Reg. No. :

Question Paper Code : 40817

B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2021.

Seventh/Eight Semester

Mechanical Engineering

ME 8093 – COMPUTATIONAL FLUID DYNAMICS

(Common to B.E. Aeronautical Engineering/B.E. Manufacturing Engineering/ B.E. Mechanical Engineering (Sandwich)/B.E. Mechanical and Automation Engineering)

(Regulations 2017)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Classify the behaviour of the following partial differential equation within the region $-1 < y < 1$, from the roots of the characteristic equation. $y\dfrac{\partial^2\phi}{\partial x^2} + \dfrac{\partial^2\phi}{\partial y^2} = 0$.

2. List the different stages of CFD simulation process.

3. Starting from Taylor series derive the finite difference schemes to approximate the following derivatives about node at, i.

   $\left(\dfrac{dT}{\partial t}\right)_i$, using the nodes at i and $i+1$.

4. Derive the finite difference scheme for the following 1-Dimensional unsteady heat conduction equation using an explicit lime marching technique $\dfrac{\partial T}{\partial t} - \alpha\dfrac{\partial^2 T}{\partial x^2} = 0$.

5. Write short notes on conservativeness properties of finite volume based discretization schemes using relevant examples.

6. Write short notes on steady correction diffusion of a property.

7. Mention the issue of odd-even decoupling of velocity and pressure pertinent to a structured collocated finite volume grid.

8. Write a short note on PISO algorithm and what it is abbreviated for?

9. List the three major classifications of turbulence modelling technique.

10. Write the mathematical relationship for the Boussinesq approximation of Reynolds stresses and define the terms involved in it.

PART B — ($5 \times 13 = 65$ marks)

11. (a) Consider an infinitesimally small moving fluid element in a flow field. Derive systematically the mathematical form substantial derivative and state its physical significance. (13)

Or

(b) Prove that divergence of velocity $\nabla . V = \frac{1}{\delta V} \frac{D(\delta V)}{Dt}$ using a suitable model of flow and physically interpret its meaning. (13)

12. (a) Derive the finite difference scheme to approximate the following 2D heat conduction equation using line by line approach with under relaxation technique. (13)

$$k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) + Q = 0.$$

Or

(b) 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. (13)

13. (a) 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) $u_e, u_w > 0$;

Or

(b) 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)

14. (a) 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. (13)

Or

(b) 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. (13)

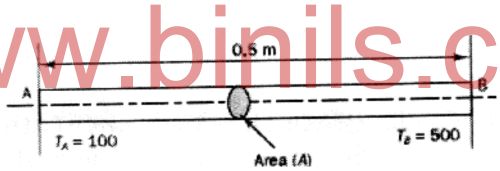
15. (a) Write the k-ε two equation turbulence model and explain the physical significance of each term in the derived equations. (13)

Or

(b) What is the difference between grid-oriented velocity components and Cartesian velocity Components? What are the merits and demerits of grid oriented velocity components? (13)

PART C — (1 × 15 = 15 marks)

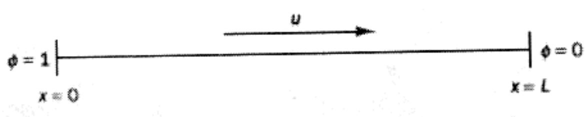
16. (a) Consider the problem of source-free heat conduction in an insulated rod whose ends are maintained at constant temperatures of 100°C and 500°C respectively. The one-dimensional problem sketched in the following Figure is governed by $\frac{d}{dx}\left(k\frac{dT}{dx}\right)=0$. (15)



Thermal conductivity k equals 1000 W/m.K, cross-sectional area A is 10×10^{-3} m^2. Divide the length of the rod into five control volumes and discretize the above mentioned governing equation on these control volumes, using central differencing scheme for the diffusion term, Represent the resulting set of algebraic equations in a matrix form which are solved to calculate the steady state temperature distribution at the respective cell centres of the chosen control volumes.

Or

(b) A property ϕ, is transported by means of convection and diffusion through the one-dimensional domain sketched in following Figure. The governing equation is given by $\frac{d}{dx}(\rho u\phi)=\frac{d}{dx}\left(\Gamma\frac{d\phi}{dx}\right)$. (15)



The boundary conditions are $\phi_0 = 1$ at $\phi_L = 0$ at $x = L$. Divide the domain into five equally spaced control volumes and discretize the above mentioned governing equations on these control volumes, using central differencing scheme for convection and diffusion terms. Represent the resulting set of algebraic equations in a matrix form which are solved to calculate the distribution of ϕ at the respective cell centres of the chosen control volumes for u = 0.1 m/s. The following data apply: length L = 1.0 m, ρ 1.0 kg/m^3, Γ = 0.1 kg/ms.
