TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEEING
Examination Control Division
Model Question

Exam	**Regular**		
Level	BE/BAR	**Full Marks**	60
Program	BCH	**Pass Marks**	24
Year / Part	III / II	**Time**	3 Hrs

Subject:- Computational Fluid Dynamics *(ENCH 355)*

- ✓ Candidates are required to give their answers in their own words as far as practicable.
- ✓ Attempt **All** questions.
- ✓ The figures in the margin indicate **Full marks.**
- ✓ Assume suitable data if necessary.

1. Define Initial Conditions and Boundary Conditions in the context of a CFD simulation. Explain why properly specified boundary conditions are mathematically required to solve the differential equations of fluid flow. [4]
2. What is the fundamental difference between Explicit and Implicit time integration schemes in transient CFD simulations? Discuss both methods in terms of computational memory, step-size limits, and numerical stability.[4]
3. Define Grid Convergence (Mesh Independence). Why is it essential to perform a grid convergence study before accepting the numerical results of a CFD simulation for engineering design? [4]
4. Explain the physical meaning and dynamic significance of the Reynolds Stress Tensor. Describe how its presence complicates the numerical closure of fluid flow equations compared to laminar momentum equations. [4]
5. Explain the concept of Boundedness and Transportiveness in spatial discretization schemes. Why does the Upwind Differencing Scheme (UDS) guarantee absolute boundedness whereas the Central Differencing Scheme (CDS) fails under high convective speeds? [4]
6. Derive the complete conservative differential form of the Navier-Stokes Momentum Equation in the x-direction for a viscous fluid, identifying the pressure gradient, body force and viscous shear stress terms. [4]
7. A 1D steady-state pure heat conduction bar of length L = 0.8 m (k = 40 W/mK) without volumetric heat generation is divided into 4 equal control volumes ($\Delta x = 0.2$ m). The boundary conditions are fixed at T(0) = 400 ^{0}C (left boundary) and a convective heat flux into an ambient fluid at $T_\infty = 25^0$C with heat transfer coefficient h = 50 W/m^{2}K at the right boundary x = L. [6]
8. Detail the mathematical steps required to calculate Element Skewness using the equilateral volume method for triangular mesh elements. Explain how severe skewness deteriorates the conditioning of the solver's coefficient matrix and degrades convergence. [6]
9. A viscous boundary layer mesh is generated over a chemical turbine blade. The first cell height near the wall is specified as y_1 = 0.02 mm with a constant growth rate (expansion ratio) r = 1.20.
   a. Calculate the height of the 6th prism layer.
   b. Calculate the total cumulative height of all 6 inflation layers combined. [6]
10. Detail the mathematical formulation of the PISO (Pressure-Implicit with Splitting of Operators) algorithm for unsteady flows. Explain why PISO performs two explicit pressure-

correction steps per time step and state why it outperforms SIMPLE in transient incompressible flow simulations. [6]

11. Explain the operational formulation of the k-ω SST (Shear Stress Transport) two-equation turbulence model. How does its blending function smoothly transition between the k-ω formulation near solid walls and the k-ε formulation in the freestream and why does this make it superior for predicting adverse pressure gradient flows? [6]
12. Differentiate between the Finite Rate Chemistry model and the Eddy Dissipation Concept (EDC) for turbulent reacting flows. State under what flow conditions (chemically controlled vs. turbulence-controlled mixing) each model is applicable in chemical reactor simulations. [6]