INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

AEROSPACE ENGINEERING DEPARTMENT

Date: Time: 3 Hrs, Full Marks: 50

No of Students: 60 End-Autumn Semester Examination 2015-16

AE21001 **Introduction to Aerodynamics**

2^{nd} Year B. Tech. (H) & DD

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*Answer **any seven (7) questions**.*

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

Notations have their usual meaning unless specified otherwise.

Some important vector identities:

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

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

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

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

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

Complex velocity at a point on the circle of radius a (*in the circle* (f) *plane with the centre at* f_0):

$$W(f)=q_\infty e^{-i\alpha}+\frac{i\Gamma}{2\pi}\ \frac{1}{f-f_0}-\frac{q_\infty a^2 e^{i\alpha}}{\left(f-f_0\right)^2}$$

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1. Obtain an expression for the stress tensor in a moving fluid that can be assumed Newtonian and isotropic. Derive the complete momentum transport equation for such flows. Further assume the flow to be incompressible and show that the viscous force per unit volume acting on an element is given by vorticity alone. Since vorticity does not produce stress, how is it possible?

2. Consider the flow of an isotropic Newtonian fluid where the body force field is potential and the heat transfer is by conduction only. Obtain the integral form of the energy conservation equation for the flow. Hence or otherwise show that for a frictionless non-conducting fluid with steady pressure field the quantity $E+\frac{1}{2}q^2+\frac{p}{\rho}+\Psi$ is constant along the path of a

Turn Over

material element, where q is the flow speed, E is the specific internal energy and Ψ is the body force potential.

3. Under what conditions a flow can be considered incompressible? State the conditions without derivation. If the flow is further assumed inviscid and irrotational it is known as ideal flow. Get the appropriate governing equation and boundary conditions. Is any additional information needed to solve the flow over a given geometric configuration? What will be the rate of expansion or dilatation at an arbitrary point in this flow field?
Derive the velocity field associated with a point doublet (3-dimensional).

4. A jet of water 20 mm in diameter strikes a flat plate at an angle of 30^0 to the normal of the plate. The jet velocity is 10 m/s and uniform over the cross section just before impact. Find the force exerted by the jet on the plate when the plate is stationary. What will be the force if the plate moves against the jet with a velocity of 2 m/s? Viscous stresses can be ignored.
Find the maximum lift force per unit length acting on an infinite spinning cylinder such that the circulation produced around it is Γ.

5. If a point source is immersed in a uniform stream the resultant flow represents the ideal flow past a 2-dimensional semi-infinite fairing. Determine the source location and strength if the maximum thickness of the fairing is 0.2 m and the uniform stream is at 40 m/s. Find the pressure coefficient on the surface of the fairing at the point corresponding to the location of the source.

6. Find the velocity on the surface of a 12% thick, 4% cambered Zhukovsky airfoil at the three-quarter-chord point. Given that $\alpha = 5^o$, $q_\infty = 50\ m/s$. Find the lift coefficient.

7. A 12% thick Zhukovsky airfoil set at zero angle of attack to a free stream of 50 m/s has a lift coefficient of 0.24. What will be the lift coefficient if the thickness and camber are increased respectively by 3% and 1% and the angle of attack is made 5^o?

8. A long elliptic cylinder of fineness ratio of 11 is set at 0^o incidence to an air stream flowing at 40 m/s. Calculate the pressure difference between pressure holes set in the nose and at the point of maximum thickness.

9. Explain Kutta condition and its' significance in potential flow.
The lift curve slope of an airfoil $\left(\frac{dC_l}{d\alpha}\right)$ is 2π. Find the slope of the pitching moment curve $\left(\frac{dC_m}{d\alpha}\right)$ when the pitching moment coefficient is computed about the mid-chord point.