Reg. No. :

Question Paper Code : 20843

B.E./B.Tech. DEGREE EXAMINATIONS, APRIL/MAY 2022.

Seventh/Eighth Semester

Aeronautical Engineering

ME8093 – COMPUTATIONAL FLUID DYNAMICS

(Common to: Manufacturing Engineering/Mechanical Engineering/ Mechanical Engineering (Sandwich)/ Mechanical and Automation Engineering)

(Regulations 2017)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is substantial derivative and what does it represent significantly?

2. Why time averaged equation is required for turbulent modelling?

3. Derive the first order forward difference equation for temperature.

4. What is the difference between finite volume method and finite difference method?

5. State if the following statements are (True/False)

   (a) Crank-Nicholson's Scheme is stable and second order accurate in both time and space for the unsteady diffusion equation.

   (b) For Crank-Nicolson's scheme, the point of discretization is (i, j).

6. Define discretization error and roundoff error.

7. What are the advantages of staggered grid in control volume method?

8. Define and state the significance of Courant Number and Peclet Number.

9. What do you mean by structured grid?

10. Define turbulence and mention different turbulence models.

PART B — (5 × 13 = 65 marks)

11. (a) Discuss the various boundary conditions available to solve partial differential equations (PDE). And derive momentum equation in differential form. (4+9)

Or

(b) (i) Write down both conservation and non-conservation form of energy equation for a 3D unsteady, compressible and viscous flow. (5)

(ii) Derive the continuity equation for infinitesimally small element fixed in space and obtain the non-conservative differential form. (8)

12. (a) Derive the discretized equation for 1-D transient heat conduction in a slab using explicit scheme. (13)

Or

(b) (i) What are the differences between explicit and implicit approach?

(ii) What are the physical behaviours of elliptic and parabolic partial differential equation?

(iii) What are the sufficient and necessary conditions for the convergence of iterative scheme? (3+5+5)

13. (a) Consider 1-D, steady convection and diffusion problem. Discretize the governing equation using hybrid scheme. (13)

Or

(b) Derive the discretized equations of $\frac{\partial T}{\partial t} + \alpha \frac{\partial T}{\partial x^2} = \alpha \frac{\partial^2 T}{\partial x^2}$ using

(i) explicit scheme,

(ii) implicit scheme and

(iii) Crank Nicolson scheme using finite difference method with central difference scheme. (4+4+5)

14. (a) Discuss the SIMPLE (Semi implicit methods for pressure linked equations) algorithm in detail with help of an example. (13)

Or

(b) Discretize the unsteady 1-D heat conduction equation without heat generation for DuFort- Frankle Scheme and discuss its consistency. (13)

15. (a) Discuss the standard k-ε and low Reynolds k-ε model. (13)

Or

(b) Describe the advantages and disadvantages of structured and unstructured grid. Write a brief note on various methods of discretisation in unstructured grid. (5+8)

PART C — (1 × 15 = 15 marks)

16. (a) A thin plate is initially at a uniform temperature of 200 °C. At a certain time t = 0, the temperature of the east side of the plate is suddenly reduced to 0°C. The other surface is insulated. Use the explicit finite volume method in conjunction with a suitable time step size (take time step as 2s and with of interval between nodes as 0.004 m) to calculate the transient temperature distribution of the slab (at least for two nodes). The data are: plate thickness L = 2 cm, thermal conductivity k = 10 W/mK and volumetric heat capacity $(\rho_c) = 10 \times 10^6\ J/m^3K$. (15)

Or

(b) A cylindrical fin with cross-sectional area 'A'. The base is at temperature (T_b) of 100°C 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

$$\frac{d}{dx}\left(kA\frac{dT}{dx}\right) - hP(T - T_\infty) = 0$$

Where, h = convection heat transfers co-efficient, P = perimeter, k = thermal conductivity of the material and T_∞ is the ambient air temperature. L is length of the fin, Calculate the temperature distribution along the fin and compare it with analytical solution given by the following expression.

$$\frac{T - T_\infty}{T_b - T_\infty} = \frac{\cosh[z(L - x)]}{\cosh(zL)}$$

where, $z^2 = hP/(kA), x$ is the distance along the fin, Consider, L=1 m, $hP/(kA) = 25/m^2$ (note that KA is constant). To get finite volume solution, assume uniform grid, and divide the total length into five control volumes. (8+7=15)
