ELIZADE UNIVERSITY, ILARA-MOKIN, ONDO STATE, NIGERIA

DEPARTMENT OF AUTOMOTIVE ENGINEERING

FIRST SEMESTER EXAMINATIONS

2020/2021 ACADEMIC SESSION

COURSE:	ATE 503 – CFD for Engineering Applications (3 Units)
CLASS:	500 Level Automotive Engineering
TIME ALLOWED:	3 Hours
INSTRUCTIONS:	Attempt questions **ONE & TWO** and any other **THREE** questions **(125 marks)**

HOD'S SIGNATURE

Date: March, 2021

Question 1 (25 marks)

a) Use a flowchart to describe the relationship between Computational Fluid Dynamics (CFD) and real-life fluid dynamics.

...2.5 marks

b) Write short notes on CFD computational resources and computational time.

...2.5 marks

c) Itemise five areas where CFD finds applications in automotive engineering.

...5 marks

d) Use diagrams to show the two types of frame of reference relevant to CFD.

...2.5 marks

e) State three merits and two demerits of CFD.

...2.5 marks

f) What is the full meaning of EOS and how is it relevant to CFD analysis?

...5 marks

g) List the following:

i. Basic conservation laws applicable to CFD, and

...2.5 marks

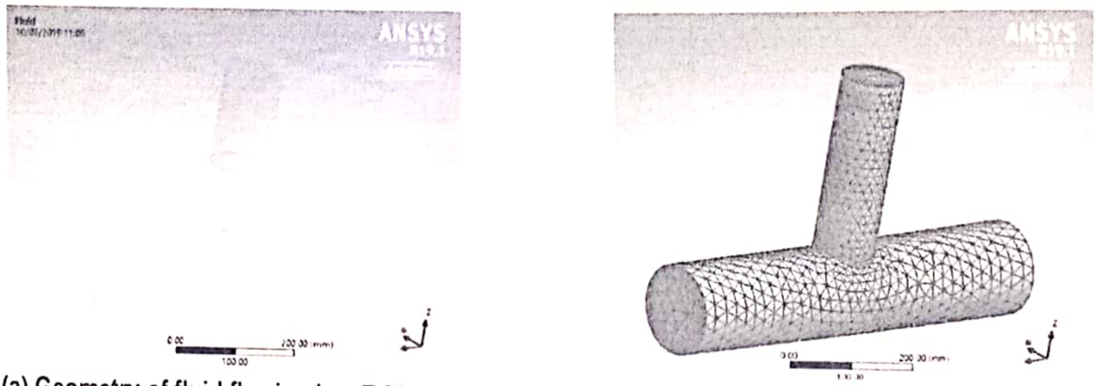
ii. The measurable flow variables associated with each conservation law.

...2.5 marks

Question 2 (25 marks)

a) Briefly describe the procedure for meshing the fluid in Figure (7.1)(a) to obtain Figure (7.1)(b):

...10 marks



(a) Geometry of fluid flowing in a T-Pipe (b) Mesh of fluid flowing in a T-Pipe

Figure (7.1): Geometry and mesh of fluid flow in ANSYS

b) Briefly describe the procedure for analysing mixing of hot and cold water in a T-Pipe. Figure (7.2) shows the contour plot of temperature distribution in the flow. Colours "red" and "blue" depict "hot water inlet" and "cold water inlet" respectively; the third end is the outlet of the mixture.

...15 marks

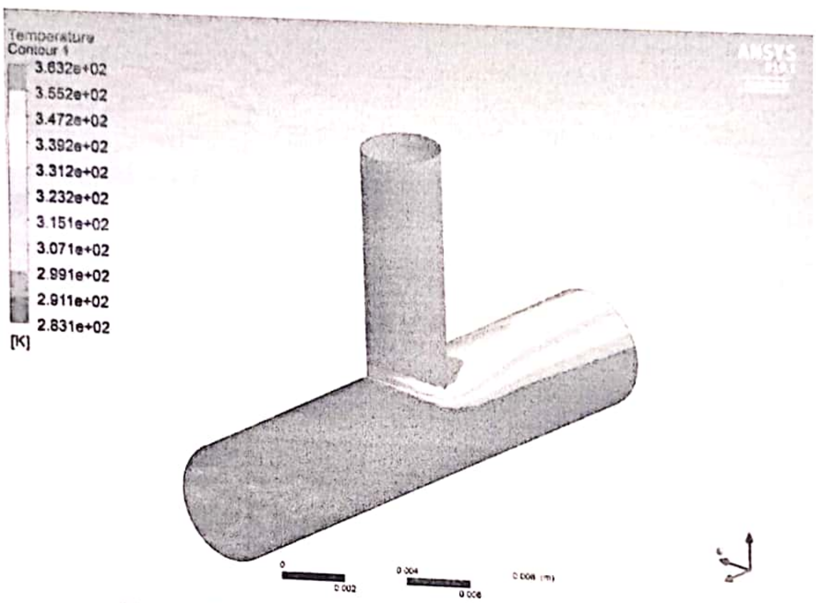


Figure (7.2): Mixing of hot and cold water in a T-Pipe

Question 3 (25 marks)

a) Briefly outline the procedure for CFD analysis.

...5 marks

b) Fluid elements deform during fluid motion. Use diagrams to illustrate deformation by Stretching and Shear.

...10 marks

c) Use Figure 2.1 to answer the following questions:

   i. State the type of grid.

   ...2 marks

   ii. Name and draw all possible element types.

   ...4 marks

   iii. List all terms (terminology) with respect to the grid.

   ...4 marks

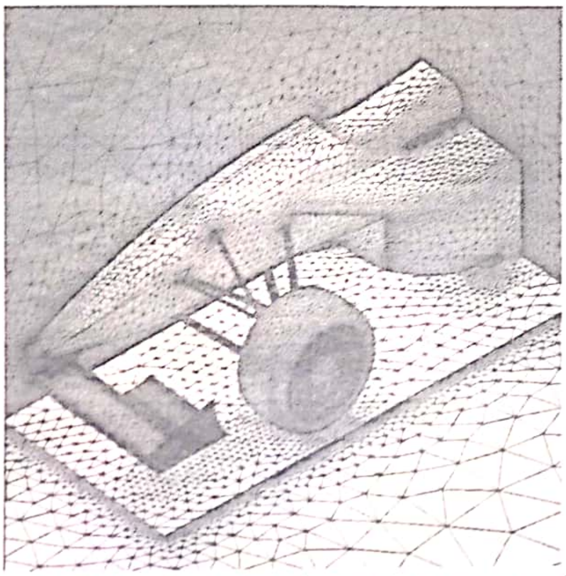


Figure 2.1: Grid or Mesh of the front part of a Formular-1 car

Question 4 (25 marks)

a) If the Crank-Nicolson approximation of Equation (4.1) is given in Equation (4.2).

$$\frac{\partial U}{\partial t} + \frac{\partial F}{\partial x} = 0 \qquad (4.1)$$

$$U_i^{n+1} = U_i^n - \frac{\Delta t}{2}\left[\left(\frac{\partial F}{\partial x}\right)_i^n + \left(\frac{\partial F}{\partial x}\right)_i^{n+1}\right] \qquad (4.2)$$

i. Obtain the Crank-Nicolson approximation for Equation (4.3) under two-dimensional condition.

$$\frac{\partial}{\partial t}(\rho\varphi) = -\frac{\partial}{\partial x}(\rho u\varphi) - \frac{\partial}{\partial y}(\rho v\varphi) - \frac{\partial}{\partial z}(\rho w\varphi) + \frac{\partial}{\partial x}\left[\Gamma\frac{\partial\varphi}{\partial x}\right] + \frac{\partial}{\partial y}\left[\Gamma\frac{\partial\varphi}{\partial y}\right] + \frac{\partial}{\partial z}\left[\Gamma\frac{\partial\varphi}{\partial z}\right] \qquad (4.3)$$

...15 marks

ii. What is the final expression when $n = 100$.

...5 marks

iii. What is the final expression when $n = 956$

...5 marks

Question 5 (25 marks)

a) With the aid of a flowchart, write short note on CFD Visualisation Procedure.

...10 marks

b) Simplify the given general governing equation in differential form for a one-dimensional, steady, compressible flow, without source terms. Show the steps and explain your working.

$$\frac{\partial}{\partial t}(\rho\varphi) + \frac{\partial}{\partial x}(\rho u\varphi) + \frac{\partial}{\partial y}(\rho v\varphi) + \frac{\partial}{\partial z}(\rho w\varphi) = \frac{\partial}{\partial x}\left[\Gamma\frac{\partial\varphi}{\partial x}\right] + \frac{\partial}{\partial y}\left[\Gamma\frac{\partial\varphi}{\partial y}\right] + \frac{\partial}{\partial z}\left[\Gamma\frac{\partial\varphi}{\partial z}\right] + S$$

...15 marks

Question 6 (25 marks)

a) Briefly differentiate between Grid discretisation and Problem discretisation.

...5 marks

b) The governing equations for fluid dynamics systems are generally described as the Navier-Stokes equations (NSE) which consist of five (5) equations and several unknown variables. Demonstrate how zero-degree-of-freedom can be achieved. Support your answer with the aid of equations where applicable.

...20 marks

Question 7 (25 marks)

a) Name the four terms in the following general equation:

$$\frac{\partial}{\partial t}(\rho\beth) = -\nabla\cdot\left(\rho\vec{U}\beth\right) + \nabla\cdot(\Gamma\nabla\beth) + S$$

...5 marks

b) Write the expressions for the explicit and implicit finite difference approximation of the following equation:

$$\frac{\partial F}{\partial t} = a\frac{\partial F}{\partial x} + b\frac{\partial F}{\partial y}$$

...20 marks