Exam Date & Time: 28-Nov-2022 (09:00 AM - 12:00 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

MANIPAL INSTITUTE OF TECHNOLOGY
VII SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV. 2022

Computational Fluid Dynamics [AAE 4075]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) A) Write the continuity equation for three-dimensional, unsteady and compressible flow in general and vector forms. (2)

B) Derive an expression for the Navier-Stokes equation in non-conservation form. (4)

C) What do you mean by the characteristic line? Explain the procedure to determine the characteristic line. (4)

2) A) Obtain the finite difference quotient form for $\left(\frac{\partial u}{\partial x}\right)_{i,j}$ using Newton's backward difference scheme. (4)

B) Consider a large uranium plate of thickness 3 cm and thermal conductivity of 28 W/m°C in which heat is generated uniformly at a constant rate of 6×10^5 W/m^3. One side of the plate is insulated while the other side is subjected to convection to an environment at 30°C with a heat transfer coefficient of 60 W/m^2 °C. Considering four equally spaced nodes with a nodal spacing of 1 cm, obtain the finite difference formulation and write the linear equations in matrix form. (3)

C) Consider a large uranium plate of thickness 3 cm and thermal conductivity of 28 W/m°C in which heat is generated uniformly at a constant rate of 6×10^5 W/m^3. One side of the plate is insulated while the other side is subjected to convection to an environment at 30°C with a heat transfer coefficient of 60 W/m^2 °C. Considering four equally spaced nodes with a nodal spacing of 1 cm, determine the nodal temperatures under steady conditions. (3)

3) A) Consider the initial boundary value problem

$$\frac{\partial u}{\partial t} = \alpha \frac{\partial^2 u}{\partial x^2}$$ (5)

Where, u is non-dimensional temperature, α is constant and t > 0.

The initial conditions are $u(x, 0) = e^{\pi x/4}$ for 0 < x < 1 and

boundary conditions are u(0, t) = 1, u(1, t) = 2.195 for all time, t ≥ 0

Use, $r = \frac{\alpha t}{(\Delta x)^2} = 0.8 \; and \; \Delta x = 1/4$

Determine the non-dimensional temperatures using a suitable method.

B) Show that for the abrupt variation in thermal conductivity, the interface conductivity is the harmonic mean of thermal conductivities of adjacent grids. (3)

C) What are the essential requirements of a control volume discretization scheme in order to get a physically realistic solution? (2)

4) In case of one-dimensional convection-diffusion flow, write a note on transportiveness property. (2)

A)

B) Derive an expression for the discretization equation by using the upwind differencing scheme considering the positive flow direction. (3)

C) The non-dimensional temperature distribution inside a metal block is given by

$$\frac{dy}{dx} = 2y + 7$$

(5)

The non-dimensional temperature at the extreme right grid is 11. Taking six grid points with spacing between the successive grids as 0.1, determine the non-dimensional temperature values at all grids using the Upwind Differencing Scheme.

5) State the advantages and disadvantages of staggered grid, in case of pressure linked velocity equations. (2)

A)

B) Explain the procedure to determine the pressure and velocity field using the SIMPLE algorithm. (3)

C) A one-dimensional convection-diffusion equation is given by

$$\frac{d}{dx}(\rho u \phi) = \frac{d}{dx}\left(\Gamma \frac{d\phi}{dx}\right)$$

The boundary conditions are $\phi_o = 1$ at x = 0 and $\phi_L = 0$ at x = L. Using five equally spaced cells and central differencing scheme for convection and diffusion, formulate the distribution of ϕ as a function of x for u = 0.5 m/s, L = 1 m, ρ = 1 kg/m^3 and Γ = 0.3 kg/m.s. (5)

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