DHANALAKSHMI SRINIVASAN

COLLEGE OF ENGINEERING AND TECHNOLOGY

MAMALLAPURAM, CHENNAI

(Affiliated to Anna University, Chennai ,Approved by AICTE and Accreditated by NACC)

DEPARTMENT OF AERONAUTICAL ENGINEERING

COURSE CODE	:	C403
SUBJECT CODE	**:**	**ME8093 (Regulation 2017)**
SUBJECT NAME	**:**	**COMPUTATIONAL FLUID DYNAMICS**
YEAR / SEMESTER	**:**	**IV / VII**

QUESTION BANK

Subject Code & Name : ME8093 – Computational Fluid Dynamics

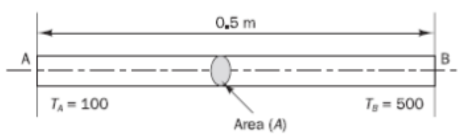
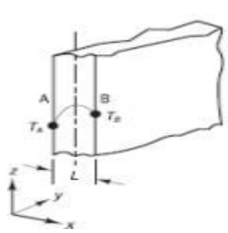
Year / Sem : III / V

UNIT I GOVERNING EQUATIONS AND BOUNDARY CONDITIONS			
Q.No	**Question**	**BT Level**	**Competence**
	PART – A		
1.	Classify the behaviour of the following partial differential equation within the region $-1 < y < 1$, from the roots of the characteristic equation. $y\frac{\partial^2\phi}{\partial x^2} + \frac{\partial^2\phi}{\partial y^2} = 0$.	BTL2	Understanding
2.	List the different stages of CFD simulation process.	BTL1	Remembering
3.	When do you use forward and backward difference expressions?	BTL2	Understanding
4.	Consider the following PDE. How many initial and/or boundary conditions are needed for completely defining the problem ? $\frac{\partial^2 T}{\partial r^2} + \frac{1}{r}\frac{\partial T}{\partial r} = \frac{1}{\alpha}\frac{\partial T}{\partial t}$.	BTL1	Remembering
5.	List the types of partial differential equation.	BTL1	Remembering
6.	Write the discretized form of $\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0$.	BTL2	Understanding
7.	What are the fundamental governing equation of fluid dynamics?	BTL2	Understanding
8.	What are the mathematical statement of three fundamental physical principles of fluid dynamics equations?	BTL2	Understanding
9.	Define control Volume	BTL2	Understanding
10.	Write the energy equation for viscus flow	BTL1	Remembering
11.	Example of explicitly method	BTL2	Understanding
12.	Define source and sink	BTL1	Remembering
13.	What are the important application of CFD in engineering	BTL2	Understanding
14.	Write the complete navier – stokes equation in conservation form	BTL2	Understanding
15.	Define control surface	BTL2	Understanding
16.	Different between elliptic , parabolic and hyperbolic equation	BTL2	Understanding
	PART – B & PART - C		

1.	Consider an infinitesimally small moving fluid element in a flow field. Derive systematically the mathematical form substantial derivative and state its physical significance.	BTL3	apply
2.	Prove that divergence of velocity using a suitable model of flow and physically interpret its meaning. $\nabla . V = \frac{1}{\delta V}\frac{D(\delta V)}{Dt}$	BTL3	Apply
3.	Explain the continuity equation and momentum equation.	BTL2	apply
4.	Write the characteristic and application of elliptic and parabolic equation	BTL2	Understanding
5.	Derive the X- momentum equation for an unsteady 3D compressible flow	BTL3	Apply
6.	Derive the general 3D equation for heat condition in cartesian coordinates.	BTL3	Apply
7.	Distinguish between elliptic, parabolic and hyperbolic system of PDEs applied to fluid flows. What are the types of boundary condition specific for flow problems	BTL2	Understanding
8.	Derive Turbulent–Kinetic Energy Equations	BTL3	Apply

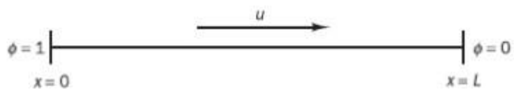
UNIT II FINITE DIFFERENCE AND FINITE VOLUME METHODS FOR DIFFUSION			
Q.No	**Question**	**BT Level**	**Competence**
PART – A			
1	Starting from Taylor series derive the finite difference schemes to approximate the following derivatives about node at, i. $\left(\frac{dT}{\partial t}\right)_i$, using the nodes at i and $i+1$.	BTL1	Remembering
2	Derive the finite difference scheme for the following 1 Dimensional unsteady heat conduction equation using an explicit lime marching technique $$\frac{\partial T}{\partial t} - \alpha\frac{\partial^2 T}{\partial x^2} = 0.$$	BTL3	Applying
3	What are the stability criteria for explicit and semi implicit schemes?	BTL1	Remembering
4	Obtain an expression for dp/dx, that is fourth order accurate	BTL1	Remembering
5	Define grid generation.	BTL1	Remembering
6	Write the advantage of structure grids in computation.	BTL1	Remembering
7	Differentiate between structure and unstructured grids.	BTL2	Understanding
8	State the merits and demerits of numerical grid generation technique.	BTL2	Understanding
9	Name the important error that occurs in numerical solution?	BTL2	Understanding
10	Bring out difference between Finite Volume and Finite Element Method?	BTL2	Understanding
11	What is Lax method?	BTL2	Understanding
12	Define node?	BTL1	Remembering
13	Define cell center?	BTL2	Understanding
14	Compare and Contrast Explicit and Implicit scheme?	BTL2	Understanding

15	.What is meant by no slip condition?	BTL2	Understanding
16	What is meant by no slip condition?	BTL2	Understanding
17	What is free surface?	BTL2	Understanding
	PART – B & PART C		
1	Derive the finite difference scheme to approximate the following 2D heat conduction equation using line by line approach with under relaxation technique. $$k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)+Q=0\,.$$	BTL3	Applying
2	Derive the integral form of the general transport equation for property ϕ in the mathematical form which is appropriate to finite volume methods. Also write in words the physical significance and meaning of each term in the derived integral equation.	BTL3	Applying
3	Explain any two algebraic/analytical methods of grid transformation. How are the boundary condition specified with respect to the transformation?	BTL2	Understanding
4	What is the need for grid generation? Explain how grid generation is achieved by the numerical solution of elliptic poison’s equations.	BTL2	Understanding
5	In the final worked example of this chapter we discuss the cooling of a circular fin by means of convective heat transfer along its length. Convection gives rise to a temperature-dependent heat loss or sink term in the governing equation. Shown in Figure 4.9 is a cylindrical fin with uniform cross-sectional area A. The base is at a temperature of 100°C (T_B) and the end is insulated. The fin is exposed to an ambient temperature of 20°C. One-dimensional heat transfer in this situation is governed by $$\frac{d}{dx}\left(kA\frac{dT}{dx}\right)-hP(T-T_\infty)=0 \qquad (4.40)$$ where h is the convective heat transfer coefficient, P the perimeter, k the thermal conductivity of the material and T_∞ the ambient temperature. Calculate the temperature distribution along the fin and compare the results with the analytical solution given by $$\frac{T-T_\infty}{T_B-T_\infty}=\frac{\cosh[n(L-x)]}{\cosh(nL)} \qquad (4.41)$$	BTL3	apply

6	A rectangular fin of length 2 cm, thickness 2 mm and breath 20 cm is attached to a plane wall. The wall temperature T_w = 200°C and ambient temperature T_∞ = 25°C. For the fin material, k = 45 W/m-K and the operating h = 15 W/m²-K, determine the steady state temperature distribution in the fin using finite volume method by taking 5 equal control volumes. Assume the fin tip is insulated.	BTL3	apply
7	A slab of steel L = 5 cm thick is initially at uniform temperature T_i = 450°C. Suddenly one of its surfaces is cooled to 90°C while the other surface is kept insulated. By using finite difference or finite volume method and mesh size Δx = 1 cm. Calculate the transient temperature distribution in the slab after 2 time steps. Take ρ = 8000 kg/m³, c = 0.42 kJ/kg-K and k = 50 W/m-K.	BTL3	apply
8	Consider the problem of source-free heat conduction in an insulated rod whose ends are maintained at constant temperatures of 100°C and 500°C respectively. The one-dimensional problem sketched in Figure 4.3 is governed by $$\frac{d}{dx}\left(k\frac{dT}{dx}\right)=0 \quad ....1$$ Calculate the steady state temperature distribution in the rod. Thermal conductivity k equals 1000 W/m.K, cross-sectional area A is 10×10^{-3} m2. 	BTL3	apply
9	Now we discuss a problem that includes sources other than those arising from boundary conditions. Figure 4.6 shows a large plate of thickness L = 2 cm with constant thermal conductivity k = 0.5 W/m.K and uniform heat generation q = 1000 kW/m3. The faces A and B are at temperatures of 100°C and 200°C respectively. Assuming that the dimensions in the y- and z-directions are so large that temperature gradients are significant in the x-direction only, calculate the steady state temperature distribution. Compare the numerical result with the analytical solution. The governing equation is $$\frac{d}{dx}\left(k\frac{dT}{dx}\right)+q=0$$ 	BTL3	apply

UNIT III FINITE VOLUME METHOD FOR CONVECTION DIFFUSION			
Q.No	**Question**	**BT Level**	**Competence**
	PART – A		
1.	Write short notes on conservativeness properties of finite volume based discretization schemes using relevant examples.	BTL1	Remembering
2.	Write short notes on steady correction diffusion of a property.	BTL1	Remembering
3.	What is upwind differencing scheme?	BTL1	Remembering
4.	Mention any two differences between implicit and explicit method.	BTL1	Remembering
5.	Define boundary layer.	BTL1	Remembering
6.	State the advantages of upwind differencing	BTL1	Remembering
7.	What is meant by conservativeness?	BTL2	Understanding
8	What is the need of upwind scheme?	BTL2	Understanding
9.	What is parabolizing and linearizing equation?	BTL2	Understanding
10.	What is linearizing equation?	BTL2	Understanding

11.	Define convergence and Lax equivalence Theorem?	BTL2	Understanding
12.	Define Peclet number and state its importance?	BTL2	Understanding
13.	What are the limitations of panel method?	BTL2	Understanding
14.	What are the thermal conditions at boundary wall?	BTL2	Understanding
15.	Define vortex sheet?	BTL2	Understanding
16.	Define over determined system?	BTL2	Understanding
17.	Define courant method?	BTL2	Understanding
18.	Where are CFD used?	BTL2	Understanding
19.	What is the formulation of FVM?	BTL2	Understanding
PART – B & PART – C			
1	Consider the model equation $\frac{\partial u}{\partial t} + a\frac{\partial u}{\partial x} = \alpha\frac{\partial^2 u}{\partial x^2}$. i) Write an explicit formulation using a first-order forward differencing in time, a first-order backward differencing in space for the convection term and a second-order central differencing for the diffusion term. ii) Use von Neumann stability analysis to determine the stability requirement of the scheme.	BTL3	apply
2	Explain a typical implicit time dependent method for the solution of viscous compressible flows with model flow equations.	BTL3	Applying
3	Describe upwind discretization.	BTL3	Applying
4	Explain the explicit scheme of discretization and its stability properties.	BTL2	Understanding
5	Derive the discretized equations for a 1D convection – diffusion for the boundary nodes using QUICK scheme. Take 5 equal control volumes.	BTL3	Applying
6	Derive the discretized equations for a 1D convection – diffusion for interior nodes using upwind scheme for convective terms. Take five equal control volumes.	BTL3	apply
7	The steady convection diffusion of a property φ in a one dimensional flow field, u is given by $\frac{d(\rho u\varphi)}{dx} = \frac{d}{dx}\left(\Gamma\frac{d\varphi}{dx}\right)$. Integrating this transport equation over a control volume, derive the finite volume schemes using exponential scheme. (13)	BTL3	apply
8	The steady convection diffusion of a property φ in a one dimensional flow field, u is given by $\frac{d(\rho u\varphi)}{dx} = \frac{d}{dx}\left(\Gamma\frac{d\varphi}{dx}\right)$. Integrating this transport equation over a control volume, derive the finite volume schemes using QUICK scheme for, (13) (i) $u_e, u_w < 0$; (ii) $u_e, u_w > 0$;	BTL3	Applying

9	A property ϕ is transported by means of convection and diffusion through the one-dimensional domain sketched in Figure 5.2. The governing equation is (5.3); the boundary conditions are $\phi_0 = 1$ at $x = 0$ and $\phi_L = 0$ at $x = L$. Using five equally spaced cells and the central differencing scheme for convection and diffusion, calculate the distribution of ϕ as a function of x for (i) Case 1: $u = 0.1$ m/s, (ii) Case 2: $u = 2.5$ m/s, and compare the results with the analytical solution $$\frac{\phi - \phi_0}{\phi_L - \phi_0} = \frac{\exp(\rho u x/\Gamma) - 1}{\exp(\rho u L/\Gamma) - 1} \quad (5.15)$$ (iii) Case 3: recalculate the solution for $u = 2.5$ m/s with 20 grid nodes and compare the results with the analytical solution. The following data apply: length $L = 1.0$ m, $\rho = 1.0$ kg/m^3, $\Gamma = 0.1$ kg/m.s. 	BTL3	apply

UNIT IV FLOW FIELD ANALYSIS			
Q.No	**Question**	**BT Level**	**Competence**
PART - A			
1.	Mention the issue of odd-even decoupling of velocity and pressure pertinent to a structured collocated finite volume grid.	BTL1	Remembering
2.	Write a short note on PISO algorithm and what it is abbreviated for?	BTL1	Remembering
3.	Mention any two differences between implicit and explicit method	BTL1	Remembering
4.	Define shape function	BTL1	Remembering
5.	Define finite element method	BTL1	Remembering
6.	Define boundary value problem.	BTL1	Remembering
7.	Write the governing equation for a 2d incompressible flow and discuss the non- linearity present in the equation.	BTL2	Understanding
8.	Define staggered grid?	BTL2	Understanding
9.	What is the basis of FVM?	BTL2	Understanding

10	Define Delaunay Triangle?	BTL2	Understanding
11	Write the unstructured grid generation methodology?	BTL2	Understanding
12	Define mixed element grid?	BTL2	Understanding
13	Write the advantages of adaptive grid?	BTL1	Remembering
14	Define Adaptive Grids?	BTL2	Understanding
15.	What is the need of grid generation?	BTL2	Understanding
16.	What is a panel singularity?	BTL2	Understanding
17.	What is parabolizing equation?	BTL2	Understanding
18.	What is linearizing equation?	BTL2	Understanding
PART – B & PART - C			
1	Derive and explain the steps involved in the SIMPLE algorithm to solve the incompressible Navier-Stokes equation in two – dimensions indexing using a finite volume grid.	BTL3	apply
2	Derive and explain the steps involved in the PISO algorithm to solve the incompressible. Navier-Stokes equation in two — dimensions indexing using a finite volume grid.	BTL3	apply
3	Consider the solution of the steady one dimensional heat conduction problem in a region with constant thermal properties. The governing equation is $T'' = \frac{d^2T}{dx^2} = 0, 0 < x < 1$ With the boundary conditions T(0) = 1 and T(1) = 0. The analytical solution of this equation is T = 1 – x. Describe the finite element solution procedure for this problem (Take number of elements to be 4).	BTL3	apply
4	) Assume a suitable 2-D heat transfer problem and compare the relative merits of i) The Jacobi, ii) The Gauss-Seidel and iii) The successive over-relaxation methods.	BTL3	apply
5	Explain the various stages of finite element techniques.	BTL2	Understanding
6	Describe weak formulation of a boundary value problem.	BTL2	Understanding
7	Derive the discretized equations for velocity corrections (u, v) and pressure correction and discuss the solution steps using SIMPLE algorithm.	BTL3	apply

8	Discuss PISO algorithm in detail.	BTL2	Understanding
9	Derive an expression for staggered grid?	BTL3	apply
10	Derive an expression about momentum equation?	BTL3	apply
11	Derive an expression for simple algorithm?	BTL3	apply

UNIT V TURBULENCE MODELS AND MESH GENERATION

Q.No	Question	BT Level	Competence
	PART - A		
1.	List the three major classifications of turbulence modelling technique.	BTL1	Remembering
2.	Write the mathematical relationship for the Boussinesq approximation of Reynolds stresses and define the terms involved in it.	BTL1	Remembering
3.	What are the mixing lengths for jets and wakes?	BTL1	Remembering
4.	List the turbulence models available.	BTL1	Remembering
5.	Define time step.	BTL1	Remembering
6.	Write the steps involved in SIMPLE algorithm.	BTL1	Remembering
7.	What do you mean by contravariant velocity components ?	BTL2	Understanding
8.	Define Peclet number and state its importance.	BTL2	Understanding
9.	Where is CFD used?	BTL2	Understanding
10.	What are the commercial software used for CFD?	BTL2	Understanding
11.	What are the advantage of CFD?	BTL2	Understanding
12.	Why use CFD?	BTL2	Understanding
13.	What are the advantages of adaptive grid?	BTL2	Understanding
14.	How to reduce the truncation error?	BTL2	Understanding
15.	Write about grid distribution?	BTL2	Understanding
16.	State importance of mesh quality of good solution?	BTL2	Understanding

17.	What is grid refinement?	BTL2	Understanding
18.	Define structured grid?	BTL2	Understanding
19.	Define unstructured grid?	BTL2	Understanding
20.	What is advantage of FVM?	BTL2	Understanding
	PART – B & PART - C		
1	Write the k- ε two equation turbulence model and explain the physical significance of each term in the derived equations.	BTL3	apply
2	What is the difference between grid-oriented velocity components and Cartesian velocity Components? What are the merits and demerits of grid oriented velocity components?	BTL3	apply
3	i) Briefly explain explicit Lax-Vendoroff scheme of time dependent methods. ii) Discuss solution procedure for Runge-Kutta time stepping. iii) Write brief note on cell vortex formulation.	BTL3	apply
4	i) What is meant by "Wiggles" in the numerical solution ?" Describe with an example. ii) Consider steady 1-D convection-diffusion equation of a property ϕ $\frac{d}{dx}(\rho u \phi) = \frac{d}{dx}\left(\Gamma \frac{d\phi}{dx}\right)$ Using control volume approach discritise the above equation and obtain the neighboring coefficients by 1) Central difference scheme. 2) Upwind differencing scheme.	BTL3	apply
5	Describe the finite volume techniques.	BTL2	Understanding
6	With a neat sketch, explain SIMPLE algorithm.	BTL1	Remembering
7	Discuss the mixing length model.	BTL3	apply
8	Discuss any two low Reynolds number turbulence models. Discuss the various constants and functions used for predicting near wall behavior.	BTL3	apply
9	Discuss any two low Reynolds number turbulence models. Discuss the various constants and functions used for predicting near wall behavior.	BTL2	Understanding
10	Describe about mixing model in detail?	BTL2	Understanding