AML 820: Advances in Fluid Engineering

MAJOR TEST

1st Semester 2008-09 **Date: 22nd November, 2008**

Time: 3.30 – 5.30 pm **Max Marks: 100**

1. The second order structure function is defined as $D_{ij}(r,x,t)=\langle \Delta u_i \Delta u_j \rangle$ where $\Delta u_i = u_i(x+r,t)-u_i(x,t)$; $\Delta u_j = u_j(x+r,t)-u_j(x,t)$. For isotropic turbulence $D_{ij}=D_{ij}(r)$. Using the Kolmogorov hypotheses, derive the form of D_{ij} in the inertial range ($l_0 >> l >> \eta$). **(10)**

2. The drag force on a sphere at very low Reynolds numbers ($Re = \frac{\rho V a}{\mu} \to 0$, V is the relative velocity of the sphere with respect to the fluid, 'a' is the radius of the sphere, ρ and μ have their usual meaning) is given by 6πμVa. Discuss the suitability of using 100 μm diameter hollow glass spheres with average specific gravity 1.2 as tracer particles in a PIV measurement of turbulent convection with estimated RMS velocities of 3 cm/s. **(10)**

3. What is peak-locking? Does it depend on the particle size? Is it the physical size of the particle? Does it depend on the sensor characteristics? Which are those characteristics, if they are relevant. Can you eliminate peak-locking by averaging over a large number of measurements? Which is a better sub-pixel estimator: Gaussian or Parabolic, with regards to peak-locking? **(8)**

4. **(a)** Discuss the optimum particle size for PIV. What are the considerations in determining the optimal particle size? Does the physical size of the particle matter? **(4)**

(b) Discuss the camera orientations in a stereo PIV evaluation. Which would you prefer in case of a relatively weak laser source? **(3)**

5. You are asked to evaluate new commercial package HiddenCFD for computing fluid flows that does not release its source code. You notice that one of the options for a finite difference scheme is the 4th order scheme given below

$$\left(\frac{\partial \phi}{\partial x}\right)_i = \frac{-\phi_{i+2}+8\phi_{i+1}-8\phi_{i-1}+\phi_{i-2}}{12\Delta x} + O\left((\Delta x)^4\right)$$

But you are suspicious about whether it has been programmed correctly. To test the actual order of the programmed scheme, you decide to test HiddenCFD for a low Reynolds number where the $u_{\max}$ for the flow is known. Briefly outline a series of steps by which you can determine if the claim that the programmed scheme is 4th order is correct or not. **(5)**

6. You are also given another package OpenCFD which does release its source code. It also happens to have the above scheme in it. After a careful look at the program and running tests you find that the scheme is programmed correctly and is 4th order accurate.

a) Someone suggests that you use this scheme in OpenCFD to do a DNS of homogeneous, isotropic turbulence. Would you agree or disagree with the suggestion? Why? **(2)**

b) Determine the effective wave number k_{eff} of this scheme. Plot k vs k_{eff} and support the conclusion you made in **(a)** **(7)**

c) You are asked to write a completely new set of subroutines to run direct numerical simulations for homogeneous, isotropic turbulence at a given set of Reynolds numbers. What choices would you make for the following?

- **i)** Grid size and grid type
- **ii)** Time-marching scheme
- **iii)** Spatial differentiation **(4)**

d) Which of these would you change if you want do DNS of channel flow? **(2)**

7. After writing and running the DNS module, you find that the computational resources available to you are not sufficient to run the cases you want. You don't have the money for more computational resources but still want accurate simulations for fundamental studies of turbulence.

- **i)** What could you do to make this possible? **(1)**
- **ii)** Describe briefly the conceptual steps involved in making this modification. **(8)**
- **iii)** What would be the greatest source of theoretical uncertainty in your modification? **(2)**
- **iv)** What is the simplest choice you could make for this uncertain part? **(1)**
- **v)** What are the problems with the simplest possible choice? **(3)**

8. (a) What do you understand by Swirl? How does it influence the growth or development of a jet? **(6)**

(b) What are the different Methods used to generate Swirl in Laboratory experiments? **(6)**

(c) What do you understand by Secondary flows? Explain through example. **(3)**

9. (a) Briefly explain the various regimes of flow in the flow of solid-liquid suspension through a horizontal pipeline. **(8)**

(b) Define and distinguish between corrosion and erosion in a slurry pipeline. Briefly explain how they can be controlled. **(7)**