Code No: RR322104 **Set No. 1**

III B.Tech II Semester Regular Examinations, Apr/May 2006

COMPUTATIONAL AERODYNAMICS-II

(Aeronautical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions

All Questions carry equal marks

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1. (a) Comment on the statement that CFD will in future eliminate the necessity of wind tunnel testing in airplane design. What are your comments on the statement?

   (b) Explain the impact of CFD techniques on the automotive industry for shaping and designing road vehicles? Describe with one example. [16]

2. The Y-component of Navier-Stokes equations is given by $\frac{\partial(\rho v)}{\partial t} + \nabla.(\rho v V) = -\frac{\partial \rho}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yy}}{\partial y} + \frac{\partial \tau_{zy}}{\partial z} + \rho f_y$ .Identify each component and explain its significance in creating balance of forces. Explain the occurrence of the terms 'time rate of strain' in this equation. Complete the full form of this equation in all the three components. [16]

3. Bring out the significance of Integral and differential form of the equations of fluid dynamics by giving examples from applications to various problems. Hence discuss the utility of conservation and non-conservation form of equations. [16]

4. Consider the irrotational, two dimensional inviscid, steady flow of a compressible gas. If the perturbation components of u and v are u' and v' respectively and M_∞ is the free stream Mach number, then the governing continuity , momentum and energy equations can be reduced to the system $(1 - M_\infty^2)\frac{\partial u'}{\partial x} + \frac{\partial v'}{\partial y} = o, \frac{\partial u'}{\partial y} - \frac{\partial v'}{\partial x} = 0$.If $M_\infty < 1$,which type of partial differential equation is represented by these equations? Present your work . [16]

5. Find the characteristics of p.d.e. given by $\frac{\partial^2 u}{\partial x^2} + 4\frac{\partial^2 u}{\partial x \partial y} + 2\frac{\partial^2 u}{\partial y^2} = 0$ [16]

6. Consider the function $\phi(x, y) = e^x + e^y$ .Consider the point (x,y) =(1,1).Use first order backward differences, with Δx=Δy=0.01 , to calculate approximate values of $\frac{\partial \phi}{\partial x}$and $\frac{\partial \phi}{\partial y}$ at (1,1).Calculate the percentage difference when compared with the exact solution at (1,1). [16]

7. A solution of p.d.e. $\frac{\partial u}{\partial t} = \frac{\partial}{\partial x}\left[a(x)\frac{\partial u}{\partial x}\right]$, $a(x) \neq 0$ with finite difference approximation on a rectangular mesh (x=mh ,t=nk, m,n are integers,r= $\frac{k}{h^2}$) is given by $U_m^{n+1} = (1 - 2ra)U_m^n + ra(U_{m+1}^n + U_{m-1}^n) + \frac{rh}{2}a'(U_{m+1}^n - U_{m-1}^n)$.Obtain L.T.E. [16]

8. The Thompson scheme for generating grids is based upon the following equations ; $\xi_{xx} + \xi_{yy} = P(\xi, \eta)$, $\eta_{xx} + \eta_{yy} = Q(\xi, \eta)$; where (ξ, η) represent coordinates in the computational domain and P and Q are terms which control the point spacing in the interior of the domain. Derive the computational domain equations. [16]

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Code No: RR322104 **Set No. 2**

III B.Tech II Semester Regular Examinations, Apr/May 2006
COMPUTATIONAL AERODYNAMICS-II
(Aeronautical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. (a) Why should Computational aerodynamics be termed Numerical experiments? Explain the basis with one example.
   (b) Explain with one convincing example the impact of CFD on the problems of aerodynamics of road vehicles. [16]

2. The partial differential equation representing conservation of mass as $\frac{\partial \rho}{\partial t} + \nabla.(\rho \nu)$ =0 is one form of the equation of continuity in fluid dynamics. Derive it from the first principle. Put this equation in other forms known in the dynamics of fluid. Present your work. [16]

3. What is the significance of Integral and differential form of the equations of fluid dynamics? Explain by giving examples from applications to various problems. Hence discuss the utility of conservation and non-conservation form of equations. [16]

4. Consider the irrotational, two dimensional inviscid, steady flow of a compressible gas. If the perturbation components of u and v are u' and v' respectively and M_∞ is the free stream Mach number, then the governing continuity , momentum and energy equations can be reduced to the system$(1 - M_\infty^2)\frac{\partial u'}{\partial x} + \frac{\partial v'}{\partial y} = o$, $\frac{\partial u'}{\partial y} - \frac{\partial v'}{\partial x} = 0$. Show that for $M_\infty > 1$, the above equations are hyperbolic partial differential equations. Present your work. [16]

5. Find the characteristics of p.d.e. given by $\frac{\partial^2 u}{\partial x^2} - 3\frac{\partial^2 u}{\partial x \partial y} + 2\frac{\partial^2 u}{\partial y^2} = 0$ [16]

6. Show how can you derive difference approximation for mixed partial derivatives $\left(\frac{\partial^2 u}{\partial x \partial y}\right)_{i,j} = \frac{1}{2\Delta x}\left(\frac{u_{i+1,j+1} - u_{i+1,j}}{\Delta y} - \frac{u_{i-1,j+1} - u_{i-1,j}}{\Delta y}\right) + O\left[(\Delta x)^2, \Delta y\right]$ [16]

7. $(1 + r)U_m^{n+1} - \frac{1}{2}r(U_{m+1}^{n+1} + U_{m-1}^{n+1}) = (1 - r)U_m^n + \frac{1}{2}r(U_{m+1}^n + U_{m-1}^n)$ is a finite difference approximation of $\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$over a rectangular mesh (x=mh ,t=nk, m,n are integers,r= $\frac{k}{h^2}$).where the Taylor series expansion is taken about (mh ,k(n+1/2) . Obtain this result.This is known as Crank-Nicolson's semi-implicit scheme. Hence show that C-N scheme is unconditionally stable. [16]

8. Consider the domain ABCD bounded by the lines x=0.5; y=0; x=-0.5 and the circular arc $y = (1 - x^2)^{\frac{1}{2}}$ and the transformation $\xi = \frac{y}{(1-x^2)^{\frac{1}{2}}}$, $\eta = x + 0.5$ Obtain the body conforming grid. Describe the principles, capabilities and utilities of structured grid . [16]

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Code No: RR322104

Set No. 3

III B.Tech II Semester Regular Examinations, Apr/May 2006
COMPUTATIONAL AERODYNAMICS-II
(Aeronautical Engineering)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks

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1. (a) Justify with one example that computational aerodynamics is also called numerical experiments. What are the specific advantages of numerical experiments?
   (b) How did the discipline of CFD influence the aerodynamics of road vehicles? Explain. [16]

2. The partial differential equation depicting conservation of mass as $\frac{\partial \rho}{\partial t} + \nabla.(\rho \nu) = 0$ is one form of the equation of continuity in fluid dynamics. Derive it from the first principle. Put this equation in other forms known in the dynamics of fluid. Present your work. [16]

3. Put the Governing equations for three dimensional, compressible, viscous flows in conservation form .Recast the equations suitable for computational work. How can a time marching problem be formulated? [16]

4. The partial differential equation $\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$, represents unsteady thermal conduction in 1-Dimension. Work out the type of partial differential equation [16]

5. The function U satisfies the equation $\sqrt{x}\frac{\partial U}{\partial x} + U\frac{\partial U}{\partial y} = -U^2$ and the condition U=1 on y = 0, $0 < x < \infty$ .Obtain the Cartesian equation of the characteristic through R(1.5,0). [16]

6. Consider the function $\phi(x, y) = e^x + e^y$ .Consider the point (x,y) =(1,1).Use first order central differences, with Δx=Δy=0.025, to calculate approximate values of $\frac{\partial \phi}{\partial x}$and $\frac{\partial \phi}{\partial y}$ at (1,1).Calculate the percentage difference when compared with the exact solution at (1,1). [16]

7. $U_m^{n+1} = (1 - 2ra)U_m^n + ra(U_{m+1}^n + U_{m-1}^n)$ gives finite difference approximation of $\frac{\partial u}{\partial t} = a(x)\frac{\partial^2 u}{\partial x^2}, a(x) \neq 0$ over a rectangular mesh (x=mh ,t=nk, m,n are integers,r= $\frac{k}{h^2}$).Obtain the local truncation error. [16]

8. Describe the necessity of the grid generation in the area of Computational Fluid Dynamics. Explain with an appropriate illustration that ‘A problem having simple equations but complex boundary conditions gets transformed in to a problem now having complex equations and simple boundary conditions’ with the application of the technique of Grid Generation. [16]

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1. (a) Why should Computational aerodynamics be termed Numerical experiments in the discipline of aerodynamics? Explain the basis with one example.

   (b) Explain with one solid example the impact of CFD on the problems of aerodynamics of road vehicles. [16]

2. The X-component of Navier-Stokes equations is given by $\frac{\partial(\rho u)}{\partial t} + \nabla.(\rho u \nu) = -\frac{\partial \rho}{\partial x} + \frac{\partial \tau_{xx}}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + \rho f_x$ .Identify each component and explain its significance in creating balance of forces. Explain the occurrence of shear stress terms in this equation. Complete the full form of this equation in all the three components. [16]

3. Consider the conservation form of equations of motion in fluid mechanics. How do these equations differ from the non-conservation form of these equations? Hence explain differences between integral and differential forms of equations. [16]

4. Given is a system of quasi-linear partial differential equations as below, $a_1\frac{\partial u}{\partial x} + b_1\frac{\partial u}{\partial y} + c_1\frac{\partial v}{\partial x} + d_1\frac{\partial v}{\partial y} = \int_1, a_2\frac{\partial u}{\partial x} + b_2\frac{\partial u}{\partial y} + c_2\frac{\partial v}{\partial x} + d_2\frac{\partial v}{\partial y} = f_{2_1}$, where u and v are the dependent variables, continuous functions of x and y and the coefficients a, b, c, d and f can be functions of x, y, u, and v. Work out to show the conditions under which the above system of equations represents Hyperbolic partial differential equations. [16]

5. How is an elliptic partial differential equation different from a parabolic and hyperbolic type of equations? Comment upon the domain of integration in this case vis-a'-vis the other types of equations. Consider the equation $\nabla^2\phi = f(x, y)$ and explain. [16]

6. Consider the function $\phi(x, y) = e^x + e^y$ .Consider the point (x,y) =(1,1).Use first order forward differences, with Δx=Δy=0.025, to calculate approximate values of $\frac{\partial \phi}{\partial x}$and $\frac{\partial \phi}{\partial y}$ at (1,1).Calculate the percentage difference when compared with the exact solution at (1,1). [16]

7. $U_m^{n+1} = (1 - 2r)U_m^n + r(U_{m+1}^n + U_{m-1}^n)$ gives finite difference approximation of $\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$ over a rectangular mesh (x=mh ,t=nk, m,n are integers,r= $\frac{k}{h^2}$) .Using Taylor series expansion, obtain the principal part of the local truncation error. [16]

8. If the Thompson scheme for generating grids is based upon the following equations ; $\xi_{xx} + \xi_{yy} = P(\xi, \eta)$, $\eta_{xx} + \eta_{yy} = Q(\xi, \eta)$; where (ξ, η) represent coordinates in the computational domain and P and Q are terms which control the point spacing in the interior of the domain ,then derive the computational domain equations. [16]

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