INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

AEROSPACE ENGINEERING DEPARTMENT

Date: Time: 2 Hrs, Full Marks: 30

No of Students: 52 Mid-Autumn Semester Examination 2018-19

AE21001 **Introduction to Aerodynamics**

2nd Year B. Tech. (H) & DD

Assumptions, if required, can be made with appropriate justifications.

Notations have their usual meaning unless specified otherwise.

Some important vector identities:

$$\nabla\times(s\vec{u})=s\nabla\times\vec{u}-\vec{u}\nabla s$$

$$\nabla\times(\vec{u}\times\vec{v})=\vec{v}\nabla\vec{u}+\vec{u}\nabla\cdot\vec{v}-\vec{u}\nabla\vec{v}-\vec{v}\nabla\cdot\vec{u}$$

$$\nabla^2\vec{u}=\nabla\cdot\nabla\vec{u}=\nabla(\nabla\cdot\vec{u})-\nabla\times(\nabla\times\vec{u})$$

$$(\vec{u}\cdot\nabla)\vec{u}=\frac{1}{2}\nabla(\vec{u}\cdot\vec{u})-\vec{u}\times\nabla\times\vec{u}$$

Part A

Answer all the questions from this part. Give brief and to the point answer. Add neat sketches wherever necessary.
Each question in this part can be answered in maximum three/four sentences.

(10×1)

1. How are the leading and trailing edge points located in an airfoil with rounded trailing edge?
2. What are spars and ribs in an airplane?
3. How does the airfoil chord line differ from the camber line?
4. Explain rolling moment? How is the rolling moment coefficient defined?
5. What do the elevators of an aircraft do?
6. What are aerodynamic centre and centre of pressure of an airfoil? Which of them changes with angle of attack?
7. The pitching moment coefficient of a wing in low speed flights at a given angle of attack is described by $C_M = f(\mathrm{Re})$. Explain dynamic similarity using the statement.
8. What are reconcilable circuits? How many irreconcilable circuits can be drawn in an n-ply connected region? How many of them are reducible?
9. What conditions need to be satisfied to have a unique solution of a fluid flow problem in a doubly connected space when the velocity field is irrotational and solenoidal?

10. A trapezoidal wing has an aspect ratio of 8.0 and taper ratio of 0.8. Evaluate the aerodynamic mean chord in percentage of the root chord.

Part B

Answer any three (3) questions from this part.

(3×2)

1. Show that stress tensor in a simple fluid is symmetric and only normal stresses can act when the fluid is at rest.
2. Show that a vortex tube cannot end in a fluid.
3. Derive an expression for the velocity vector associated with a point doublet.
4. Assuming a constant viscosity variable density fluid find the local rate of change of vorticity in a flow. State physical significance of each term.

Part C

Answer all questions from this part.

(4×3.5)

1. An open cylindrical vessel 1.5 m in diameter contains oil 2 m deep when at rest. Specific gravity of the oil is 0.8. If it is rotated about its vertical axis at a speed of 20 rad/s, determine the smallest depth the vessel can have without spilling oil over the sides.

2. A velocity field associated with a fluid motion is described by the components $u(x,y,z)=cx+2\omega_0 y+u_0$, $v(x,y,z)=cy+v_0$, $w(x,y,z)=-2cz+w_0$ where c, ω_0, u_0, v_0, and w_0 are constants. Compute the rate of strain tensor. Is the motion rotational?

3. A 2D fluid motion is specified in the Lagrangean manner by the position coordinates $x=x_0e^{kt}$, $y=y_0e^{-kt}$. Find the path of a particle and the Eulerian velocity components. Is the motion steady and represent a kinematically possible incompressible flow?

4. The Eulerian velocity components of a fluid motion are given by $u=\frac{x}{t}$, $v=y$, $w=0$. Find the equations for the path lines and the streak lines.