INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

AEROSPACE ENGINEERING DEPARTMENT

Date: Time: 2 Hrs, Full Marks: 30

No of Students: 61 Mid-Autumn Semester Examination 2015-16

AE21001 **Introduction to Aerodynamics**

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

Answer question (1) and any three of the remaining. Marks are indicated within parentheses.
All parts of a multi-part question must be answered together.
Assumptions, if required, can be made with appropriate justifications.

Notations have their usual meaning unless specified otherwise.

Some important vector identities:

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

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

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

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

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

1(a) Define the following terms: airfoil chord, airfoil angle of attack, wing planform, geometric and aerodynamic mean chord of a wing, wing spars and ribs, wash-in and wash-out.

(b) Define aerodynamic centre and centre of pressure. Establish a relationship between their locations. Which of the two will be closer to the leading edge for a positively cambered airfoil generating positive lift?

(12)

2(a) Show that the stress tensor in a simple fluid is symmetric.

(b) Show that the definition of a simple fluid implies that the stress tensor in a fluid at rest is everywhere isotropic and only normal stresses act. Hence or otherwise derive the equation that governs a fluid in equilibrium.

(6)

Turn Over

3(a) State the Buckingham π theorem. Use this theorem to show that the non-dimensional aerodynamic moments are functions of free stream Mach number and Reynolds number.

(b) State and explain various components, based on contributing causes, of drag force. Which of these components can be estimated without taking the fluid viscosity in to account? (6)

4(a) Explain streamlines, streak lines and vortex lines. Show that vortex lines cannot end in a fluid

(b) A fluid motion is described by the Eulerian velocity components $u = a + by - cz$, $v = d - bx + ez$ and $w = f + cx - ey$ where a, b, c, d, e, f are constant. Find the equation of the vortex lines. (6)

5(a) 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.

(b) 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 30 rad/s, determine the smallest depth the vessel can have without spilling oil over the sides. (6)