7. For a steady state incompressible fluid flow through the geometry shown in Fig. 4, form a solution matrix using upwind scheme for the two intermediate nodes in between 1 and 2. Given: $A = A_0 - |K|x$, u_1 and u_2 are the respective velocities at node 1 and 2 respectively, p_1 and p_2 are the pressure values read at node 1 and 2 respectively.

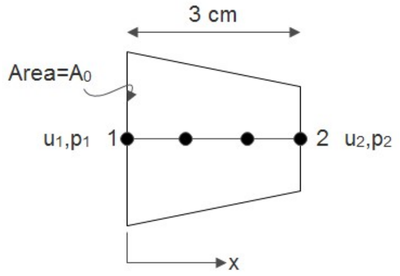


Fig.4

12

Group – E

8. A liquid of density 1000 kg/m^3 and viscosity 0.001 Pa.s is flowing over the inclined plane as shown in Fig. 5. Using artificial compressibility method, develop a solution matrix for evaluating pressure and velocity at three intermediate nodes. Assume the flow is in streamlined condition. Given: sound velocity =1520 m/s.

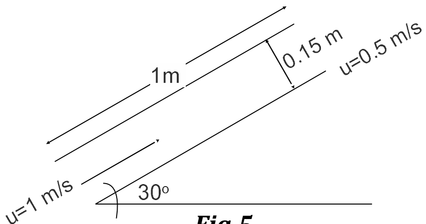


Fig.5

12

9. Using SIMPLE-C algorithm develop the solution matrix for the problem given in Fig. 6 after considering three intermediate nodes. Assume the flow is at steady state condition. Evaluate the pressure and velocity at the nodes after execution of one iteration.

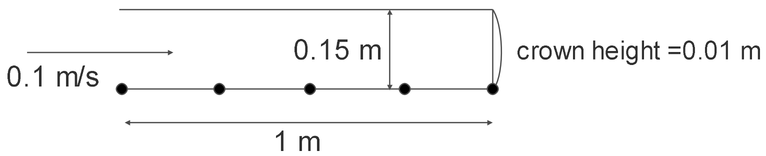


Fig. 6

(7 + 5) = 12

COMPUTATIONAL FLUID DYNAMICS
(CHEN 3232)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Central difference scheme can be applied for Peclet number
(a) greater than 2 (b) less than 2
(c) equal to 2 (d) both (a) and (c).

(ii) For creeping flow, the Reynold's number is less than or equal to
(a) 0.1 (b) 1.0 (c) 2.0 (d) 0.5.

(iii) In SIMPLE-C algorithm, the deviation in the neighbourhood property against a node
(a) is equal to the deviation in the property at the node
(b) is more than the deviation in the property at the node
(c) is equal to the deviation in the property at the node
(d) is equal to the deviations in the pressure gradient at the node.

(iv) The validity of periodic boundary condition is justified for
(a) a finite domain on the control volume
(b) an infinite domain on the control volume
(c) an infinite domain on the control surface
(d) both (b) and (c).

(v) Marching problem mainly attributes to
(a) parabolic equation (b) hyperbolic equation
(c) elliptical equation (d) Poisson equation.

(vi) The artificial compressibility factor is defined as
(a) the square of the acoustic velocity
(b) the square root of the acoustic velocity
(c) the cube root of the acoustic velocity
(d) the cube of the acoustic velocity.

(vii) During multigrid method the internodal distance at level 2 of coarse grid is equal to
(a) twice of fine grid internodal distance
(b) four times of fine grid internodal distance
(c) eight times of fine grid internodal distance
(d) thirtytwo times of fine grid internodal distance.

(viii) The stability of the scheme is achieved when amplification factor is
(a) equal to one (b) greater than 1
(c) less than 1 (d) both (a) and (c).

(ix) In finite volume method, every property is estimated ___________ of the control volume.
(a) at the centre
(b) at the faces
(c) both (a) and (b)
(d) at any interpolated point between the centre and face.

(x) Acceptability of meshing can only be ensured when the orthogonality of the meshing is in the range
(a) 0.01-0.10 (b) 0.10-0.15 (c) 0.15-0.20 (d) 0.01-0.15.

Group – B

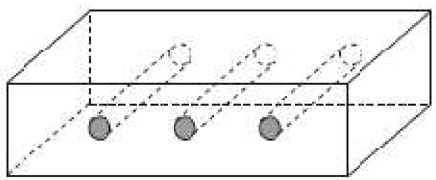
2.

Fig. 1

Derive one convection-diffusion type equation for the one directional fluid flow between two parallel plates (Fig. 1) of width 'w' m and 'D' m apart. The velocity of the fluid at the leading edge is u m/s. The viscosity and density of the fluid are μ Pa.s and ρ kg/m³ respectively.

12

3. Define the computational domain and write the full system of governing equations and boundary conditions for the following situations. In all of them, consider a long straight duct with smooth walls and uniformly distributed circular pipes crossing the duct in the direction perpendicular to the duct axis and parallel to one set of walls:



(i) There is a flow of air along the duct. Air can be assumed incompressible and having constant temperature equal to the temperature of the duct walls and pipes.

(ii) The same as in (i), but now temperature varies. The cylinders are maintained at constant temperature T_c, which is significantly higher than the air temperature T_i at the duct inlet. The duct walls are thermally perfectly insulating. Air is still assumed incompressible.

(iii) The duct is now filled with a solid material of density ρ, specific heat C, and conductivity κ. Temperature of the cylinders is T_c and the temperature of the walls is T_w.

(4 + 4 + 4) = 12

Group – C

4. For an unsteady state heat conduction problem given by $\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$, find out the value of temperature (T) at three equi-spaced nodes on a 4 m iron rod after 0.2 s using implicit scheme. Given: T(x = 0) = 90°C; T(x = 4) = 30°C; $\alpha = 2.3 \times 10^{-5}$ m²/s; Δt = 0.1 s.

12

5. The convection-diffusion equation that is applicable here is given as below, $\frac{\partial \varphi}{\partial t} = \alpha\left(\frac{\partial^2 \varphi}{\partial x^2} + \frac{\partial^2 \varphi}{\partial y^2}\right)$. Applying ADI scheme evaluate the property value at 1, 2, 3 and 4 node at time 1 s. Δt = 0.5 s; Δx = 0.1 cm; Δy = 0.1 cm.

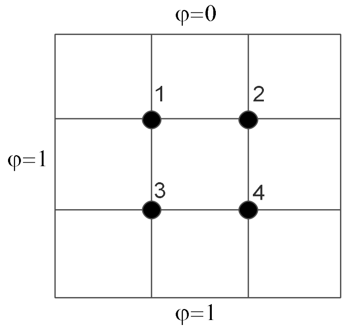


Fig.2

12

Group – D

6. In Fig. 3 air flows at a speed of 3 m/s over a flat surface of a volatile matter 'A'. The concentration boundary layer grows with a constant slope leading to a maximum thickness (δ) as shown in the figure. Assuming the process is at the steady state, formulate an error matrix for the next level coarse grid using multigrid technique. Given: Δx = 0.125 m; Δy = 0.05 m; diffusion coefficient of A in air at 25°C and 1 atm = 8.3×10^{-6} m²/s.

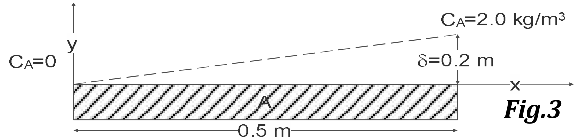


Fig.3

12