UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: May 2023

Module Number: ME7218

Module Name: Computational Fluid Dynamics for Design and Analysis of Engineering Systems

[Three Hours]

[Answer **all questions**, each question carries **ten** marks]

Q1 (a) "Computational Fluid Dynamics (CFD) is playing a vital role in the design and analysis of industrial product and processes". Explain this statement giving suitable examples.

[03 Marks]

(b) A complete CFD analysis consists of several steps. Explain all of them briefly.

[03 Marks]

(c) What are the industrial applications of CFD? Explain briefly **four** of them.

[04 Marks]

Q2 (a) What are the governing equations that can be used to model fluid flow problems?

[03 Marks]

(b) X-direction momentum equation for an incompressible two-dimensional flow can be expressed using the following equation, where symbols have their usual meaning.

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial x^2} + \nu\frac{\partial^2 u}{\partial y^2}$$

Discuss the physical meaning of each term.

[03 Marks]

(c) Convert the equation in Q2(b) for steady two-dimensional flow condition, without the pressure term.

[02 Marks]

(d) Convert the equation in Q2(b) for steady one-dimensional flow condition.

[02 Marks]

Q3 (a) Briefly explain the Finite Difference Method (FDM) used for discretisation of governing partial differential equations.

[03 Marks]

(b) Briefly explain the limitations of the FDM.

[02 Marks]

(c) Briefly explain the Finite Volume Method (FVM) used for discretisation of governing partial differential equations.

[03 Marks]

(d) Compare the advantages of the FDM and FEM.

[02 Marks]

Q4 (a) **Figure Q4** shows an insulated rod whose ends maintained at constant temperatures of 200 °C and 500 °C, respectively. The rod has a constant thermal conductivity (k) of 1000 W/mK and a uniform heat generation (q) of 200 kW/m³. If this one-dimensional heat transfer problem is governed by the following equation, answer the following questions.

$$\frac{d}{dx}\left(k\frac{dT}{dx}\right) + q = 0$$

i) Re-sketch the domain by dividing it into **five** control volumes and apply the FVM to discretise the domain. Derive the discretised equations for nodal points.

ii) Obtain the resulting set of algebraic equations to calculate the steady state temperature distribution.

iii) Find the coefficient matrix of the system of algebraic equations.

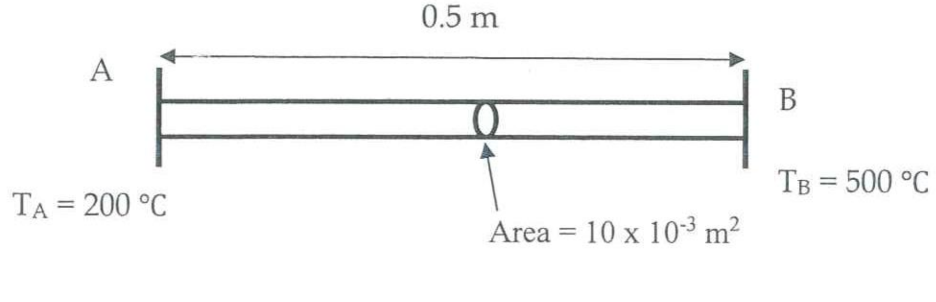

Figure Q4

[10 Marks]

Q5 **Figure Q5** shows a two-dimensional computational fluid flow domain assumed to analyse the flow around a helmet. Inlet of the flow is uniform. If the flow is considered as turbulent, answer the following questions based on the simulation results obtained for the computational domain,

i) Draw the streamline patterns around the helmet and explain the relevant flow characteristics.

ii) How to select the mesh around the helmet and in other areas?

iii) What are the boundary conditions proposed for this domain?

iv) What are the parameters that should found by analysing the results?

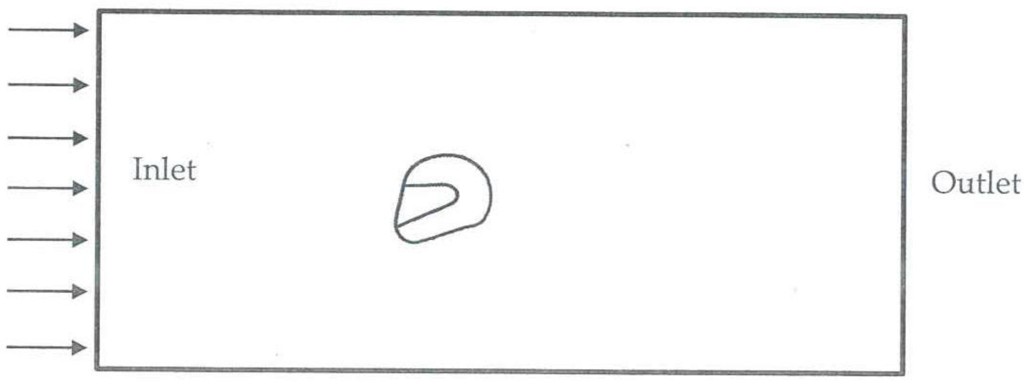

Figure Q5

[10 Marks]