(v) SIMPLE - C algorithm shows ________________ the SIMPLE algorithm
(a) slower convergence than
(b) faster convergence than
(c) same convergence as
(d) none of these.

(vi) For tetrahedral mesh the skewness of the cell is defined as ____________
(a) $\max\left[\frac{\theta_{max}-60^o}{120^o}, \frac{60^o-\theta_{min}}{60^o}\right]$ (b) $\max\left[\frac{\theta_{max}-90^o}{90^o}, \frac{90^o-\theta_{min}}{90^o}\right]$
(c) $\min\left[\frac{\theta_{max}-60^o}{120^o}, \frac{60^o-\theta_{min}}{60^o}\right]$ (d) $\min\left[\frac{\theta_{max}-90^o}{90^o}, \frac{90^o-\theta_{min}}{90^o}\right]$.

(vii) In ________________ framework, the property value depends on the initial position
(a) lagrangian (b) eulerian
(c) both (a) and (b) (d) none of these.

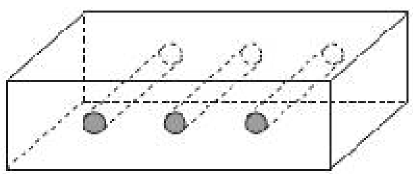
(viii) To obtain the solution of Navier - Stokes equation for a fluid flowing through a pipe with constant pressure drop, the meshing may be done with the __________________________grid formation.
(a) staggered (b) collocated
(c) both (a) and (b) (d) none of these.

(ix) In case of shock wave formation in a compressible flow, Mach number (Ma) is ____________________
(a) equal to 1 (b) less than 1
(c) greater than 1 (d) equal to any value between 0 to 10.

(x) For acceptable meshing of a domain, the orthogonality of mesh must be in between
(a) 0.001 and 0.14 (b) 0 and 0.001
(c) 0.03 and 0.15 (d) 0.15 and 0.2.

Group – B

2. 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:



Group – E

8. (a) "Artificial compressibility method is capable to solve a transient domain." – Justify the correctness of the statement.

(b) For an incompressible fluid flow inside a rectangular pipe along the length, apply the artificial compressibility technique in order to solve the flow domain (show two iterations)
ρ_{fluid} = 1000 kg/m^3; μ = 0.001 Pa.s; length of the pipe = 1 m; width of the pipe = 0.5 m; velocity = 0.1m/s

3 + 9 = 12

9. (a) "For a pressure-velocity coupled flow field, the staggered grid conformation becomes useful instead of collocated grid." – Justify the appropriateness of the statement with relevant mathematical expression.

(b) The free stream velocity of water inside two flat plates kept 0.1 m parallel is 5 m/s. The gauge reading shows that there is a pressure drop of 0.5 kgf / m^2, for the entire flow path length of 1 m. Consider the flow is laminar and the surface of the plates are very smooth and their width is equal to 0.5 m. The kinematic viscosity of water = 10^{-6} m^2/s. Calculate the pressure and velocity profile within the plate using SIMPLE algorithm (do for one iteration).

3 + 9 = 12

B.TECH/CHE/6TH SEM/CHEN 3232/2017
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 <u>any 5 (five)</u> from Group B to E, taking <u>at least one</u> 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) To apply upwind difference scheme the Peclect number of the cell should be ________________
(a) equal to 2 (b) greater than 2
(c) less than 2 (d) none of these.

(ii) The unsteady state heat equation for one dimensional heat transfer problem is a _________________________ type of equation
(a) parabolic (b) elliptic
(c) hyperbolic (d) none of these.

(iii) Multigrid method ________________
(a) converts higher order to lower order error distribution
(b) converts lower order to higher order error distribution
(c) reduces the residuals at each level
(d) both (a) and (c).

(iv) For application of Gauss - Siedel method, ________________________
(a) the coefficent matrix must be diagonally dominant
(b) the matrix must consists of non - zero diagonal elements
(c) the matrix must have a non - zero determinant
(d) all of the above.

(a) 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.

(b) The same as in (a), 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 insulated. Air is still assumed incompressible.

(c) 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

3. (a) For a flow inside an open channel, what may be the nature of the grids? Justify your answer.

(b) Evaluate the unsteady momentum balance equation inside a rectangular duct (L × W × H dimension), where the Reynold's number for the flow is equal to 190,000 considering the following facts:

- The flow is unidirectional with a free stream velocity U_∞.
- The viscosity and the density of the fluid are given as μ and ρ respectively.
- For a turbulent flow, the fluctuating terms are given as u' (velocity in the direction of the flow), v' (velocity normal to the direction of the flow) and p' (fluctuating term for pressure).

5 + 7 = 12

Group – C

4. (a) Consider the generic transport equation $\varphi_t + u\varphi_x = \mu\varphi_{xx}$, where u is a known function of x and t and μ is a constant coefficient. Assume that the computational grid is uniform with steps Δx and Δt. Write the finite difference schemes satisfying the following requirements:

i. Explicit scheme of the first order in time and second order in space. Use central differences for the space derivatives.

ii. Follow the requirements in (a), but the scheme is implicit.

(b) For a problem $\frac{\partial \phi}{\partial t} - u\frac{\partial \phi}{\partial x} = 0$, show that forward in time-central in space (FTCS) scheme is consistent, but unstable.

(4 + 3) + 5 = 12

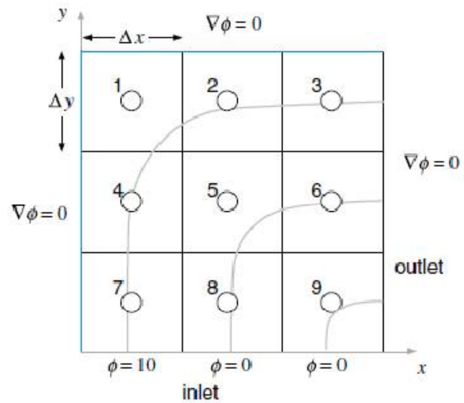
5. (a) A 1 m long bar has an initial temperature at 35^{0}C. Suddenly its temperature is raised to 70^{0}C. Solve the system using ADI method. Thermal diffusivity of the bar = 17.03 × 10^{-6} m^2/s. Assume within the bar there is only unidirectional energy flow and thermal diffusivity is invariant to the temperature. Show atleast two iterations.

(b) If one wants to solve a unidirectional unsteady state heat transfer problem using explicit method, for what maximum value of time step the scheme may be stable? Assume step size in space (Δx) = 0.1 unit.

10 + 2 = 12

Group – D

6. Consider the steady transport of a scalar / in the domain shown in the figure below. The governing conservation equation is given by, $\nabla\bullet(\rho v\phi) = 0$, where ρ = 1, $v = 2yx^2\hat{i} - 2xy^2\hat{j}$ and Δx = Δy = 1/3. Using UPWIND scheme discretize the equation over the computational domain and find the value of ϕ at each element centroid.



12

7. (a) For a convection-diffusion property transport problem in one direction the equation is given as $\frac{\partial \phi}{\partial t} = \Gamma\frac{\partial^2 \phi}{\partial x^2}$. Find out the solution matrix for the system within a length of 1 m using upwind differencing, when Γ = 0.1 kg/ms, u=2.5 m/s, ρ=1 kg/m^3. The boundary conditions are given as Φ(0) = 1 and Φ(1) = 0. Assume Δx = 0.1.

(b) Comment on the significance of cell Peclet number on the selection of finite volume method.

10 + 2 = 12