DEPARTMENT OF APPLIED MECHANICS

AML820 Advances in Fluids Engineering

Major Examination Part A (CLOSED BOOK) *3.30 pm to 4.30 pm*

Please answer all the questions. Marks are given alongside. (Max. marks 48)

Q1a. Explain thru figures the effect of expansion ratio, expansion shape and downstream blockage on the flow characteristics of contra-swirling co-axial jets exhausting into a confined space. (12)

Q1b. Discuss methods that can be used for controlling boundary-layer separation. (4)

Q2) Discuss the various factors that govern the choice of the following parameters while transporting solid material in a slurry pipe line system:

(i) Particle size distribution (ii) Concentration of solids
(iii) Velocity of flow (iv) Pipe material. (16)

Q3a) A turbulent flow is simulated using the following models.

i) DNS
ii) $k-\varepsilon$ model
iii) Spalart Allmaras model
iv) Mixing length model
v) LES

Rearrange the above in order of,

a) Increasing computational time.
b) Increasing accuracy of solution. (4)

Q3b) In the two equation class of models, a new model is proposed where the two quantities for which turbulence equations are solved are, the turbulent kinetic energy and a turbulent time scale. Suggest an expression for ν_t, the eddy viscosity for this model. (4)

Q3c) Consider the following set of ODEs:

$$dX / dt = - PXY + PY$$
$$dY / dt = - Y + rX^2 + XY$$

Where the dependent variables X and Y are functions of the independent variable time t. P and r are parameters (like Re in the Navier Stokes equations).

We wish to carry out an averaging on X and Y.

Thus, $X = \langle X \rangle + x$; $Y = \langle Y \rangle + y$ (with $\langle x \rangle = \langle y \rangle = 0$).

a) Obtain equations for $\langle X \rangle$ and $\langle Y \rangle$.
b) Is this set of equations closed? If yes, explain why? If no, then identify the unclosed terms. (8)

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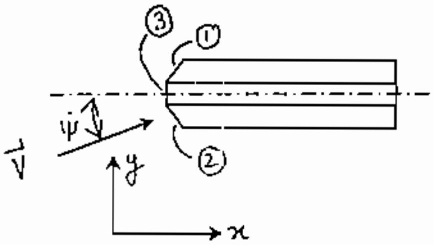
Major Examination Part B (OPEN BOOK) *4.30 pm to 5.30 pm*

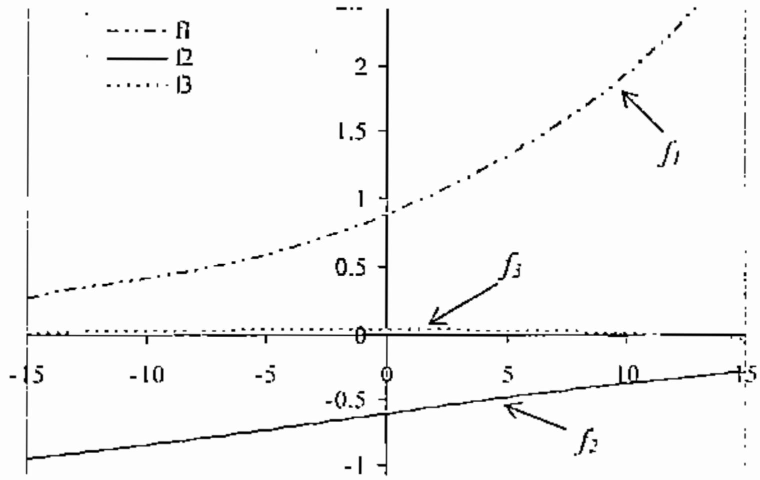
Please answer all the questions. Marks are given alongside. *(Max. marks 52)*

Q4) Calibration curves for a 3-hole probe are given below according to the geometry and convention shown. One set of experimental readings yields: $p_1 = 14$; $p_2 = 10$ and $p_3 = 20$. (All the measurements are mm of water.) Determine the total pressure p_o, the static pressure p, and the mean velocity vector in the xy plane. The flowing fluid is air with density $\rho_{air} = 1.2$ kg/m^3. (12)



$$f_1 = \frac{p_3 - p_1}{p_3 - p_2}, \qquad f_2 = \frac{p_2 - p_3}{p_o - p}$$

$$f_3 = \frac{p_o - p_3}{p_2 - p_3}$$



Q5) In the Orr-Sommerfeld equation if we neglect the viscous term we get the Rayleigh equation. Write down the resulting equation and the appropriate boundary condition(s) near a solid wall for inviscid flow. If the wave number, α, is assumed real then this equation also leads to an eigenvalue problem wherein the wave speed, c, is obtained as a complex eigenvalue with a corresponding complex eigenfunction, ϕ. Show that if $c = c_r + i\,c_i$ is an eigenvalue with the eigenfunction $\phi = \phi_r + i\phi_i$, then $c^* = c_r - i\,c_i$ is also a valid eigenvalue with corresponding $\phi^* = \phi_r - i\phi_i$. (16)

Q6) Prove that for undertaking the linear stability analysis of fully developed viscous laminar flow in a 2-D channel, it is sufficient to consider 2-D disturbances. (12)

Q7) The photos below (A and B) show the flow past two spheres at nearly the same Reynolds number.

(i) Give a possible reason for the large difference in the wake patterns.

(ii) Can you guess which visualization method has been used?

(iii) If the smallest scale in photo B is 0.002D (where D is the diameter) can you estimate the Reynolds number of the turbulence? (12)

Photo A

Photo B