Reg. No.									

MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

SECOND SEMESTER M.TECH.
(APPLIED COMPUTATIONAL FLUID DYNAMICS)
END SEMESTER EXAMINATION, MAY 2024

Linking CFD with Experiments [AAE 5406]
REVISED CREDIT SYSTEM

Time: 3 Hours | **Date: 07 MAY 2024** | **Max. Marks: 50**

Instructions to Candidates:
- Answer **ALL** the questions.
- Missing data may be suitably assumed.

Q.NO	Questions	Marks	CO	BTL
1A	Evaluate and Interpret grid convergence study by solving a simple supersonic flow past a wedge. Three grids are explored, and the table below outlines the grid spacing and Mach Number computed for each grid. Compute (Fs=1.25) 1. the relative error between the grids 2. GCI and $GCI_{asymptotic}$	06	04	04

Grid number	*Grid spacing*	*r = h_2/h_1*	*C_p*
1	2	0.5	0.3252
2	1	0.5	0.3439
3	0.5	-	0.3498

Formula:

$$f_{h=0} \approx f_1 + \frac{f_1 - f_2}{r^p - 1}\ ;\ p = \frac{ln\left(\frac{f_3 - f_2}{f_2 - f_1}\right)}{ln(r)};\ E_1 = \frac{\varepsilon}{r^p - 1};\quad \varepsilon = \frac{f_2 - f_1}{f_1}\ ;\ GCI = \frac{F_S|\varepsilon|}{(r^p - 1)}$$

Q.NO	Questions	Marks	CO	BTL
1B.	Evaluate and interpret the condition number for 1) $f(x) = 1 + \sqrt{\lvert x - 1\rvert}\ for\ x = 1.00001$ 2) $f(x) = (e^{-x} - 1)/x\ \ for\ x = 0.001$	04	01	03

2A.	Use Richardson's extraPolation to estimate the second order derivative of $f(x) = 2^x/x$ at $x = 2$ using the step size $h_1 = 0.1$ *and* $h_2 = 0.2$. Employ central difference formula of $O(h^2)$ for the initial estimation. Compare the results with the exact derivative. $f''(2)=0.574617$	05	02	03

Formula: *Centeral Difference Formula*:

$$f''(x_i) = \frac{f(x_{i+1}) - 2f(x_i) + f(x_{i-1})}{(\Delta x)^2}$$

Richardson's extrapolation:

$$A_k(h) = \frac{1}{4^k - 1}\left(4^k A_{k-1},(h|2) - A_{k-1}(h)\right) = L + O(h^{2k})$$

2B.	Evaluate the temperature distribution for the numerical solution of 1D heat equation using explicit scheme.	05	03	04

$$\frac{\partial T}{\partial t} = \mathrm{k}\frac{\partial^2 T}{\partial x^2}$$

boundary conditions are as follows

T (x=0) = 100 °C and $\frac{\partial T}{\partial x} = 0$ (at x=10cm)

k = 0.835 cm^2/s

Consider Δx = 2 cm.

Choose Δt=0.1s to get a solution after 0.3s.

Initial condition, T (t=0) = 0 °C.

3A.	Use the first order error analysis to estimate the error of y which is given by	05	02	02

$$y = \frac{FL^4}{8EI}$$

$F = 50 \pm 2$, $L = 30 \pm 0.1$, $\mathrm{E} = 1.5 \times 10^8 \pm 0.01 \times 10^8$
and I = 0.06 ± 0.0006

Formulae:

$$\Delta f(\bar{x}_1, \bar{x}_2, \bar{x}_3, \ldots, \bar{x}_n) = \left|\frac{\partial f}{\partial x_1}\right| \Delta\bar{x}_1 + \left|\frac{\partial f}{\partial x_2}\right| \Delta\bar{x}_2 + \ldots + \left|\frac{\partial f}{\partial x_n}\right| \Delta\bar{x}_n$$

3B.	Starting from one-dimensional fluid flow problem represented explain the method of manufactured solution for	03	01	02

$$\frac{d^2u}{dx^2} = 0\ ;$$
$$u(0) = 1\ ; u(1) = 0; 0 < x < 1$$

and Manufactured solution if given by $u = 1 - x^2$

3C.	With suitable examples explain various types of errors and uncertainties in CFD solution	02	04	01

4A.	Draw a flow diagram and explain an overview of ASME Validation Approach with sources of errors	05	04	03
4B.	With suitable examples explain the quantitative and qualitative validation approaches used is CFD	03	03	02
4C.	Explain temporal Convergence criteria used in CFD; (CFL criteria)	02	02	02
5A.	Perform Von Neumann stability analysis and derive the amplification factor of one dimensional parabolic PDE.	05	03	04
5B.	Draw a flow chart and explain the difference between Validation and Verification?	03	01	02
5C.	With reference to AIAA Guide for Verification process, explain a posterior and a priori error estimation	02	04	03