

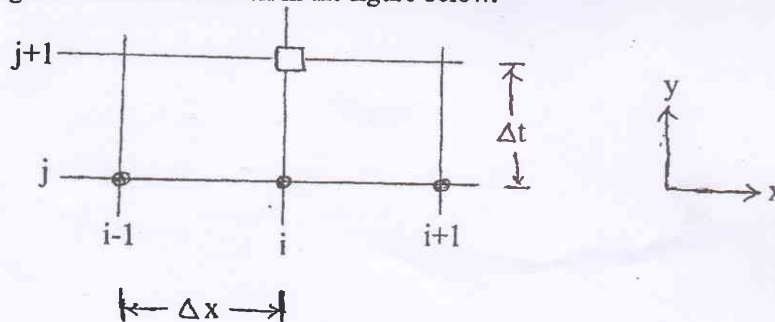
Exam.	Regular		
Level	BE	Full Marks	80
Programme	BCE	Pass Marks	32
Year / Part	IV / II	Time	3 hrs.

**Subject:** - Computational Techniques in Civil Engineering (CE751)

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt **All** questions.
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- ✓ Candidate should use separate answer book for each group (Water and Structure).
- ✓ Assume suitable data if necessary.

**Group A (Water Part)**

- Describe basic steps in finite difference method. Explain explicit and implicit schemes in finite difference method using suitable examples and expressions. [2+2+2]
- A finite difference grid of points constructed to solve for the unsteady flow problems in a wide rectangular channel is shown in the figure below.



Using an appropriate finite difference scheme for two governing equations of fluid flow (continuity and momentum), compute the velocity and flow depth at grid point (i, j+1) for the following given data:

Velocity :  $y_{i-1}^j = 2.2\text{m/sec}$ ,  $V_i^j = 1.8\text{m/sec}$ ,  $V_{i+1}^j = 1.5\text{m/sec}$

Flow depth :  $y_{i-1}^j = 1.6\text{m/sec}$ ,  $y_i^j = 2.0\text{m/sec}$ ,  $y_{i+1}^j = 2.4\text{m/sec}$

Bed slope = 1%, Manning's  $n = 0.032$ ,  $\Delta x = 1000\text{ m}$ ,  $\Delta t = 4\text{ minutes}$ , No lateral in flow. [6]

- What is meant by method of characteristics and why it is necessary? Derive finite difference equations of the characteristic form of unsteady flow equations in a pipe to obtain solution in terms of head and discharge. [2+6]
- Derive a suitable finite difference expression for two dimensional (2D) groundwater simulation in steady state condition for homogeneous and isotropic aquifer. also describe the iterative procedure for computing potential at each grid and seepage rate under a dam. [5+3]

**Group B (Structure Part)**

- Discuss about the software used to evaluate the problems in FEM and FDM. [4]
- What is meant by discretization, describe with example? [4]

6. Explain different solution techniques of linear equations. For the given linear system

$$\begin{bmatrix} 12 & -6 & 0 \\ -6 & 12 & -6 \\ 0 & -6 & 6 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} 24 \\ 24 \\ 0 \end{Bmatrix}$$

Using the starting vector  $x^{(0)} = (4, 4, 0)^T$ , carry out two iterations of conjugate gradient method and show the result.

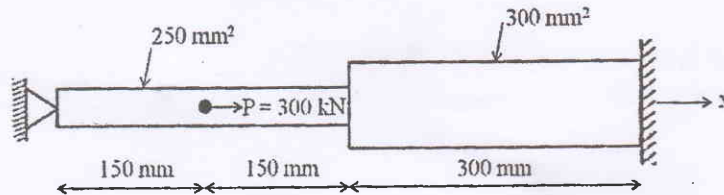
[3+5]

7. Derive constitutive relation for plane stress problems. Explain axi-symmetric problems with examples.

[5+3]

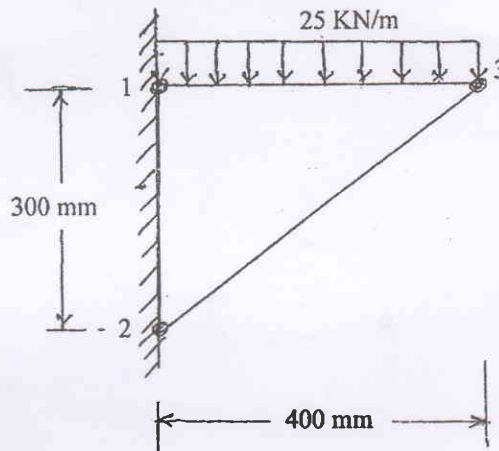
8. Determine the nodal displacements, element stresses and support reactions for the bar as shown in figure below. Take  $E = 200 \text{ GPa}$ .

[10]



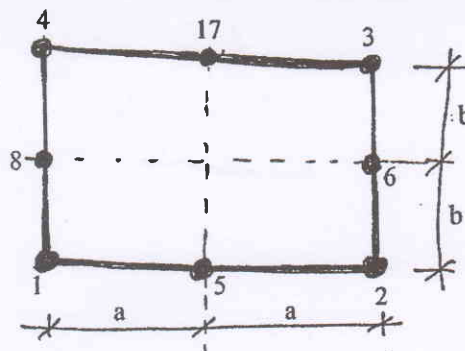
9. A steel plate of uniform thickness 10 mm is being loaded as shown in the figure below. Considering the plane stress condition for this CST element, determine (a) element stiffness matrix, (b) nodal displacements, and (c) strains and stresses at the centroid of the element. Take  $E = 210 \times 10^3 \text{ MPa}$ , and  $G = 105 \times 10^3 \text{ MPa}$ . The unit weight of steel is  $78.5 \text{ KN/m}^3$ .

[10]



10. Derive the shape functions for the eight noded 2 - D rectangular element given in figure.

[8]



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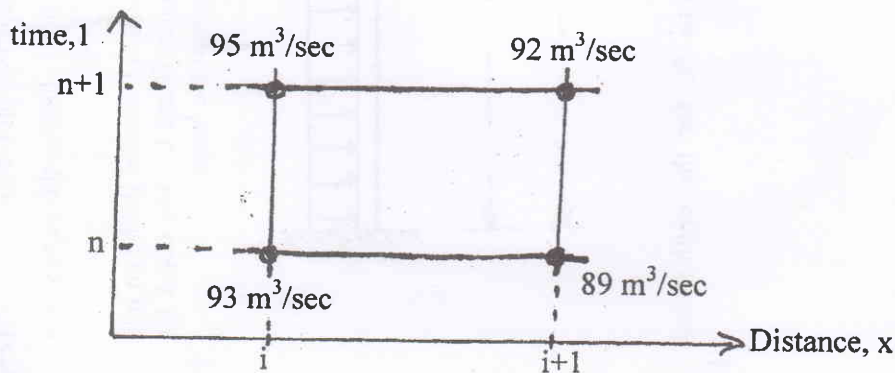
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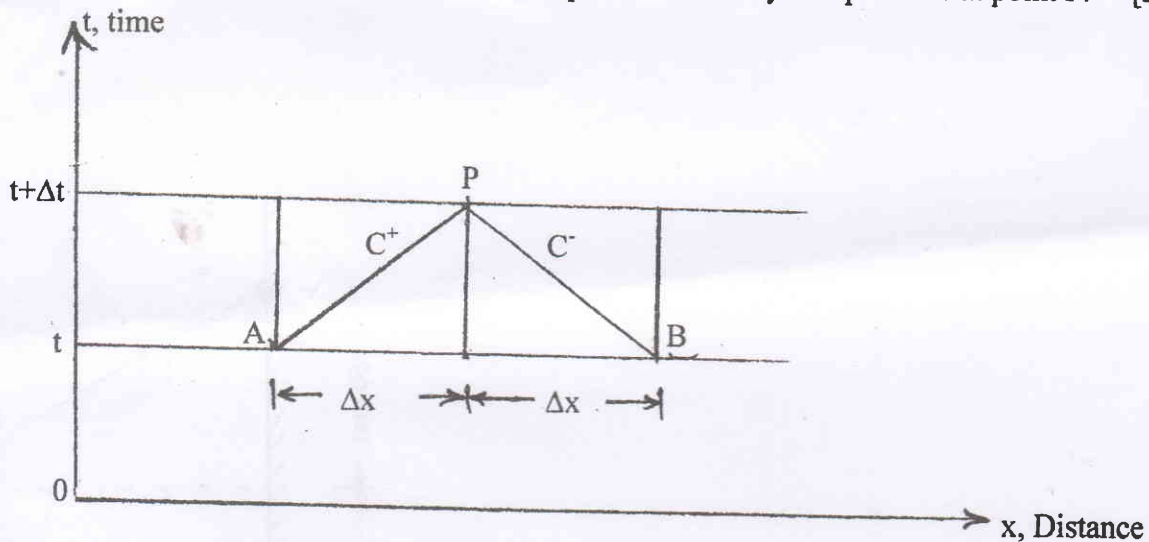
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**Group A (Water)**

- Derive the finite difference equations for full Saint-Venant equations representing the fluid flow using second order accurate explicit scheme. [6]
- Describe numerical dispersion, diffusion and stability of Finite Difference Schemes. The value of flow rate  $Q$  at four points in the space time grid are shown in the figure below. Determine the value of first-order derivations  $\partial Q/\partial t$  and  $\partial Q/\partial x$  by using four-point implicit method. Given:  $\Delta t = 1$  hour,  $\Delta x = 600$  m and  $\theta = 0.55$  [4+4]



- What do you understand by characteristic curve? Explain, A pipe of diameter 35 cm carrying water has the following data at two points A and B:  $V_A = 6$  m/sec,  $V_B = 6.25$  m/sec,  $p_A = 102$  KN/m<sup>2</sup>,  $p_B = 124$  KN/m<sup>2</sup>,  $\Delta x = 500$  m,  $\Delta t = 0.5$  sec,  $f = 0.02$ ,  $a = 1000$  m/sec  $\left(\frac{dx}{dt} = \pm a\right)$ , elevation difference between A to P = 2.50 m. By the use of finite difference form of characteristics equation, compute the velocity and pressure at point P. [2+6]



- Develop a steady state 2D model for the simulation of seepage under a dam. Also describe the iterative procedure for computing potential at each grid and seepage rate. [6]

**Group B (Structure)**

5. Describe the concepts and applications of finite element and finite difference method with their advantages and disadvantages with other methods of numerical computations used in solving civil engineering problems. [3+3+2]

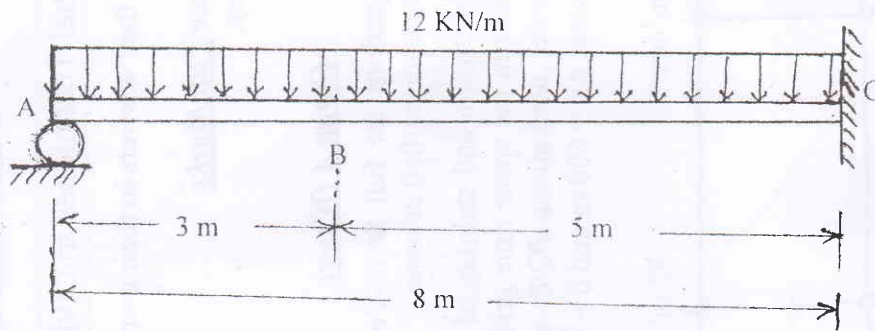
6. Describe briefly about the Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT). Carry out the three iterations of conjugate gradient method for the following system of linear equations: [4+4]

$$\begin{bmatrix} 10 & -6 & 0 \\ -6 & 8 & -2 \\ 0 & -2 & 5 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} 12 \\ 0 \\ 0 \end{Bmatrix}$$

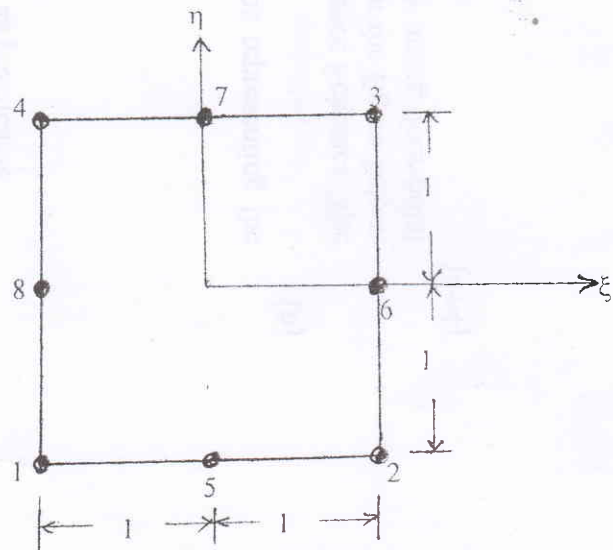
7. a) Describe about the plane stress, plane strain and axisymmetric problems with their examples and constitutive relations to be used for stress analysis problems. [2+2+2]

b) Differentiate between isotropic and anisotropic material body. Derive the expressions for Lamé's constants for linearly elastic isotropic material body. [2+2]

A propped cantilever beam is loaded as shown in figure below. Discretize the beam into two elements and find deflection at point B and rotations at point B and C. Also check the result using single element model. Take EI as constant throughout the beam. [6+4]

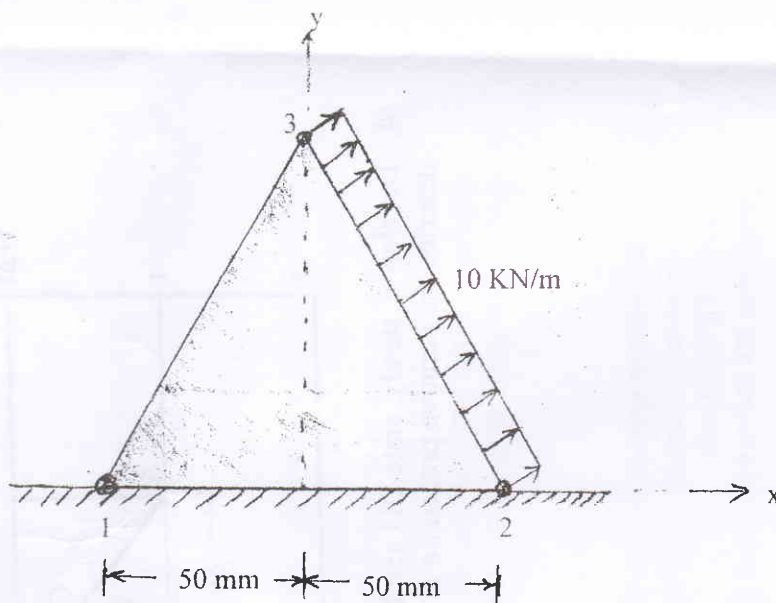


9. What is isoparametric formulation? Obtain shape functions  $N_i$  for the eight-noded rectangular element as shown in figure below. [1+5]



10. A steel plate of thickness 10 mm is being loaded as shown in figure below. Considering the plane stress condition, determine the stresses and strains at the centroid of the CST element. Take  $E = 210 \times 10^3$  MPa,  $\nu = 0.30$  and unit weight of steel is  $78.50 \text{ KN/m}^3$ , length of each side = 100 mm.

[10]



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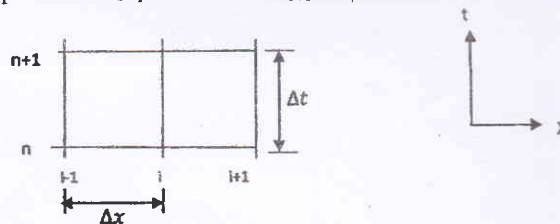
**Group A**  
**(Water)**

1. a) With appropriate expressions and graphs, explain first and second order accurate schemes of finite differences of partial differential equations. [4]

b) Using any explicit finite difference scheme for full Saint Venant equations, compute discharge and flow depth at grid (i, n+1) for the following data: [6]  
 Rectangular channel, width = 10m, Bed slope = 0.0002, Manning's n = 0.04,  
 No lateral flow,  $\Delta x = 1\text{km}$  and  $\Delta t = 5\text{min}$

Discharge:  $Q_{i-1}^n = 40\text{m}^3/\text{s}$  and  $Q_i^n = 38\text{m}^3/\text{s}$ ,  $Q_{i+1}^n = 37.5\text{m}^3/\text{s}$

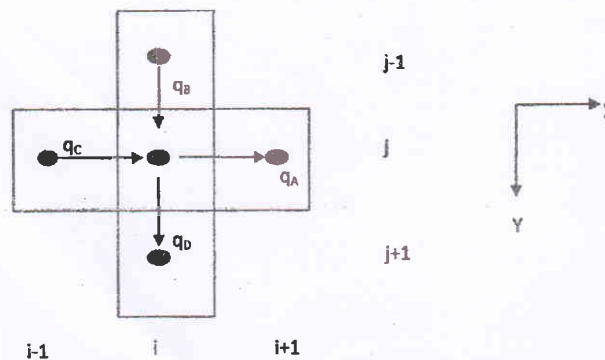
Flow depth  $y_{i-1}^n = 1.9\text{m}$ ,  $y_i^n = 1.85\text{m}$ ,  $y_{i+1}^n = 2.0\text{m}$



2. The figure below shows a central grid surrounded by four grids for simulating two dimensional groundwater flow under steady state condition. Values of potential function ( $\phi$ ) are given below:

$\phi_{i-1,j} = 12$ ,  $\phi_{i+1,j} = 14$ ,  $\phi_{i,j} = 13$ ,  $\phi_{i,j-1} = 13.5$ ,  $\phi_{i,j+1} = 11$

Transmissivity in X-direction =  $0.013\text{m}^2/\text{S}$  for all grids, Transmissivity in Y-direction =  $0.015\text{m}^2/\text{S}$  for all grids. Taking  $\Delta X = 20\text{m}$  and  $\Delta Y = 25\text{m}$ , compute Darcy fluxes  $q_A$ ,  $q_B$ ,  $q_C$  and  $q_D$  from the finite difference equation in terms of  $\phi$ . [6]



3. Develop a finite difference solution of the characteristics form of unsteady flow equations to obtain solution in terms of velocity and pressure. [6]
4. Develop tridiagonal coefficient matrix to evaluate river stage-water table interactions for an aquifer along a river. [6]

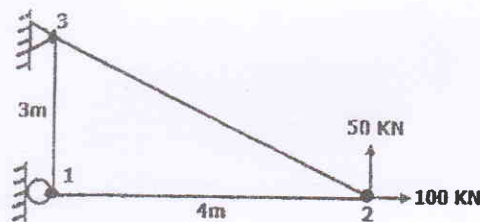
**Group B**  
**(Structure)**

5. Describe the different solution techniques in civil Engineering and list their suitability. [4+4]
6. Write down the algorithm for conjugate gradient method. Consider the system

$$\begin{bmatrix} 2 & -1 & 0 \\ 1 & 6 & -2 \\ 4 & -3 & 8 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} 2 \\ -4 \\ 5 \end{Bmatrix}$$

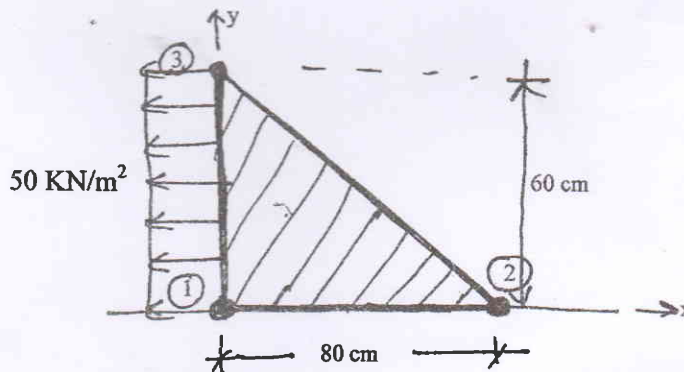
Solve the above system by using Gauss-Seidel iteration starting with  $x^{(0)} = (0,0,0)^T$ . [4+4]

7. Define plane stress and plane strain problems. Derive the differential equation of equilibrium for three dimensional problems. [3+7]
8. Determine the nodal displacements, reaction forces, and member forces of the given truss structure, loaded as shown in figure. Given that for each member, sectional area,  $A = 2 \times 10^{-3} \text{ m}^2$  and modulus of elasticity,  $E = 2 \times 10^5 \text{ MPa}$ . [10]



9. Derive the relation of strain-Displacement [B] matrix for constant strain triangle. [6]
10. A steel plate of 10mm thick is loaded as shown in figure below. For the plane stress problem, obtain the nodal deformations and the stresses in the CST element. [10]

Take  $E = 2 \times 10^5 \text{ MPa}$ ,  
 $G = 105 \times 10^3 \text{ MPa}$  and  
unit weight of steel is  $78.5 \text{ KN/m}^3$ .



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**Group A**  
**(Water Part)**

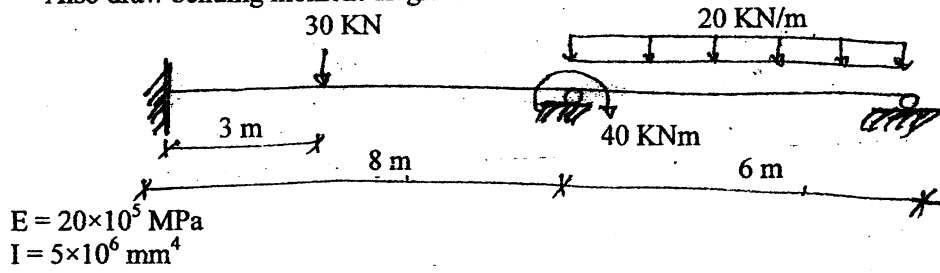
1. a) Derive the expression for second order accurate explicit finite equation for dynamic wave model. [6]
- b) A channel with a width of 40 m, bed slope 2% and Mannings  $n=0.03$  carries a discharge of  $100 \text{ m}^3/\text{s}$  through a section. If  $\Delta x$  is taken as 1500 meters, recommended the maximum time step for stable solution of kinematic wave routing in this condition. Assume hydraulic radius equal to flow depth. [6]
2. a) Write an algorithm for simulation of water hammer process using method of characteristics. [4]
- b) If the MOC is applied for  $t_1 = 1$  sec and  $t_2 = 2$  sec, time levels for a pipe with diameter 30 cm carrying water. If  $Q_A = 0.7 \text{ m}^3/\text{s}$ ,  $Q_B = 0.76 \text{ m}^3/\text{s}$  and  $Q_C = 0.74 \text{ m}^3/\text{s}$ ,  $H_A = 20$  m,  $H_B = 20.6$  m and  $H_C = 20.4$  m are the values at grid points. Find the values of  $Q$  and  $H$  at  $t_1 = 1$  sec that will be required for finding  $Q$  and  $H$  at  $P$  when characteristics do not lie on diagonal. Here,  $\Delta x = 1000$  m,  $\Delta t = 1$  sec,  $f = 0.02$  and  $c = 800$  m/s [4]
3. Derive expression for finite difference scheme for 2D groundwater simulation in steady state for homogeneous and isotropic aquifer. Describe about the boundary conditions and flow coefficients. [8]

**Group B**  
**(Structure Part)**

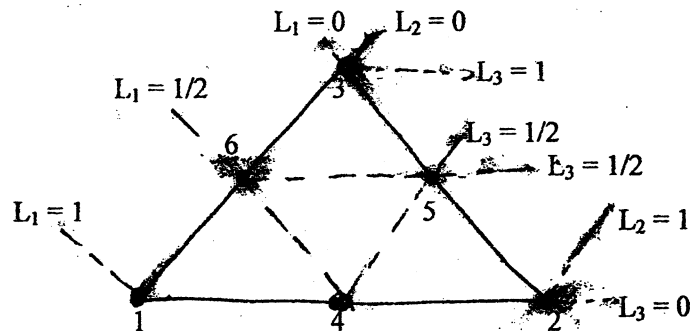
4. Describe briefly the various solution techniques used for solving civil engineering problems. Also give their advantages and disadvantages. [8]
5. Explain different solution techniques of linear equations. Write the algorithm for conjugate gradient method. [5+3]
6. Explain the terms axi-symmetric problem with examples. Derive strain-displacement and constitutive relationships that exist in plane stress problem for isotropic material. [4+6]



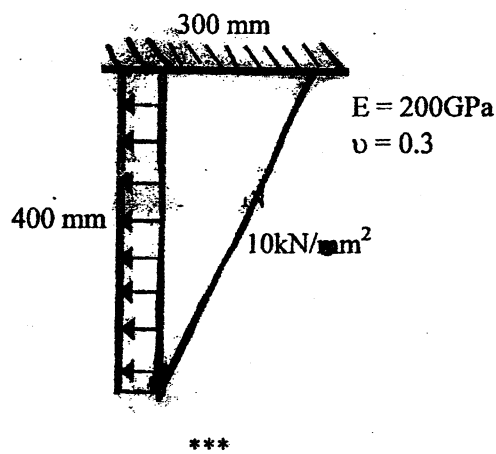
7. a) Determine the support reactions and deflections at mid-span for the given structure. Also draw bending moment diagram. [10]



- b) Derive shape function for the element as shown in figure below. [6]



8. A steel plate of thickness 10 mm is being loaded in the structural system as shown in figure below. Calculate stresses at the centroid of the plate. [10]



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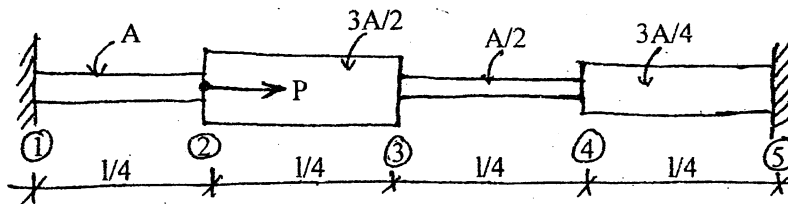
**Group A**  
(Water)

1. a) Derive the first order accurate implicit Finite Difference equation for kinematic wave model in the non-linear form. [6]
- b) Using the Finite Difference equation developed in question (a), compute the discharge at 1 km d/s of location X at time 14:00 hrs, for the following data: [6]
  - Rectangular channel, width = 20 m, Bed slope = 0.001, Manning's n = 0.03
  - Discharge at location X at time 14:00 hrs = 14 m<sup>3</sup>/s
  - Discharge at location X at time 13:45 hrs = 12 m<sup>3</sup>/s
  - Discharge at 1 km d/s of location X at time 13:45 hrs = 11 m<sup>3</sup>/s
  - No lateral flow, wetted perimeter approximately equal to width of channel.
2. Define characteristic curve and method of characteristics (MOC). Develop the characteristic equations from the partial differential form of the unsteady pipe flow equations. [2+6]
3. Explain the continuity equation used in groundwater flow analysis. Write down the algorithm for simulation of seepage under a dam. [3+5]

**Group B**  
(Structure)

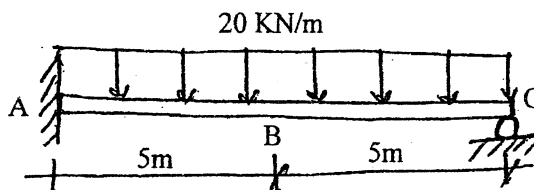
1. List the computational techniques used in Civil Engineering. Why FEM is predominating others? Explain briefly the steps involved in FEM. [2+2+4]
2. a) Write the algorithm for conjugate gradient method. [3]
- b) Solve the given system of equations using conjugate gradient method. [5]
 
$$\begin{bmatrix} 3 & 0 & 2 \\ 0 & 1 & 1 \\ 2 & 1 & 3 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} 1 \\ 0 \\ -1 \end{Bmatrix}$$
3. a) Derive the constitutive relation ( $\{\sigma\} = [D] \{E\}$ ) for an elastic isotropic material. [6]
- b) What are the conditions at which axisymmetric stress exists? Write the stress-strain relations for axisymmetric condition. [4]

4. a) For the given stepped bar obtain nodal displacements at nodes 2, 3 and 4. Also obtain forces developed at the supports. [8]

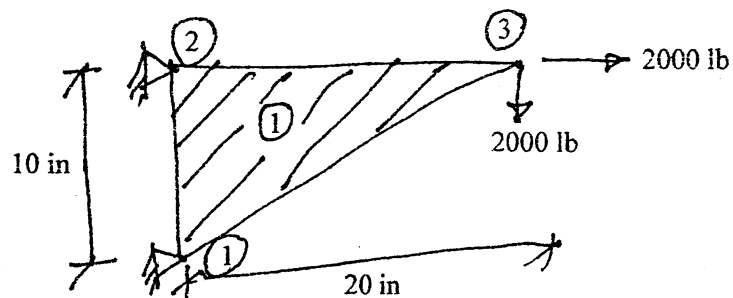


Take  $E = \text{constant}$  and cross-sectional areas as indicated in the figure.

- b) For the given beam find deflection at point B and rotations at points B and C. Take  $EI$  as constant throughout the beam. Discretise the beam into two elements. [10]



- c) A thin plate is subjected to the loads as shown in figure below. The plate thickness is 0.3 in and the other dimensions are shown in figure. Given that the Poisson's ratio = 0.3 and the modulus of elasticity  $E = 30 \times 10^6 \text{ psi}$ . Determine nodal load displacements and the elemental stresses. [8]



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**Group A**

1. With the help of mechanics, explain various numerical methods for solving civil engineering problems. Given their advantages and disadvantages. [8]
2. a) Derive the expression for Lamé constants. [5]  
 b) Define plane stress and plane strain problems with necessary conditions and suitable examples. [5]
3. a) Derive the shape function for the element as shown in the Fig. 1. [8]

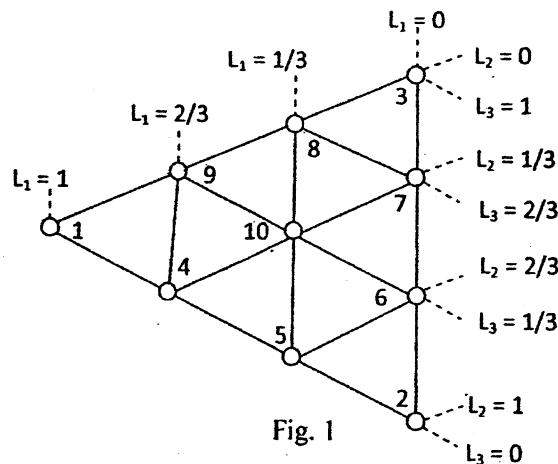


Fig. 1

- b) Considering plane stress condition, find out the nodal displacements and stresses of the CST element as shown in Fig. 2.  $E = 30 \times 10^6$  psi,  $t = 0.3$  in,  $\gamma = 460$  lb/in<sup>3</sup>,  $\nu = 0.3$ ,  $T_3 = 360$  psi with usual notations. [12]

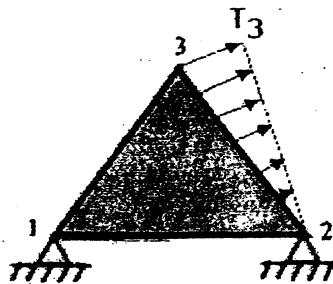


Fig. 2

**Group B**

4. a) Why conjugate gradient method is used in computation over Gaussian methods? [4]  
b) Solve the following equation by using conjugate gradient method (max. 5 iterations) [8]

$$\begin{bmatrix} 3 & 0 & 1 \\ 0 & -1 & 3 \\ 1 & 3 & 0 \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} 1 \\ -12 \\ 2 \end{Bmatrix}$$

5. a) Write down the complete governing equations describing the movement of fluid. [2]  
b) Derive the kinematic wave approximation for the movement of fluid. [4]  
c) Derive a second order accurate finite difference scheme of linear kinematic wave equation which computes discharge for unknown time and location. [8]
6. Prepare an algorithm to compute discharge and head based on the following form of finite difference equations for unsteady pipe flow problem using rectangular grid. [8]

$$H_{pi} = H_{i-1} - B(Q_{pi} - Q_{i-1}) - RQ_{i-1} |Q_{i-1}|$$

$$H_{pi} = H_{i+1} + B(Q_{pi} - Q_{i+1}) + RQ_{i+1} |Q_{i+1}|$$

Where H = head, Q = discharge,  $H_{pi}$  and  $Q_{pi}$  = head and discharge at point of intersection of two characteristics, B and R = coefficients.

7. Explain the 1D implicit model to evaluate the river stage water table interaction. [8]

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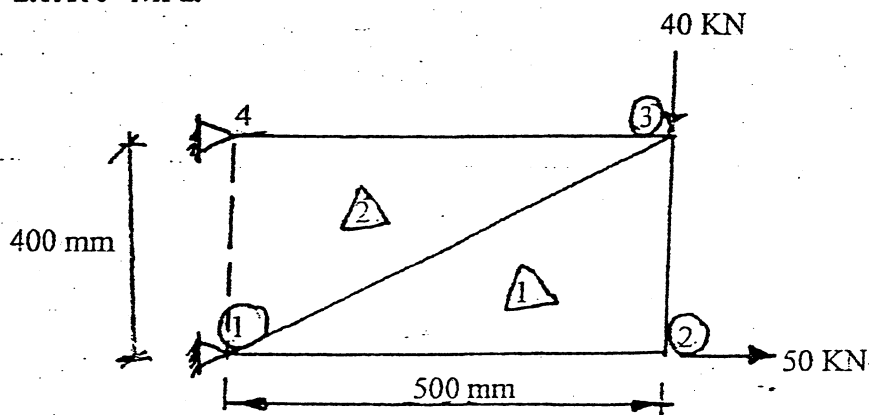
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**Group A**

1. Explain foundation of finite element method. Why this method is less appropriate for large deformation problem? How do you choose numerical method for different problems? Illustrate with examples. [8]
2. Write an algorithm and a program (C or Fortran or Matlab) for fast Fourier transform. With a suitable example explain what parameters can be identified with the help of time domain and frequency domain. [12]
3. (a) Derive equilibrium equations for 3D state of stress in a solid. [5]
 

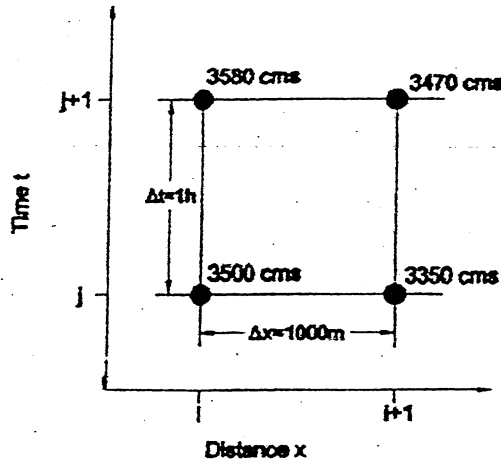
(b) What do you understand by axisymmetric problem? Write the constitutive relations and strain displacement relation for axisymmetric condition. [5]
4. (a) Formulate stiffness matrix for a bar element. Rotate the same bar element and formulate stiffness matrix for 2D truss element. [10]
 

(b) Determine the stiffness matrices for the element as shown in Fig. 1.  $A=300 \text{ mm}^2$  and  $E=2.1 \times 10^5 \text{ MPa}$ . [10]

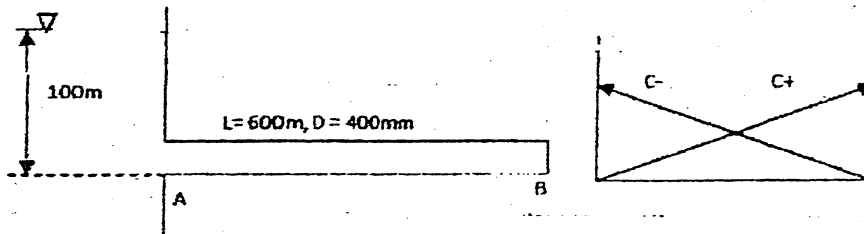


**Group B**

1. a) The value of flow rate  $Q$  at four points in the space-time grid are shown in figure below.  $\Delta t=1$  h,  $\Delta x=1000$ m and  $\theta=0.55$ , calculate the values of  $\partial Q/\partial t$  and  $\partial Q/\partial x$  by four point implicit method.  $\theta$  = weighting factor. [6]



- b) A flood of  $150\text{m}^3/\text{s}$  peak discharges passed a gaging station at 12:00 noon on a river. There is a community adjacent to the river 7.2 km downstream. What will be the value of peak discharge at that community at 12:00 noon of the velocity of flow is  $1.2\text{m/s}^2$  and peak discharge at that community at 9:00 A.M is  $100\text{m}^3/\text{s}$ . Assume width of river as inside and use first order accurate numerical scheme of kinematic wave equation, Take  $\Delta x= 7.2$  km and  $\Delta t = 1$  hrs. [6]
2. A pipe conveys water from a reservoir as shown in the figure. Take  $f = 0.02$ ,  $C = 1200\text{m/s}$ . The hydraulic grad line (HGL) at the reservoir is given as  $H_{PA} = 100+3\sin(\pi t)$ . The discharge at the downstream end is zero at all times. By using only one reach, compute discharge from A and elevation of hydraulic grad line at B at 3Sec using discretized equation of the method of characteristics in the form of HGL and discharge. [8]



3. Finite difference equation for simulating river stage-water table interactions considering one dimensional flow. [8]

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