Name:

Enrolment No:

UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES
End Semester Examination, May 2018

Course: Laminar & Turbulent Flows (ASEG7012) **Semester: II**
Program: M. Tech. CFD
Time: 03 hrs. **Max. Marks: 100**

Instructions: Make use of *sketches/plots* to elaborate your answer. Brief and to the point answers are expected.
The Question paper has three sections: Section A, B and C. Section C has internal choices.

SECTION A [20 Marks]

S. No.		Marks	CO
Q 1.	Compare the hydrodynamic and thermal entry lengths for the flow of mercury in a circular tube when the flow is either laminar or turbulent.	**[04]**	**CO1**
Q 2.	An aircraft is analyzed using CFD simulation for both High and Low Reynolds number conditions using k-ϵ turbulence model. Answer the questions asked below: a. Provide the expressions of the Wall functions: $u+$ and T^+ b. Give the k-ϵ turbulence model equations for low Reynolds number. c. Explain in detail the modifications made to the actual k-ϵ turbulence model for solving low Reynolds number condition.	**[04]**	**CO3**
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?	**[04]**	**CO2**
Q 4.	What is the effect of surface roughness as boundary condition for a turbulent flow?	**[04]**	**CO2**
Q 5.	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	**[04]**	**CO4**

SECTION B [40 Marks]

Q 6.	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]**	**CO3**
Q 7.	Use the Staggered Grid method and derive completely the SIMPLE Algorithm. Also, draw the flow chart of the sequence of operations in a CFD procedure which employs the SIMPLE algorithm.	**[10]**	**CO4**

Q 8.	Consider a steady flow between two parallel plates. If U is the velocity of the upper plate and the lower plate is stationary. Describe type of flow under following cases; i. positive U and favorable $dp/dx < 0$, ii. positive U and adverse $dp/dx > 0$,	**[10]**	**CO2**
Q 9.	CFD study is to be done on a NACA4412 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.	**[10]**	**CO4**
SECTION-C [40 Marks]			
Q 10.	Derive the Reynolds-averaged Navier-Stokes (RANS) equations for incompressible flow resulting in the time-average transport equation for scalar φ. Explain the occurrence of additional unknown terms and the arising closure problem.	**[20]**	**CO3**
Q 11.	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. i. Standard k-ε model ii. Reynolds stress equation model (RSM)	**[20]**	**CO4**

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SECTION A [20 Marks]

S. No.		**Marks**	**CO**
Q 1.	Write briefly explaining the nature of turbulence. How does statistics help in characterizing such flows?	**[04]**	**CO1**
Q 2.	Write a brief on transition of turbulence. What do you mean by hydrodynamic instability? Give examples of flow with and without a point of inflexion.	**[04]**	**CO3**
Q 3.	If U is uniformly distributed in the interval $a \leq V < b$ and the PDF of U is given by, $f(V) = \begin{cases} \frac{1}{b-a}, \text{ for } a \leq V < b \\ 0, \quad \text{for } V < a \text{ and } V \geq b \end{cases}$ Graphically, explain the CDF and PDF for the uniform random variable. Further show that; a) Average $(U) = \frac{1}{2}\,(a+b)$ b) Variance$(U) = \frac{1}{12}\,(b-a)^2$	**[04]**	**CO2**
Q 4.	Describe in details any two flows characterized as free turbulent flows.	**[04]**	**CO2**
Q 5.	Derive and prove that creeping motion satisfies Laplace equation. Also, consider Stokes law to prove the Stokes Range of CD for a sphere is 24/Re. Also provide the detailed explanation to determine CD as recognized by Oseen for a sphere of diameter D.	**[04]**	**CO4**

SECTION B [40 Marks]

Q 6.	Derive the complete Reynolds-averaged Navier-Stokes equation for incompressible flows. Also, provide the expression for time-averaged transport equation for scalar quantity.	**[10]**	**CO3**

Q 7.	Explain the following terms, a) Cumulative Distribution function (CDF) b) Probability Density function (PDF) c) The Exponential Distribution d) The Normal Distribution	**[10]**	**CO4**
Q 8.	Compute the time average of the function $u(t) = Ae^{-t/\tau} + B\cos(\omega t)$ using, $$\overline{u^m(x)} = \frac{1}{\Delta t}\int_{t-\Delta t/2}^{t+\Delta t/2} u^m(x,t)dt$$ Presuming this function is meant to represent a turbulent field variable with zero-mean fluctuations,$B\cos(\omega t)$, superimposed on a decaying time-dependent average, $Ae^{-t/\tau}$, what condition on Δt leads to an accurate recovery of the decaying average? And, what condition on Δt leads to suppression of the fluctuations?	**[10]**	**CO2**
Q 9.	Write a brief on transition of turbulence. What do you mean by hydrodynamic instability? Give examples of flow with and without a point of inflexion.	**[10]**	**CO4**
	SECTION-C [40 Marks]		
Q 10.	Read the cases below and derive the exact solutions of Navier-Stokes equations by considering necessary boundary conditions: a) A steady two dimensional flow between parallel plates kept at a distance *h* apart. Indicate the velocity distribution. b) Couette flow between parallel plates with top surface moving at a velocity of U_0. Indicate the velocity distribution. c) Steady laminar flow through a straight circular pipe. Consider the Darcy-Weisbach friction factor. d) Long flat plate kept in an infinite viscous fluid which is suddenly accelerated and moves in its plane at a velocity U_0.	**[20]**	**CO3**
Q 11.	Consider steady, one dimensional flow of a constant-density fluid through a duct with constant cross-sectional area. Use staggered grid as shown in the figure below, where the pressure P is evaluated at the main nodes *I* = A, B, C and D, whilst the velocity *u* is calculated at the backward staggered nodes *i* = 1, 2, 3 and 4. Below are the data given: i. Guessed pressure field, p* ii. Guessed velocity field, u* iii. Velocity correction, $u' = d(P'_I - P'_{I+1})$ iv. Corrected Velocity field, u = u* + u' v. Density = 1.0 kg/m3 is constant vi. Duct area A is constant	**[20]**	**CO4**

	vii. Multiplier *d* in the above equation is assumed to be constant; d= 1.0 viii. Boundary conditions: u_1 = 10 m/s and P_D= 0 Pa ix. Initial guessed velocity field: u2*= 8.0 m/s , u3* = 11.0 m/s and u4* = 7.0 m/s Use the SIMPLE algorithm and the above problem data to calculate pressure corrections at Nodes *I* = A, B, C and D and obtain the corrected velocity field at nodes *i* = 2, 3 and 4.		