)

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

Apply continuity

$$A_1V_1 = A_2V_2$$
$$(4A_2)\ V_2 = A_2V_2$$
$$V_2 = 4V_1$$

So, $$\frac{V_2^2}{2g} = \frac{16V_1^2}{2g}$$
$$= 16 \times 1$$
$$= 16$$

$$10 + 1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$$
$$11 = \frac{P_2}{\rho g} + 16$$
$$\frac{P_2}{\rho g} = -5$$

Statement 2 is correct.
Q is constant.
So statement 3 is wrong.

150. (a, b, c, d)

At critical flow, specific energy and specific force is minimum for a given discharge. In other words for a given specific energy or specific force discharge is maximum at critical flow and Froude number is equal to unity.

■■■■