Name:

Enrolment No:

UPES

End Semester Examination, May 2023

Course: Computational Fluid Dynamics **Semester: VI**

Program: B. Tech. Aerospace Engineering **Time : 03 hrs.**

Course Code: ASEG 3026P **Max. Marks: 100**

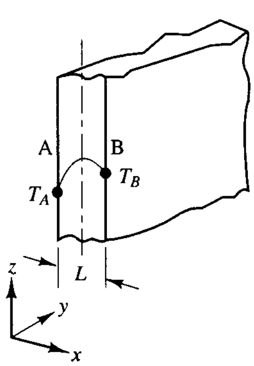
Instructions: Assume missing data appropriately. All the symbols used in the paper have their usual meanings.

SECTION A

(5Qx4M=20Marks)

S. No.		**Marks**	**CO**
Q 1	Choose the most appropriate answer. i. A finite difference solution contains diffusion error if the leading term in the truncation error has a. Second order derivative b. Third order derivative c. Fourth order derivative d. (a) or (c) ii. For inviscid flow the boundary condition at surface is a. u=0 b. v=0 c. $\mathbf{V}.\mathbf{n}$=0 d. Both a and b iii. Second order accurate discretization of second order derivatives using Taylor series involves a. 3 points b. 2 points c. 4 points d. 1 point iv. Diffusion error causes the shock wave to appear a. Thicker b. Thinner c. Wiggled	**4**	**CO2**

	d. Both a and c		
Q 2	Elucidate the use of Computational Fluid Dynamics as a research tool.	**4**	**CO1**
Q 3	Compare with illustrations, the explicit and implicit schemes for solution of partial differential equations.	**4**	**CO2**
Q 4	Discuss the effect of numerical diffusion and dispersion on the solution of the one-dimensional scalar wave equation using the explicit Forward in Time and Backward in Space (FTBS) scheme. Suggest methods to alleviate the diffusive error.	**4**	**CO2**
Q 5	Define the UDS interpolation scheme for the evaluation of fluxes at face center using the nodal values on a structured finite volume grid. Discuss its advantages and disadvantages.	**4**	**CO2**
SECTION B (4Qx10M= 40 Marks)			
Q 6	The following system of equations is elliptic. Determine the possible range of values for a. $$\frac{\partial u}{\partial x} - a\frac{\partial v}{\partial y} = 0$$ $$\frac{\partial v}{\partial y} + a\frac{\partial u}{\partial x} = 0$$	**10**	**CO1**
Q 7	Derive a second order accurate one-sided finite difference stencil for the first order derivative $\left(\frac{\partial u}{\partial x}\right)_{i,j}$.	**10**	**CO2**
Q 8	Perform a von Neumann stability analysis of the following methods for the solution of the first order wave equation given by $$\frac{u_i^{n+1} - u_i^n}{\Delta t} + c\frac{u_i^n - u_{i-1}^n}{2\Delta x} = 0$$ Hence, deduce the stability criteria for this numerical scheme.	**10**	**CO3**
Q 9	Discuss an explicit time marching algorithm for the solution of transient Euler equations in 2-dimensions. ***OR*** Consider the 2-dimensional transient heat conduction equation given below. The Crank-Nicolson discretization of the equation results in a pentadiagonal	**10**	**CO3**

	system of equations. Demonstrate an algorithm to solve the system of equations iteratively. $$\frac{\partial T}{\partial t} = \alpha \left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right)$$		
	SECTION-C **(2Qx20M=40 Marks)**		
Q 10	Consider a two-dimensional square plate ABCD with edges AB and CD maintained at temperatures of 400 K and 100 K respectively. The edge DA is maintained at a temperature of 400 K while BC is an adiabatic wall. Find the steady state temperatures of at least 9 locations on the plate. Take *AB*=*BC*=*CD*=*DA*= 4 cm. Use a point iterative relaxation scheme for at least 4 iterations with an over-relaxation factor of 1.2. The two-dimensional steady state heat conduction is governed by $$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0$$ ***OR*** Consider a large flat plate of thickness L = 2 cm with constant thermal conductivity k = 0.5 W/m.K and uniform heat generation q =1000 kW/m^3. The opposite faces A and B, as shown in figure below at maintained at temperatures of 100 ^{o}C and 200 ^{o}C respectively. Assuming the heat conduction to be one-dimensional, estimate the steady state temperature distribution in the plate.  	**20**	**CO4**

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<td>The governing equation can be assumed as

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right) + q = 0$$</td>
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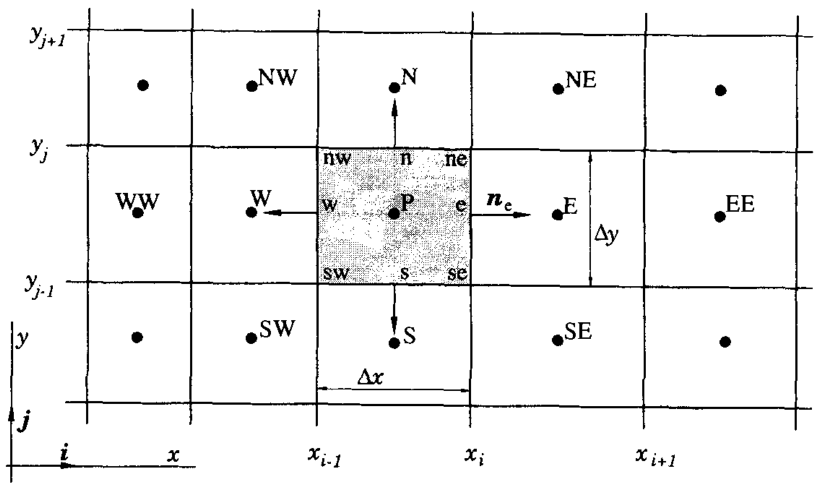
<td>Q 11</td>
<td>Consider the solution for a left to right flow of an inviscid fluid over a 2-dimensional space on a structured grid shown in the figure below.



i. If the values of various variables at the computational nodes are, $\rho_{WW} = 1.6$ kg/m^3, $u_W = 300$ m/s, $\rho_W = 1.4$ kg/m^3, $u_W = 500$ m/s, $\rho_P = 1.2$ kg/m^3, $u_P = 700$ m/s, $\rho_E = 4.8$ kg/m^3, $u_E = 200$ m/s, $\rho_{EE} = 5.0$ kg/m^3, and $u_W = 150$ m/s, calculate the value of mass flux and *x*-momentum flux at the center of the east face *e*, using CDS. Assume $x_e - x_P = 4$ mm, $x_E - x_P = 10$ mm.

ii. If the value of mass fluxes at points *ne, e, se, s, sw, w, nw*, and *n* are 5 kgm^{-2}s^{-1}, 8 kgm^{-2}s^{-1}, 11 kgm^{-2}s^{-1}, 9 kgm^{-2}s^{-1}, 7 kgm^{-2}s^{-1}, 5 kgm^{-2}s^{-1}, 5 kgm^{-2}s^{-1}, and 5 kgm^{-2}s^{-1} respectively, approximate the surface integrals of mass fluxes over east and west faces of the control volume P, using Simpson's Method.</td>
<td>20</td>
<td>CO4</td>
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