Computational Fluid Dynamics

2 Marks

Unit – I Fundamental Concepts

1. What are the important applications of CFD in engineering?

CFD analysis of temperature, velocity and chemical concentration distributions can help engineers understand the problem correctly and provide ideas for the best resolution.

2. Distinguish between *conservation* and *non-conservation* forms of fluid flow.

Conservation form	*Non-conservation form*
The finite control volume is fixed in space.	The finite control volume is moving with the fluid.
Equations will be expressed with local derivatives.	Equations will be expressed with substantial derivatives.

3. Write down the conservative form of the continuity equation and explain the terms involved.

The conservative form of the continuity equation is

$$\frac{\partial \rho}{\partial t} + \nabla.\left(\rho \vec{V}\right) = 0$$

Where,

$\frac{\partial \rho}{\partial t}$ → the *local derivative*, which is physically the time rate of change of density at a fixed point.

$\nabla.\left(\rho \vec{V}\right)$ → the *convective derivative*, which is physically the time rate of change of velocity components due to the movement of the fluid element.

4. What is the physical significance/meaning of the various terms in conservation form of momentum equation?

The various terms in conservation form of momentum equation in *x*-direction are

$\frac{\partial(\rho u)}{\partial t}$ → the *local derivative*, which is physically the time rate of change of density at a fixed point.

$\nabla.\left(\rho u \vec{V}\right)$ → the *convective derivative*, which is physically the time rate of change of velocity components due to the movement of the fluid element.

ρf_x → the *body force* on the fluid element.

$\frac{\partial p}{\partial x}$ → the *pressure force* on the fluid element.

$\frac{\partial \tau_{xx}}{\partial x}$ → the *normal force* on the fluid element due to viscous.

$\frac{\partial \tau_{yx}}{\partial y}, \frac{\partial \tau_{zx}}{\partial z}$ → the *shear forces* on the fluid element due to viscous.

5. Write down an expression for substantial derivative in Cartesian coordinates.

The substantial derivative in Cartesian coordinates is

$$\frac{Dg}{Dt} = \frac{\partial g}{\partial t} + u\frac{\partial g}{\partial x} + v\frac{\partial g}{\partial y} + w\frac{\partial g}{\partial z}$$

Where,

g → flow field variable (Density, Pressure, Temperature, etc…).

6. What are the assumptions made in panel methods?

- The flow is irrotational, inviscid and incompressible flow.
- The governing equations can be reduced to the Laplace's equation.

7. List out advantages of panel method.

- *Flexibility*: Be capable of treating the range of geometries.
- *Economy* : Get results within a relative short time.
- No need to define grids throughout the flow field.

8. Explain the difficulties of evaluating the influences of a panel at its own control point.

The boundary condition states that the sum of normal component of the velocities must be zero at its own control point. This is the crux of the panel method. The value depends on the panel geometry; they are not properties of the flow.

9. What are limitations of panel methods?

- Panel methods are ideal for concept design analysis due to their rapid turnaround time and relatively easy surface modelling, but this is countered by their inability to predict boundary layers and flow separation.
- The lack of viscosity modelling in a panel method leads to another limitation: they can't model rotational flows such as that found in a cyclone.
- Panel methods can't model supersonic flow (M > 1).

10. Define well-posed problems.

The governing equations and auxiliary (initial and boundary) conditions are well-posed mathematically if the following three conditions are met:

i. The solution exists,
ii. The solution is unique,
iii. The solution depends continuously upon the initial and boundary conditions.

11. Explain the forms of the boundary conditions.

A specification of dependent variables *u* and *v* along the boundary. This type of boundary condition is called the *Dirichlet* condition.

A specification of derivatives of the dependent variables such as $\partial u/\partial x$, etc…, along the boundary. This type of boundary condition is called the *Neumann* condition

12. What are the elementary flows to be combined to get lifting flow over circular cross sectional bodies?

The combination of source, sink and vortex flows.

Source flow + *Sink flow* + *Vortex flow* = *Lifting flow* over circular cross sectional bodies.

13. Define discretization error.

The difference between the exact analytical solution of the partial differential equation and the exact solution of the corresponding difference equation.

14. Define round-off error.

The numerical error introduced after a repetitive number of calculations in which the computer is constantly rounding the numbers to some significant figure.