Name:

Enrolment No:

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UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
Online End Semester Examination, June 2021

Course: Turbulence Modelling **Semester: II**
Program: M. Tech CFD **Time: 03 hrs.**
Course Code: ASEG 7026 **Max. Marks: 100**
Pages: 03
Instructions: Make use of sketch/plots to elaborate your answer. All sections are compulsory

SECTION A (30 marks)

1. Each Question will carry 5 Marks
2. Instruction: Type your answers in the provided space

S. No.		Marks	CO
Q 1	When fluid flow is characterized as fully turbulent, which of the following is a true statement? Why? a. Friction factor decreases with increasing Reynolds Number b. Friction factor is independent of relative roughness	**[05]**	**CO2**
Q 2	Which of these methods is not used for turbulence modelling? a) RANS b) SIMPLE c) DNS d) LES	**[05]**	**CO1**
Q 3	For laminar flow over a flat plate, how do the local heat transfer coefficient and the friction coefficient vary with distance from the leading edge?	**[05]**	**CO1**
Q 4	Which of these methods is used to overcome the high resolution of turbulent flows? a) Weighted average b) Statistical analyses c) Data analysis d) Analytical method	**[05]**	**CO2**
Q 5	Which of these values vanish near the wall boundary? a) Velocity and turbulent viscosity b) Velocity and Reynolds number c) Velocity and k-value d) k-value and Reynolds number	**[05]**	**CO3**
Q 6	Which of these is correct about the first internal node of a k-ε model? a) k-equation is not solved b) ε-equation is not solved c) Both k and ε-equations are not solved d) Both k and ε-equations are solved simultaneously	**[05]**	**CO3**

SECTION B (50 marks)

1. **Each question will carry 10 marks**
2. **Instruction: Write short/brief notes, scan and upload the document**

Q 7	Explain the concept of eddy viscosity and eddy diffusivity. How do they benefit in relation to the mathematical terms created due to time averaging of Navier-Stokes equation.	**[10]**	**CO2**
Q 8	Derive the Prandtl's mixing length model. Explain the relations used for the length and velocity scale.	**[10]**	**CO3**
Q 9	In turbulent flow, mean and fluctuating components are often denoted by an overbar (¯) and prime (′) respectively. The fluctuating velocity components in the x, y, z or 1, 2, 3 coordinate directions are u', v' and w' respectively. At a particular point in a flow of air a hot-wire anemometer measures the following turbulent statistics: u'^2 = 2.6 m^2 s^{-2} , v'^2 = 1.4 m^2 s^{-2}, w'^2 = 2.0 m^2 s^{-2}, $u'v'$ = −0.9 m^2 s^{-2}, $v'w' = w'u'$ = 0.0 The density of air is ρ = 1.2 kg m^{-3} . (a) At this point determine: (i) the turbulent kinetic energy (per unit mass), k; (ii) the dynamic shear stress τ_{12}. (b) The only non-zero mean-velocity gradients are $\partial\bar{u}/\partial y$ = 4 s^{-1} , $\partial\bar{u}/\partial x$ = −1.5 s^{-1} , $\partial\bar{v}/\partial y$ = 1.5 s^{-1} Assuming a linear eddy-viscosity model of turbulence, deduce the eddy viscosity μ_t on the basis of the shear stress found in part (a)(ii). (c) Using the eddy viscosity calculated in part (b), what does the turbulence model predict for the fluctuating velocity variances u'^2, v'^2 and w'^2.	**[10]**	**CO3**
Q 10	Derive *any one* of the turbulence models clearly stating the transport equation and the various relations used to represent the turbulent viscosity. State the advantage and disadvantage of the turbulence model. a) Standard k-ω model b) Reynolds stress equation model (RSM)	**[10]**	**CO4**
Q 11	Give a detailed description of the turbulent boundary layer adjacent to a solid surface. Clearly explaining the inner sub-regions with the following sub-layers; a) The linear sub-layer b) The buffer layer c) the log-law layer	**[10]**	**CO4**

SECTION-C (20 marks) **1. Question carries 20 Marks and has internal choice.** **2. Instruction: Write long answer, scan and upload the document**			
Q 12	Consider a NACA4412 airfoil. CFD study is to be done on the airfoil mainly to analyze the pressure and velocity behavior over the airfoil. Provide the following information: a) Suggest the best turbulence model that can be used for the above analysis. Explain why you have suggested the model and how it is advantageous over other models. b) Write the relevant Reynolds stress equation and the turbulence model equation for the suggested turbulence model. c) Give the detailed boundary conditions suitable for the suggested turbulence model. d) Provide the model constants of the suggested model. **OR** Read the cases below and derive the exact solutions of Navier-Stokes equations by considering necessary boundary conditions: a) Steady laminar flow through a straight circular pipe. Consider the Darcy-Weisbach friction factor. b) Long flat plate kept in an infinite viscous fluid which is suddenly accelerated and moves in its plane at a velocity U_0. c) A steady two dimensional flow between parallel plates kept at a distance h apart. Indicate the velocity distribution. d) Couette flow between parallel plates with top surface moving at a velocity of U_0. Indicate the velocity distribution.	**[20]**	**CO5**