ROYAL CIVIL SERVICE COMMISSION
BHUTAN CIVIL SERVICE EXAMINATION (BCSE) 2021
EXAMINATION CATEGORY: TECHNICAL

PAPER III: SUBJECT SPECIALISATION PAPER FOR CIVIL ENGINEERING

Date : October 31, 2021
Total Marks : 100
Writing Time : 150 minutes (2.5 hours)
Reading Time : 15 minutes (prior to writing time)

GENERAL INSTRUCTIONS:

1. Write your Registration Number clearly and correctly on the Answer Booklet.
2. The first 15 minutes is provided to check the number of pages of Question Paper, printing errors, clarify doubts and to read the instructions. You are NOT permitted to write during this time.
3. This paper consists of **TWO SECTIONS**, namely SECTION A & SECTION B:
   - **SECTION A** has two parts: Part I - 30 Multiple Choice Questions
     Part II - 4 Short Answer Questions

     All questions under SECTION A are COMPULSORY.
   - **SECTION B** consists of two Case Studies. Choose only **ONE** case study and answer the questions of your choice.
4. All answers should be written on the Answer Booklet provided to you. Candidates are not allowed to write anything on the question paper. If required, ask for additional Answer Booklet.
5. All answers should be written with correct numbering of Section, Part and Question Number in the Answer Booklet provided to you. Note that any answer written without indicating the Section, Part and Question Number will NOT be evaluated and no marks will be awarded.
6. Begin each Section and Part in a fresh page of the Answer Booklet.
7. You are not permitted to tear off any sheet(s) of the Answer Booklet as well as the Question Paper.
8. Use of any other paper including paper for rough work is not permitted.
9. **You must hand over the Answer Booklet to the Invigilator before leaving the examination hall.**
10. This paper has **12 printed pages**, including this instruction page.

GOOD LUCK

SECTION A

PART I: Multiple Choice Questions (30 marks)

Choose the correct answer and write down the letter of your chosen answer in the Answer Booklet against the question number e.g. 31 (d). Each question carries ONE mark. Any double writing, smudgy answers or writing more than one choice shall not be evaluated.

1. An inflow hydrograph is routed through a reservoir to produce an outflow hydrograph. The peak flow of the inflow hydrograph is $\mathbf{P_I}$ and the time of occurrence of the peak if $\mathbf{t_I}$. The peak flow of the outflow hydrograph is $\mathbf{P_o}$ and the time of occurrence of the peak is $\mathbf{t_o}$. Which of the following statement is correct?
   a) $P_I > P_o$ and $t_I > t_o$
   b) $P_I > P_o$ and $t_I < t_o$
   c) $P_I < P_o$ and $t_I > t_o$
   d) $P_I < P_o$ and $t_I < t_o$

2. The data from a closed traverse survey PQRS (run in the clockwise direction) are given in the table. The closing error of the traverse PQRS (in degrees) is

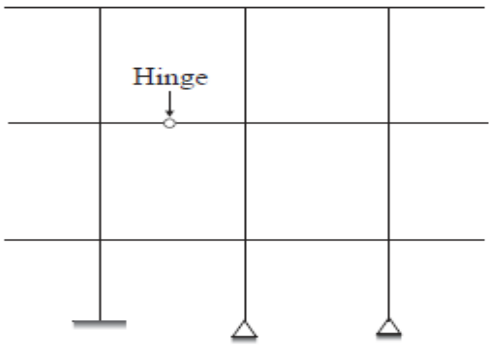
   a) 6
   b) 4
   c) 5
   d) 3

Line	Included angle (in degree)
PQ	88
QR	92
RS	94
SP	89

3. Construction of a new building founded on a clayey soil was completed in January 2010. In January 2014, the average consolidation settlement of the foundation in clay was recorded as 10 mm. The ultimate consolidation settlement was estimated in design as 40 mm. Considering double drainage to occur at the clayey soil site, the expected consolidation settlement in January 2019 (in mm, round off to the nearest integer) will be
   a) 15
   b) 10
   c) 5
   d) 25

4. The degree of static indeterminacy of the plane frame as shown in figure is

   a) 13
   b) 14
   c) 15
   d) 21



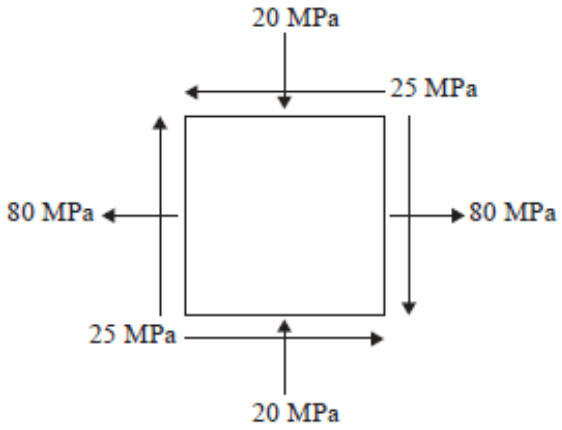
5. The critical bending compressive stress in the extreme fibre of a structural steel section is 1000 Mpa. It is given that the yield strength of the steel is 250 Mpa, width of flange is 250 mm and thickness of flange is 15 mm. As per the provisions of IS : 800 -2007, the non-dimensional slenderness ratio of the steel cross-section is
   a) 0.50
   b) 0.25
   c) 0.75
   d) 2.00

6. When a specimen of M25 concrete is loaded to a stress level of 12.5 Mpa, a strain of 500×10^{-6} is recorded. If this load is allowed to stand for a long time, the strain increases to 1000×10^{-6} . In accordance with the provisions of IS:456-2000, considering the long-term effects, the effective modulus of elasticity of the concrete (in Mpa) is
   a) 1250
   b) 250
   c) 12500
   d) 125

7. Chlorine is used as the disinfectant in a municipal water treatment plant. It achieves 50 percent of disinfection efficiency measure in terms of killing the indicator microorganisms (E-coil) in 3 minutes. The minimum time required to achieve 99 percent disinfection efficiency would be
   a) 9.93 minutes
   b) 19.39 minutes
   c) 11.93 minutes
   d) 21.93 minutes

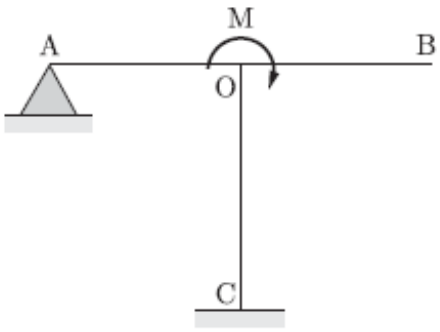
8. For a plane stress problem, the state of stress at a point P is represented by the stress element as shown in figure. By how much angle (θ) in degrees the stress element should be rotated in order to get the planes of maximum shear stress?

   a) 31.7
   b) 48.3
   c) 26.6
   d) 13.3



9. A series of perpendicular offsets taken from a curved boundary wall to a straight survey line at an interval of 6 m are 1.22, 1.67, 2.04, 2.34, 2.14, 1.87 and 1.15 m. The area (in m^2, round off to 2 decimal places) bounded by the survey line, curved boundary wall, the first and the last offsets, determined using Simpson's rule is
   a) 78.5
   b) 60.5
   c) 88.5
   d) 68.5

10. The frame below shows three beam elements OA, OB and OC with identical length L and flexural rigidity EI subjected to an external moment M applied at joint O. the correct set of sending moments $\{M_{OA}, M_{OB}, M_{OC}\}$ that develop at O in the three beam elements OA, OB, and OC respectively is

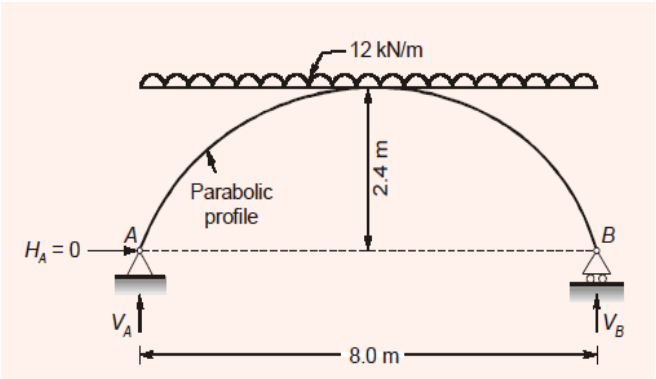


   a) $\{3M/8, M/8, 4M/8\}$
   b) $\{3M/11, 4M/11, 4M/11\}$
   c) $\{M/3, M/3, M/3\}$
   d) $\{3M/7, 0, 4M/7\}$

11. In a soil investigation work at a site, Standard Penetration Test (SPT) was conducted at every 1.5 m interval up to 30 m depth. At 3 m depth, the observed number of hammer blows for three successive 150 mm penetrations were 8, 6 and 9 respectively. The SPTN-value at 3 m depth is
   a) 14
   b) 15
   c) 17
   d) 23

12. A planar elastic structure is subjected to uniformly distributed load, as shown in the figure. Neglecting self-weight, the maximum bending moment generated in the structure (in kNm) is

   a) 48
   b) 192
   c) 96
   d) 24



13. Velocity of flow is proportional to the first power of hydraulic gradient in Darcy's law. The law is applicable to
    a) laminar flow in porous media.
    b) transitional flow in porous media.
    c) turbulent flow in porous media.
    d) laminar as well as turbulent flow in porous media.

14. A vertical retaining wall of 5 m height has to support soil having unit weight of 18 kN/m3, effective cohesion of 12 kN/m2, and effective friction angle of 30°. As per Rankine's earth pressure theory and assuming that a tension crack has occurred, the lateral active thrust on the wall per meter length (in kN/m) is
    a) 16.144
    b) 21.714
    c) 32.288
    d) 65.265

15. During the process of hydration of cement, due to increase in Dicalcium Silicate (C2S) content in cement clinker, the heat of hydration
    a) does not change.
    b) initially decreases and then increases.
    c) increases.
    d) decreases.

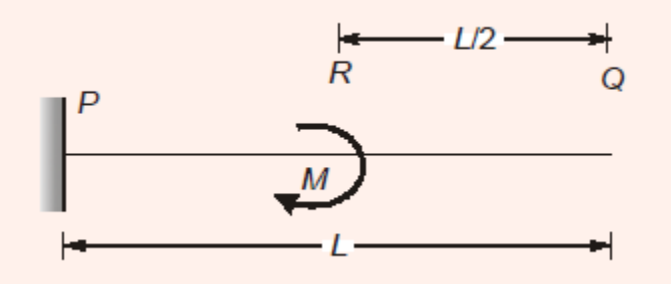
16. A cantilever beam PQ of uniform flexural rigidity (EI) is subjected to a concentrated moment M at R as shown in the figure. The deflection at the free end Q is

    a) $\frac{ML^2}{6EI}$

    b) $\frac{ML^2}{4EI}$

    c) $\frac{3ML^2}{8EI}$

    d) $\frac{3ML^2}{4EI}$

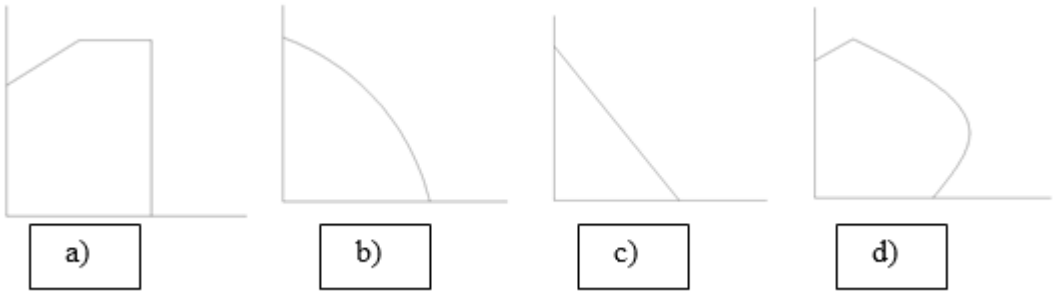


17. The following measurements were made during testing a levelling instrument. P1 is closed to P and Q1 is closed to Q. If the reduced level of station P is 100.0000 m, the reduced level of station Q is
    a) 101.000 m
    b) 99.000 m
    c) 100.000 m
    d) 102.000 m

Instrument at A	Staff reading at	
	P_1	Q_1
P	2.800 m	1.700 m
Q	2.700 m	1.800 m

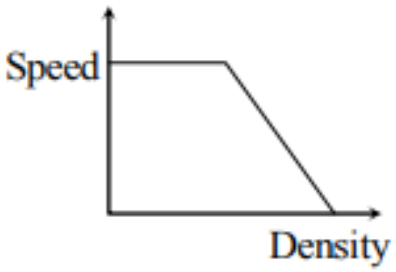
18. The probability that a 50 year flood may NOT occur at all during 25 years life of a project is
    a) 0.5
    b) 0.6
    c) 0.7
    d) 0.8

19. A rectangular RCC column with dimensions as (B x D) has been subjected to uni-axial bending moment M and axial load P. Characteristic strength of concrete is fck. Which among the following column design curves shows the relation between M (x-axis) and P (y-axis qualitatively?



20. The speed density relationship for a road section is shown in the figure. The shape of the flow-density relationship is

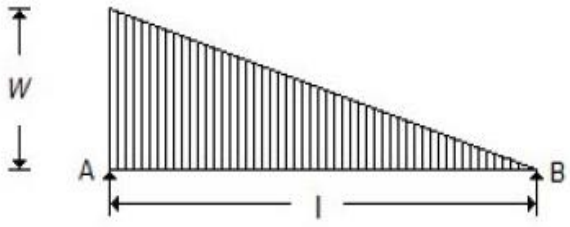
    a) piecewise linear.
    b) parabolic.
    c) initially linear then parabolic.
    d) initially parabolic then linear.



21. The width of a square footing and the diameter of circular footing are equal. If both the footings are placed on the surface of sandy soil, the ratio of the ultimate bearing capacity of circular footing to that of square footing will be
    a) 3/4
    b) 4/3
    c) 1
    d) 2/3

22. A simply supported beam with a gradually varying load from zero at ‘B’ and ‘w’ per unit length at ‘A’ is shown in the figure below. The shear force at ‘B’ is equal to

    a) wl/6
    b) wl/3
    c) wl
    d) 2wl/3



23. The target mean strength f_{cm} for concrete mix design obtained from the characteristic strength f_{ck} and standard deviation σ, as defined in IS:456-2000 is

    a) $f_{ck} + 1.35\sigma$

    b) $f_{ck} + 1.45\sigma$

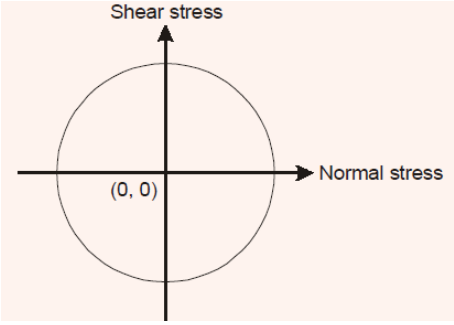
    c) $f_{ck} + 1.55\sigma$

    d) $f_{ck} + 1.65\sigma$

24. The ratio of the plastic moment capacity of a beam section to its yield moment capacity is termed as
    a) Aspect ratio
    b) Load factor
    c) Shape factor
    d) Slenderness ratio

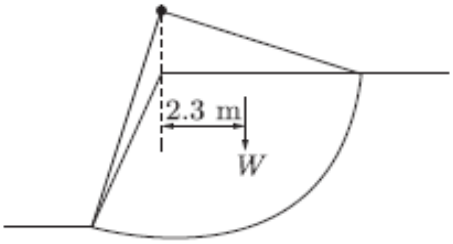
25. The state of stress represented by Mohr's circle shown in the figure is

    a) hydrostatic stress
    b) pure shear
    c) uniaxial tension
    d) biaxial tension of equal magnitude



26. The critical slip circle for a slope is shown below along with the soil properties. The length of the arc of the slip circle is 15.6m and the area of soil within the slip circle is 82m^2. The radius of the slip circles is 10.3m. The factor of safety against the slip circle failure is nearly equal to

    a) 1.05
    b) 1.22
    c) 0.78
    d) 1.28

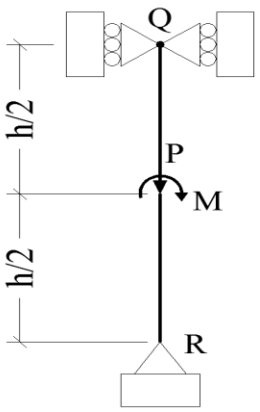


27. For an open channel flow to take place between two sections
    a) the total energy at the upstream end must be larger than the downstream end.
    b) the channel bed must always slope in the direction of the flow.
    c) the upstream depth must be larger than the downstream depth.
    d) the upstream momentum must be larger than the downstream momentum.

28. A retaining wall of height H with smooth vertical back face supports a backfill inclined at an angle β with the horizontal. The backfill consists of cohesion less soil having angle of internal friction ϕ. If the active lateral thrust acting on the wall is Pa, which one of the following statements is TRUE?

a) Pa acts at a height H/3 from the base of the wall and at an angle ϕ with the horizontal.
b) Pa acts at a height H/2 from the base of the wall and at an angle ϕ with the horizontal
c) Pa acts at a height H/3 from the base of the wall and at an angle β with the horizontal
d) Pa acts at a height H/2 from the base of the wall and at an angle β with the horizontal

29. The sketch shows a column with a pin at the base and rollers at the top. It is subjected to an axial force P and a moment M at mid-height. The reaction(s) at R is/are

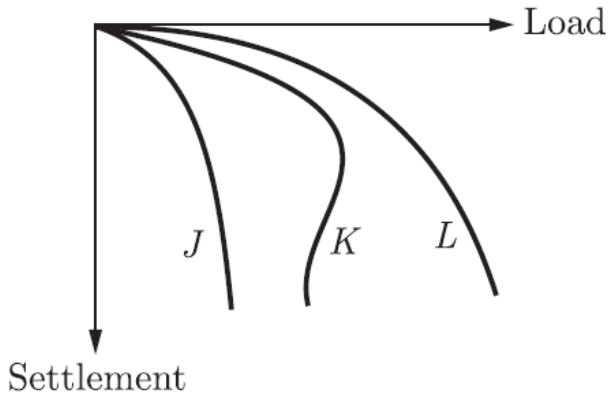


a) a vertical force equal to P
b) a vertical force equal to P and a horizontal force equal to M/h
c) a vertical force equal to P/2
d) a vertical force equal to P/2 and a horizontal force equal to M/h

30. Group I contains representative load-settlement curves for different modes of bearing capacity failures of sandy soil. Group II enlists the various failure characteristics. Match the load-settlement curves with the corresponding failure characteristics

	Group I		Group II
P	Curve J	1	No apparent heaving of soil around the footing
Q	Curve K	2	Rankine's passive zone develops imperfectly
R	Curve L	3	Well defined slip surface extends to ground surface

a) P-1, Q-2, R-3
b) P-3, Q-2, R-1
c) P-3, Q-1, R-2
d) P-1, Q-3, R-2



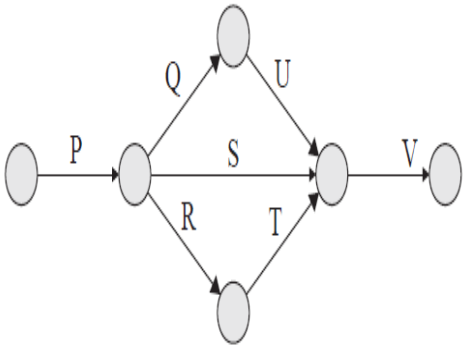
PART II – Short Answer Questions [20 marks]

This part has 4 Short Answer Questions. Answer ALL the questions. Each question carries 5 marks.

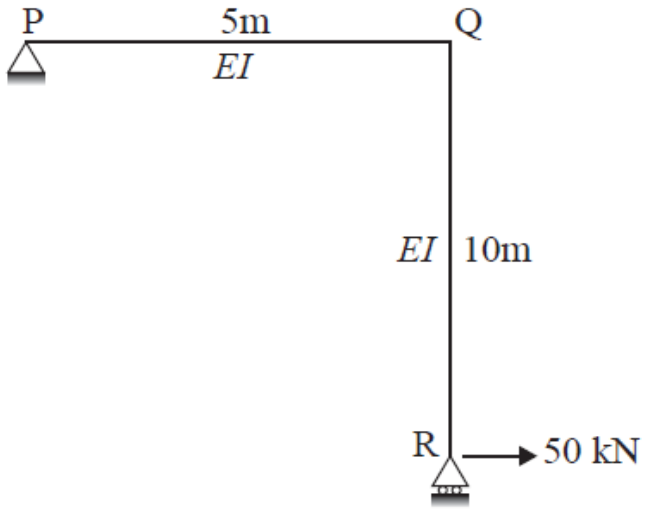
1. A circular log of timber has diameter D. Find the strongest section of the rectangular timber beam that can be cut from this piece of log to resist the moment?

2. The network of a small construction project awarded to a contractor is shown in the following figure. The normal duration, normal cost and crash cost of all the activities are shown in the table. The indirect cost incurred by the contractor is Nu 5000 per day. If the project is to be completed in sixteen (16) days, find the total cost that would be incurred by the contractor?

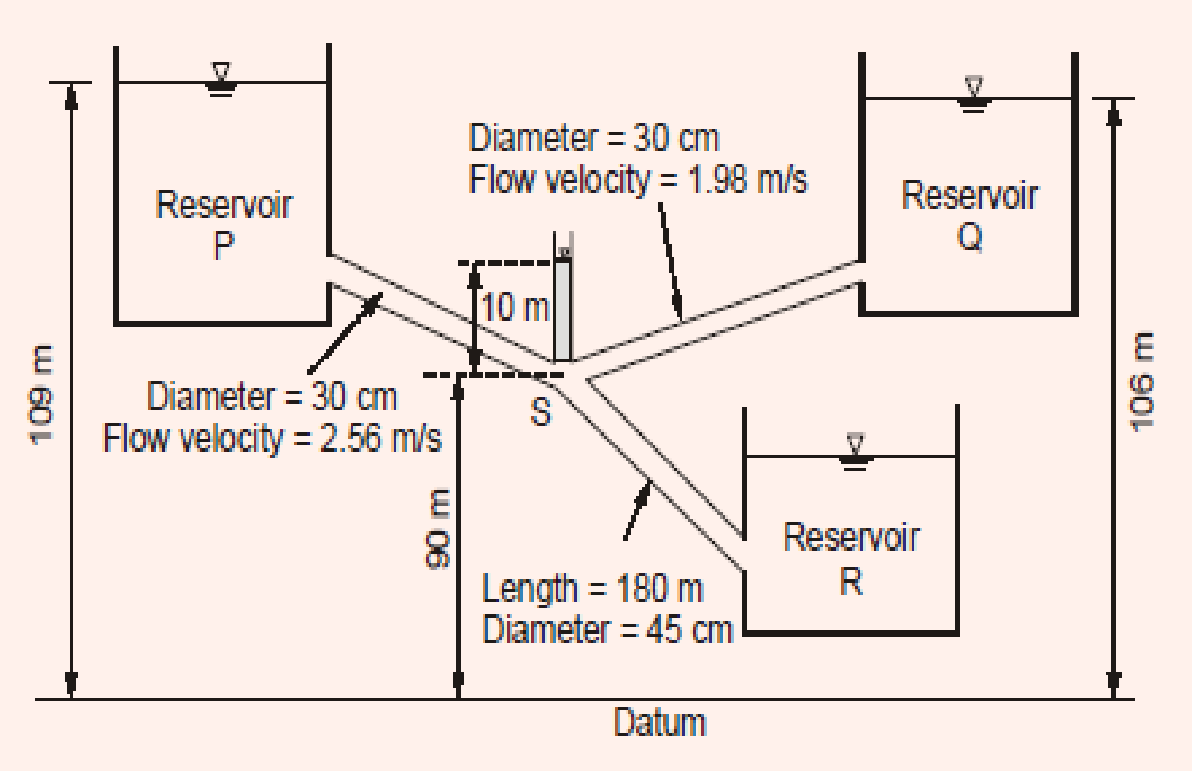
Activity	Normal duration (days)	Crash duration (days)	Normal cost (Nu)	Crash Cost (Nu)
P	6	4	15000	25000
Q	5	2	6000	12000
R	5	3	8000	95000
S	6	3	7000	10000
T	3	2	6000	9000
U	2	1	4000	6000
V	4	2	20000	28000



3. A portal frame shown in figure below has a hinge support at joint P and a roller support at joint R. A point load of 50 kN is acting at joint R in the horizontal direction. The flexural rigidity, EI of each member is 1x 10^6 kNm^2. Under the applied load, find the horizontal displacement of joint R?



4. Three reservoir P, Q and R are interconnected by pipes as shown in the figure. Piezometric head at the junction S of the pipes is 100 m. Assume acceleration due to gravity as 9.81 m/s^2 and density of water as 1000 kg/m^3 and the length of the pipe from junction S to the inlet of reservoir R is 180 m. Considering head loss only due to friction (with friction factor of 0.03 for all the pipes), find the height of water level in the lowermost reservoir R with respect to the datum?

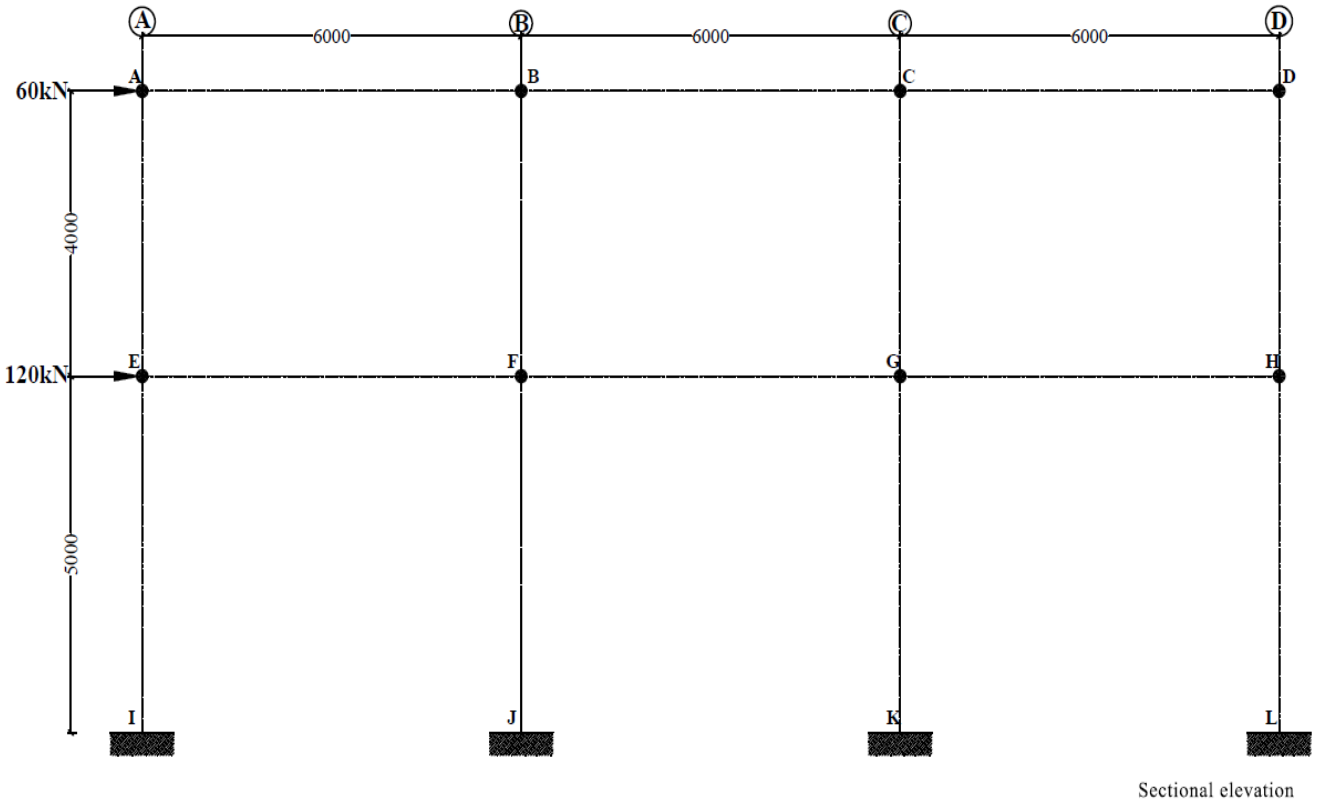


SECTION B: Case Study [50 marks]

Choose either CASE I OR CASE II from this section. Each case study carries 50 marks. Mark for each sub-question is indicated in the brackets.

CASE I

You are being recruited by a structural design consultancy firm as an assistant structural designer. The immediate task is to analyze a building frame and verify its results with a software. To convince your employer, analyze the given building frame for the lateral load by approximate method. The building frame has column size of 450 x 450mm and beams of 275 x 450mm. The frame sustains load from RC slab which is 175mm thick for both the floors. The grade of concrete used is **M25** and $\mathbf{E_c = 5000\sqrt{f_{ck}}}$.



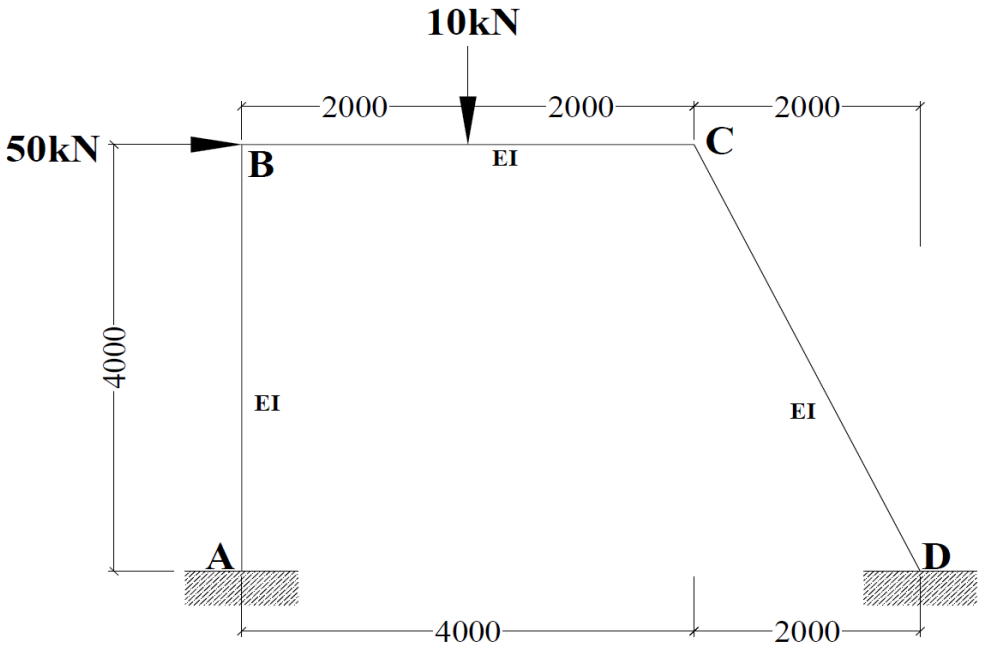
Sectional elevation

Compute the following:

1. The stiffness of the structural frame. (7 marks)
2. Fundamental natural period of the building frame. (7 marks)
3. Shear force for each structural members. (14 marks)
4. Bending moment for structural members. (14 marks)
5. Bending moment diagram for the building frame. (8 marks)

CASE II

You are directed to analyze a portal frame to compare the responses generated through computer model. In order to carry out this task, you are suggested to analyze the frame under given loading conditions using moment distribution method superimposing the responses both from non-sway and sway analysis. Assume $\mathbf{EI\Delta = 100}$ to get moments from sway analysis.



As to back up your results, compute the following:

1. Fixed end moments from external loading. (2.5 marks)
2. Relative stiffness and distribution factors. (2.5 marks)
3. Non-sway moments from moment distribution. (7.5 marks)
4. Compute imaginary force 'P' required to keep the support 'C' intact. (5 marks)
5. Fixed end moments due to deflection of the frame by an amount Δ. (7.5 marks)
6. Sway moments from moment distribution. (10 marks)
7. Imaginary horizontal force from sway analysis on the frame. (5 marks)
8. Super imposed final moments. (5 marks)
9. Final bending diagram for the frame. (5 marks)