DHANALAKSHMI SRINIVASAN ENGINEERING COLLEGE
(AUTONOMOUS)
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DEPARTMENT OF AERONAUTICAL ENGINEERING

U20AE401-LOW SPEED AERODYNAMICS

UNIT-1
PART-A

1. Differentiate control volume and control surface

Control volume has a fixed boundary, mass; momentum and energy are allowed to cross the boundary. The boundary of control volume is referred to as control surface.

2. What is aerodynamics?

Aerodynamics is the study of flow of gases around solid bodies.

3. Differentiate between steady and unsteady flows

In a steady flow fluid characteristics velocity, pressure, density, etc. at a point do not change with time but for unsteady flow these characteristics would change with time.

4. Differentiate between compressible and incompressible flow.

In a compressible flow, density of a fluid will change from point to point whereas for an incompressible flow, the density would not change from point to point in the fluid flow

5. Define a system.

The word system refers to a fixed mass with a boundary. However, with time, the boundary of the system may change but the mass remains the same.

6. What do you know about the differential and integral approach?

Differential approach aims to calculate the flow at every point in a given flow field in the form p(x,y,z,t). One may establish a big control volume to encompass the region R and calculate the overall features like

7. What is the principle of conservation of mass?

Mass cannot be created or destroyed. This is the principle for continuityequation.

8. Give the continuity equation for a steady flow

For a steady flow mass accumulation will not happen inside the control volume. So,cS∫ρVdA) =0, where V is the velocity of the fluid

9. Give the continuity equation for an incompressible flow.

For an incompressible flow, ρ, the density is constant. So,

$\partial/\partial t$ (cv∫? d? +cS∫VdA) =0

Where ? is the infinitesimal volume and V is velocity of the fluid

10. Give the continuity equation for a steady – incompressible flow.

If the flow is steady and incompressible, then the continuity equation is

cS∫VdA) =0, where V is the velocity of the fluid.

11. Consider a convergent divergent duct with an inlet area A1 = 5 m2 Air enters this duct with a velocity V1 = 10 m/s and leaves the duct with a velocity V2 = 30 m/s. What is the area at the exit of the duct?

For incompressible steady flow, the continuity equation is :

A1 x V1 = A2 x V2, therefore A2 = A1 x V1/V2 = 5X10/30 = 1.67 m^2

12. What are the forces that can be experienced by the fluid flowing in a control volume

1. Body forces like gravity, electromagnetic force or any other force that can act at a distance on the inside a control volume.
2. Surface forces like pressure and shear stress acting on the control surface S.

13. What is impulse momentum equation?

The impulse of a force 'F' acting on a fluid mass 'm' in a short interval of time 'dt' is equal to the change of momentum d(mv) in the direction of the force.

14. What is meant by streamlining a body?

Stream lining a body in a fluid flow minimises the drag due to friction by providing the body such a shape that the boundary of the body permits gradual divergence of flow with no separation of the boundary layer.

15. What is a perfect fluid?

Perfect or ideal fluid is one which is frictionless and effects of viscosity are negligible, while a perfect gas is one which obeys Boyle's and Charles laws.

16. What is a rotational flow?

A fluid flow in which every element of fluid rotates about its own centre.

17. What is a vortex line and vortex tube?

Vortex line is the vector line of the vorticity field. Vortex tube is a vectortube filled with fluid and framed by vortex lines.

18. Relate the terms irrotationality and vorticity in fluid flow.

The motion of a fluid is said to be irrotational when vorticity equals zero.That is twice the angular velocity is zero.

19. How stream function may be used to determine the discharge of fluidflow?

The stream function may be defined as the flux of the stream flow. Hence the difference between the adjacent stream functions gives the rateof flow between the stream lines.

20. If stream function or potential function of a flow satisfies Laplace equation, what does it mean?

If stream function satisfies Laplace equation, then the flow is irrotational. If the potential function satisfies Laplace equation, then the flow is continuous.\

PART-B

1. Derive the general x-momentum equation for an unsteady 3-D inviscid flow in partial differential form using a control volume approach.

2. Define angular velocity, strain rate, vorticity and dilatation of a fluid element.

3. Derive the expressions for stream function and velocity potential function.

4. Explain source, sink, free and forced vortex with neat sketches.

5. What are the characteristics of a vortex flow?

6. State and prove Kutta-Joukowski's theorem.

7. Explain how the Joukowski's transformation is used to obtain a circular are aerofoil.

8. Explain Blasius theorem for a steady two dimensional irrotational flow.

9. Enumerate the limitations and applications of Joukowski's aerofoil.

10. Explain Kutta condition.

UNIT-II
PART-A

1. How stream function and potential function are related to irrotational flow?

Stream function exists for both rotational and irrotational flows,potential function exists only for irrotational flow.

2. What is free vortex flow?

A flow field with circular streamlines with the absolute value of the velocity varying inversely with the radial distance (distance from the centre). The flow is irrotational at every point except at the centre.

3. What does a free vortex flow mean?

A flow which is free of vorticity except at the centre.

4. What is meant by a bound vortex of a wing?

The vortex that represents the circulatory flow around the wing is called the bound vortex. This vortex remains stationary with respect to the general flow.

5. What s a forced vortex flow?

A flow in which each fluid particle travels in a circular path with speed varying directly as the distance from the axis of rotation.

6. Define velocity vector with respect to a potential line.

There is no velocity vector tangential to a potential line, the velocity is perpendicular to the potential line.

7. Why tornado is highly destructive at or near the centre?

Tornado is free vortex flow such that the velocity multiplied by the distance from the centre is constant. Therefore, the velocity is maximum at the centre, hence it is highly destructive.

8. Specify the stream and potential lines for a doublet.

Stream lines are circles tangent to x-axis ($\psi = r/\sin\theta$). Potential lines are circles tangent to y-axis ($\varphi = r/\cos\theta$)

9. Specify the stream and potential lines for a source and a sink.

Stream lines are radial lines from the centre and potential lines arecircles.

10. Compare the streamlines and potential lines of a source / sink withthat of a vortex flow.

The stream lines of source / sink and potential lines of a vortex are similar. The potential lines of source / sink are similar to the stream lines ofa vortex.

11. State the properties of a stagnation point in a fluid flow.

The sudden change in momentum of fluid from a finite value to stagnant value impresses pressure force at the point of stagnation, thus whole of the velocity gets converted to pressure.

12. What is Rankine half body?

The dividing stream line y = m/2 of source, uniform flow combination forms the shape of Rankine half body.

13. What is Rankine Oval?

The dividing stream line ($\psi = 0$) of doublet, uniform flow combination forms the shape of Rankine oval.

14. **How transverse force can be introduced to a flow around a cylinder?** A: Add a circulatory flow along with the uniform flow to get a transverseforce. Spin the cylinder about its own axis to get circulatory flow.

15. How will be the stream and potential lines in source vortexcombination?

Stream and potential lines in a source vortex combination are bothequiangular, spirals. The change of direction of radial movement of fluidparticles will be equal in magnitude while in opposite direction to change intangential movement so that curves are equiangular spirals.

16. Compare vortex with source / sink flow pattern.

The stream lines of source / sink and potential lines of vortex are similar.The potential lines of source / sink and stream lines of vortex are similar.

17. State the stream function for uniform flow of velocity 'U' parallel topositive X- direction.

Stream function $\psi = -Uy$

18. State the stream function for uniform flow of velocity parallel topositive Y- direction.

Stream function $\psi = -Vx$

19. What is the diameter of a circular cylinder which is obtained by combination of doublet of strength μ at origin and uniform flow U parallel to X axis.

Diameter is $a = \sqrt{\mu}/2\pi V$

20. How a line source differs from a point source?

A two dimensional source is a point source from which the fluid is assumed to flow out radially in all directions. As this flowis restricted to one plane and to allow for the applications of the results to 3-dimensional flows, the term line source is used sometimes.

UNIT-3

PART-A

1. Define potential flow of a fluid.

The irrotational flow of an incompressible fluid is called potential flow.

2. Relate vorticity and circulation.

Vorticity is the circulation around an element divided by its area.

3. Relate vorticity and angular velocity.

Vorticity is equal to twice angular velocity. Therefore, circulation = 2* angular velocity * area

4. What is meant by Karman vortex sheet.

A body moving in a real fluid leaves two rows of vortices from its sides. These vorticies are rotating in opposite directions and gradually dissipated by viscosity as they move down stream. If the vortices are stable, for a distance between vorticies‘h; and for pitch ‘l’ of the vortices, h/l = 0.2806for Karman vortex sheet.

5. How are the streamlines in a source sink pair?

The stream lines are circles with centre on y-axis for a source sink pair. Stream lines are circles with common chord.

6. What is vortex pair?

Two vortices of equal strength but of opposite sign or with opposite directions of rotation constitute a vortex pair.

7. What is meant by complex potential?

If velocity potential ‘φ’ and stream function ‘ψ’ are combined in a single function ‘w’ such that $w(z) = \varphi + I\,\psi$, then w(z) is called complex potential function.

8. What is transformation?

A transformation is a mathematical process by which a figure may be distorted or altered in size and shape. This done by means of an algebraic relationship between the original coordinates and coordinates of the new position, the pair of coordinates being represented by complex variables.

9. When a transformation is said to be conformal?

A transformation is said to be conformal if small elements of areas are unaltered shapes (though they are in general altered in size, position and orientation.

10. What is Joukovsky transformation?

Joukovsky assumed that relation $w(z) = z + a^2/z$ so that second term is small when z is large. Thus at great distances from the origin the flow is undisturbed by the transformation.

11. What is thickness ratio (fineness ratio) of Rankine oval?

It is the ratio of maximum thickness to chord of Rankine oval.

12. Define lift and drag.

Since the fluid is in motion, we can define a flow direction along the motion. The component of the net force normal to the flow direction is called the lift and the component of the ent force along the flow direction is called the drag.

13. Define centre of pressure.

The dynamic forces act in a body through the average location of the pressure variation which is called the centre of pressure.

14. How velocity varies with radius in a vortex core?

For viscous flow around a vortex core velocity is inversely proportional to the radius.

15. How the down wash of a wing is related to down wash of tail plane?

The down wash on the tail resulting from the wing wake is almost twice as great as the down wash on the wing resulting from the wing wake.

16. What is strength of a vortex and how is it measured?

It is the magnitude of circulation around it and is equal to the product of vorticity and area.

17. How are wing tip vortices are formed – explain in brief.

Due to larger pressure below the wing surface than on the top surface, some flow is there from bottom to top round the wing tips for a finite wing. This produces velocity sideways over most of the wing surface. This causesa surface discontinuity in the air leaving the wing which rolls up to distinct vortices.

18. Suggest ways to reduce induced drag of a wing.

(i) Make lift distribution on the wing elliptical

(ii) Increase the aspect ratio.

19. State the assumptions made in simplified horseshoe vortex system of awing.

The wing is replaced by a single bound span wise vortex of constant strength which turns at right angle at each end to trailing vortices which extend to infinity behind the wing. These two trailing vortices: (i) each of which must provide the same total lift (ii) each must have same magnitude of circulation and the same circulation at mid span.

20. What is meant by Kutta – Joukovsky flow?

Kutta prescribed tangential flow condition at trailing edge of aerofoil, while Joukovsky solution permitted a rounded leading edge to have a smooth flow around the leading edge without separation.

PART-B

1. Derive the fundamental equation for thin airfoil theory and give the assumptions that are made in thin aerofoil theory.

2. Explain Biot-Savart's law with application.

3. Explain starting vortex and horse shoe vortex.

4. Explain lifting line theory and give its limitations.

5. Explain the types of drag produced due to the effects of viscosity.

6. Derive Navier-Stokes equations for an unsteady, compressible, three-dimensional viscous flow.

7. What is boundary layer separation?

8. Explain displacement thickness and momentum thickness in boundary layer theory.

9. Derive expressions for the velocity potential and stream function for a doublet.

Briefly explain Karman Treffety, Von mises and Carafoli profiler.

UNIT-4

PART-A

1. What is the effect of boundary layer in case of a Kutta – Joukovskyflow?

Separation of boundary layer at leading edge can be avoided in a small range of angle of attack due to thin boundary layer formation. The formation of boundary layer causes the flow to leave the trailing edge non tangentially.

2. State the limitations of lifting line theory.

Straight narrow wings with smooth pressure distribution, the theory agrees well.

(ii) Theory gives correct value of down wash along the centre of pressure of any distribution of lift that is symmetrical ahead and behind a straight line at right angles to the direction.

(iii) For curved or yawed lifting lines of low aspect ratio, the theory is not adequate.

3. Why a thin aerofoil is considered in sub sonic flow?

The necessity of minimising the induced drag leads to the choice of high aspect ratio for the wing design at sub sonic condition. Hence thin aerofoil is preferred. With such narrow wings the flow can be approximated to 2- dimensional flow around an infinitely long cylindrical wing of same section profile.

4. Define a slender body of revolution.

The radius of the body is very small compared to the length of the body,such a body is known as slender body of revolution.

5. State in brief the limitations of Prandtl Glauret's compressibility correction factor.

At some Mach number below unity, the value of M depends upon the thickness of aerofoil and angle of attack. Aerofoil with finite thickness the perturbation components of velocity cannot be considered small relative to the free stream velocity. (u/U and v/V are not small)

6. Why Fourier sine series in the form $\sum_1^n A_n \sin n\theta$ was assumed for distribution of circulation on an airplane wing?

Sine series was chosen to satisfy the end conditions of the curve reducing to zero at tips where y = +s. (θ = 0 to θ = π)

7. How the sine series was modified for circulation on a symmetricallyloaded

wing?

For symmetrical loading maximum or minimum should be at mid section. This is possible only when sine series of odd values of (π/2). Odd harmonics of sine series are symmetrical.

For any asymmetry due to rolling or side slip what form of distribution is acceptable. For any symmetric loading one or more even harmonics of sine series are to be incorporated in the distribution.

8. State Kelvin's circulation theorem.

Circulation and hence vortex strength does not vary with time if (i) the fluid is non viscous (ii) the density is either constant or a function of pressure only

(ii) body forces such as gravity or magnetic forces are single valued potential.

9. Compare thin aerofoil theory with vortex panel method.

Limitations of thin aerofoil theory are (i) it applies to aerofoil at small angleof attack (ii) the thickness must be less than 12% of the chord. When higher angle of attack and when aerodynamic lift of other body shapes are to be considered vortex panel method finds its application. Vortex panel method is a numerical method and provides aerodynamic characteristics of bodies of arbitrary shapes, thickness and orientation.

10. Point out the applications of horseshoe vortex analysis in aerodynamics.

Prandtl lifting line and lifting surface theory of wings

1. Interference problem of aircraft flying together
2. Ground effect of aircraft flying close to the ground
3. Influence of wing down wash field on flow over other components ofaircraft especially the tail plane.
4. Interference in wind tunnel

11. Why large spacing is to be provided to aircrafts for landing and take offtogether?

Wing tip vortices are essentially like tornadoes that trail down stream of the wing. These vortices can sometimes cause flow disturbance to aeroplane following close to it. Hence to avoid such accidents large spacing is preferred between aircraft during take off and landing.

12. What is the effect of downwash velocity on local free stream velocity?

Down wash causes local free stream to produce relative wind at a slightly higher angle of incidence. $\alpha_{eff}=\alpha - \alpha_i$

13. Why geometric angle of attack of a wing and the effective angle ofattack of local aerofoil differ?

The angle of attack actually seen by local aerofoil section is the angle between aerofoil section chord and local relative wind. Although the wing is ata geometric angle of attack, local aerofoil section sees a smaller value of angle of attack than geometrical.

14. Show that D Alembert's paradox is not true for a finite wing?

D Alembert's paradox states that there is no drag on bodies submerged in a flow of perfect fluid. The presence of down wash over finite wing creates a component of drag – induced drag with in inviscid flow of fluid when there is no skin friction or flow separation. Hence the paradox is not true in the case of flow over a finite wing.

15. Can induced drag on a wing be considered as a drag caused by pressure difference?

The three dimensional flow induced by wing tip vortices simply alters the pressure distribution on the finite wing, in such a way that there is non balance of pressure in the stream direction. This s induced drag, which may be considered as a type of pressure drag.

16. How induced drag differs from viscous dominated drag contribution?

Viscous dominated drag is due to skin friction, pressure drag and boundary layer separation drag. Induced drag is purely due to down wash induced by vortices and has nothing to do with viscosity of fluid or boundary layer formation.

17. The profile drag coefficient for a finite wing maybe taken equal to that of its aerofoil section. Why?

Profile drag is the sum of skin friction and pressure drag, which is mainly viscous dominated part of drag. This depends on the fluid flowing and on the configuration of aerofoil section and not on the extent of the wing.

18. State analogical electromagnetic theory to Biotsavart law.

The vortex filament is visualised as a wire carrying current 'I' then the magnetic field strength dB induced at a point P by a segment of wire 'dl' with current in the direction of wire is

$dB = \mu I \, dl \times r / (4 \pi (r)^3$ where 'μ' is the permeability of the medium surrounding the wire.

19. What is meant by geometric twist of a wing? How it differs from aerodynamic twist?

A small twist is given to the wing so that α (angle of attack) at different span wise stations is different. This is called geometric twist. The wings of modern aircraft have different aerofoil sections along the span with values of zero angle that is called aerodynamic twist of wing.

20. Why the lift over the span is not uniform?

Geometric twist causes angle of incidence variation from root to tip of the wing. The wings of airplanes have different aerofoil sections along the span with different zero lift incidence. As a result of this, lift per unit span is also different at various locations from the centre. There is distribution of lift per unit span length along the span.

PART-B

1. Using thin aerofoil theory derive expressions for the C1, Cmpe of a flat plate at an angle of a attack ά.

2. Clearly explain the method of obtaining the Zoukowski transformation to get a cambered airfoil.

3. What is a rankine oval? What combination of flows is required to obtain the Oval?

4. The X and Y velocity components of an fluid flow are given byU=2xy+4y+6x and v=3y+2x2+6xy. Is the flow irrotational? Is it is a physically possible flow?

5. A thin airfoil has a mean chamber line is given by y/c = 0.25 [0.8 (x/c) – (x/c)2] for 0 x/c 0.4 and y/c = 0.11 [0.2 + 0.8(x/c) – (x/c)2] for 0.4 x/c 1.0 where c is chord of the airfoil, x,y are the axis parallel and perpendicular to the chord respectively.Based on thin airfoil theory calculate at zero lift,

6. Moment coefficient at quarter chord point.

7. Clearly explain the method of obtaining the Zoukowski transformation to get a cambered airfoil.

8. Explain the terms ‘Bound vortex’, ‘Starting vortex’ and ‘ Horse shoe vortex’

9. Show that for an elliptical wing loading the induced drag is minimum.

10. Show that the combination of doublet flow and the uniform flow is equivalent to a non-lifting flow overa cylinder. Obtain the expression for velocity potential function and stream function for the combination.

UNIT-5

PART-A

1. What is geometric twist? Differentiate between "wash out" and "wash in".

The wings of an aircraft are slightly twisted from fuselage towards the tip so that the angle of incidence of the individual aerofoil sections are different at various span wise stations. If the tip of the wing is at lower angle of incidence than the root, the wing is said to 'wash out' and if the tip is at higher angle of incidence than the root, the wing is said to have 'wash in'

2. Why induced drag is said to be due to lift?

Induced darg is the consequence of the wing tip vortices which are produced by the difference in pressure between upper and lower surface of the wing. The lift is also produced by the same pressure difference. Hence the cause of induced drag is closely associated with the production of lift in a finite wing.

3. When lift is high drag is also high and becomes a major part of the total drag, why?

Induced drag coefficient varies as the square of the lift coefficient for elliptical load distribution over a wing for higher lift induced drag is also high and becomes a major part of total drag of the aircraft.

4. Aspect ratio of a conventional aircraft should have a compromise between aerodynamic and structural requirements – discuss briefly.

Larger the aspect ratio, smaller will be the induced drag coefficient and vice versa. Hence there is reduction in induced drag. In a design of high aspect ratio wing becomes slender and has poor structural strength. A compromise between these two should be aimed while designing the aspect ratio of a wing.

5. How lift distribution, plan form and down wash velocity are related in an airplane wing?

A: For elliptical lift distribution on the span of a wing, chord variation from root to tip section may be assumed elliptical or elliptical plan form may be assumed. In such cases the downwash velocity may be constant throughout the span.

6. Give the advantages of a tapered wing in brief.

elliptical plan forms are difficult and expensive to manufacture compared to rectangular plan forms. Rectangular plan forms do not generate optimum lift distribution. A compromise is something in between these two plan forms, viz., tapered plan form so that lift distribution approximate the elliptical case. A tapered wing can be designed with an induced drag reasonable close to minimum value. It is easier to make straight leading and trailing edges of tapered plan form. That is why most conventional aircraft employ tapered rather than elliptical plan forms.

7. What is the range of aspect ratio for a typical sub sonic airplane?

Aspect ratio is from 6 to 22 for most wings. For wind tunnel testing it is upto 6

8. Specify the criteria for design for minimum drag.

A: The design criteria is that the plan form should be close to an elliptical one and the aspect ratio as large as possible.

9. What is relation between aspect ratio and lift curve slope?

With reduction of aspect ratio, lift curve slope reduces for a finite wing. For an infinite wing, aspect ratio is infinite and the lift curve slope is larger.

10. To what plan forms the lifting line and lifting surface theory are applicable?

Lifting line theory gives a reasonable result for straight wing at moderateand high aspect ratio. At low aspect ratio, straight, swept and delta wings havea more sophisticated model of lifting line theory and lifting surface theory is applied.

11. What do you understand by tangency condition on every point on wing surface?

The wing plan form is assumed as the stream surface of flow in lifting surface theory. There is no flow velocity component normal to this stream surface. Hence, induced velocity and normal component of free stream velocity to be zero at all points on the wing. This is called the tangency condition.

12. If two wings (with high and low aspect ratio) have the same lift coefficient, how are their aspect ratio and angle of attack are related?

A wing of low aspect ratio will require a higher angle of attack than a wing of higher aspect ratio in order to produce the same lift coefficient.

i.e., $C_L \infty AR * \alpha$ (appxx)

13. Justify the statement "the bound vortex strength is reduced to zero at the wing tip".

The pressure coefficient distribution goes to zero at the tips of the wings because of pressure equalisation from the bottom to top surface of wing. This causes no discontinuity of velocity between upper and lower surface of a wingat its tips. At wing tips single bound vortex of constant strength turns through right angle at each wing tip to form trailing vortices. This is equivalent to vortex filament of equal strength joined at tips.

14. How the span of a simplified vortex system worked out for the given bound vortex of a wing?

Simplified system may replace the complex vortex system of a wing when considering the influence of the lifting system on distant points in a flow. Wingis replaced by a single bound span wise vortex of constant strength which is turned at right angles at each wing tip forming trailing vortices which extend to infinity. When general vortex is simplified following points are to be noted: (i) the bound vortex and the simplified vortex must provide the same total lift (ii) must have the same magnitude of circulation about the trailing edge vortices and hence same circulation at mid span.

15. What is the length of semi span of equivalent horseshoe vortex forelliptical distribution of circulation on a wing span of '2s'?

Equivalent semi span s' = π s/4

16. Explain why downwash for downstream of the wing is twice that of thewing itself.

The downwash near the bound vortex is due to two infinite trailing vortices.

W = r (cos θ + cos α) / 4 πy. Substituting 0 for both the angles, we get

W = r (cos 0 + cos 0) / 4 πy. = r/2 πy. That is twice the downwash velocity value of the bound vortex

17. State Helmholtz vortex theorems.

Strength of a vortex cannot increase or decrease along its axis or length, the strength being the circulation around it and it is equal to vorticity x area.

Vortex cannot end in a fluid. It forms a closed- loop, vortex can end only on asolid boundary.

There is no fluid interchange between tube and surrounding fluid and thesame fluid particles move with the vortex.

18. Where can a vortex end?

Vortex cannot end in a fluid. It forms closed loop in a fluid. Vortex can have a discontinuity when there is a solid body against it or where there is surface of separation.

19. Can a vortex tube change in its strength between two of its sections?

A vortex tube cannot change its strength between two of its sections unless vortex filament of equivalent strength join or leave the vortex tube.

20. State Blasius theorem for 2-D incompressible, irrotational flow.

This theorem provides a general method of determining the resultant force and moment exerted by a fluid in a steady 2-dimensional flow past a cylinderof any cross section provided that the complex potential for the flow pattern is known. If x and y components of the resultant force are Px and Py and moment of the resultant force about the origin is Mz, then

$Px – I\ Py = ½\ I\ \rho \int (dw/dz)^2 dz$ and

$Mx + I\ My = ½\ I\ \rho \int z\ (dw/dz)^2 dz$ where integrals are taken around the contour of the cylinder.

PART-B

1. What do you understand by the terms displacement thickness, momentumthickness and energy thickness?

2. What are the boundary conditions used for solution of boundary layerequations. Explain the significance of each boundary condition.

3. Explain using a neat sketch the boundary layer separation.Q4: What is profile

drag for an aerofoil?

4. Write a short note on boundary layer separation.

5. Obtain the boundary layer equations for laminar boundary layer over a flatplate using order of magnitude analysis.

6. Derive Navier Stokes equations for a real fluid flow.

7.

Q1: Derive the general continuity equation for an unsteady 3 dimensional flow. Either Cartesian component wise or control volume approach may be used.

Q2: Derive the general continuity equation for an unsteady 3 dimensional flow. Either Cartesian component wise or control volume approach may be used.

Q3: Derive the energy equation for an unsteady 3 dimensional flow using control volume approach.

Q4: A turbojet engine in flight travels at 864 km/hr. Ambient atmospheric pressure is 0.7 kg/cm^2. Airflow to the engine is 22.7 kg/s. Fuel flow is 0.018 kg/s. Nozzle outlet area is 0.103 m^2 and the outlet pressure is 0.9 kg/cm^2. Outlet gas velocity is 560 m/s. Assuming that the pressure at the inlet sectionis equal to the atmospheric pressure, calculate the thrust produced by the engine.

UNIT-2

Q1:Show that the lines of constant stream function are circles of radius $\mu/(4\pi\psi)$ and centres $(0, \mu/(4\pi\psi))$

Q2: Show that the flow around a long circular cylinder can be given by a 'doublet' in a uniform horizontal flow.

Q3: Calculate the equation of a streamline passing through the point (0, 5) for a given velocity field given by $u= y/(x^2+y^2)$ and $v= -x/(x^2+y^2)$

Q4: A guard for supporting the strut of a wind tunnel is designed by the combination of a source at the origin with a free stream of uniform velocity U_o. Show the pressure distribution on the surface of the guard is $p - p_o = \frac{1}{2} \rho U_o^2 (\sin 2\theta/\theta - \{\sin\theta/\theta\}^2)$ where p is the pressure on the surface and p_o at free stream.

Q5: A two dimensional irrotational flow is produced by a source 200 m^2/s in a stream 40 m/s together with sink of equal strength 2 m down from source.Find the fineness ratio of the oval represented by the dividing streamline.

Q6: Show how to construct (by a graphical method) the streamlines representing the flow of a source in the neighbourhood of a plane wall. Also deduce the analytical expression for the streamlines.

Q7: A line source of strength σ is at the origin in an otherwise uniform streamof an inviscid incompressible fluid of velocity –U parallel to x-axis. Write down the resulting stream function for the combined flow and determine the equation of the streamline which branches at the stagnation point. In particular, determine in terms of σ and U the maximum distance measured parallel to the y-axis between the branches. What is the value of pressure coefficient on the streamline at the points where the y-axis cuts it? Discuss very briefly how this solution can be used to describe the flow past a half body.

Q8: A two dimensional irrotational flow is produced by a source 200 m^2/s in a stream 40 m/s together with sink of equal strength 2 m down from source.Find the fineness ratio of the oval represented by the dividing streamline.

UNIT-3

Q1: State the Blasius theorem and give proof for the same for a two dimensional incompressible and irrotational flow..

Q2: Obtain Joukovsky aerofoil using conformal transformation.

Q3: Write the general expression for Joukovsky transformation and use thesame to transform a circle into a cambered aerofoil. Obtain the thickness chord ratio for the cambered aerofoil.

Q4: Explain how a flow over circular cylinder can be transformed into a flowover a flat plate using Joukovsky transformation.

Q5: Apply Joukovsky transformation $w = z + a^2/z$ to a circle in z-plane and centre at origin. Hence obtain an expression for the velocity at any point onthe surface of a cylinder in an otherwise uniform stream.

Q6: The thickness ratio of a symmetrical Joukovsky section is 0.156. Estimate the pressure coefficient midway along the chord for two dimensional incompressible flow at zero incidence.

UNIT-4

Q1: Develop an expression to calculate velocity induced at appoint in z=0 planeby an L shaped vortex element associated with an aeroplane wing surface located at a point P(x, y).

Q2: Obtain an expression for instantaneous down wash velocity due to a pair of infinite straight vortices (of equal strength but of opposite sign) along a linejoining their centres, in terms of the strength and distance apart of the vortices.

Q3: Two semi-infinite legs of a horse shoe vortex of equal strength Γ are at a distance of δs apart and the direction of spin is such that there is a down washbetween them. Find an expression of induced velocity and its direction at a point on the cross vortex at a distance y from the centre.(10)

Q4: Derive the fundamental equation for thin aerofoil theory with a neatsketch.

Q5: Explain Prandtl's lifting line theory with neat sketches.

Q6: The mean camber line for an aerofoil is given by

$y/c = 2.7595 [(x/c)^3 - 0.6075 (x/c)^2 + 0.1147 (x/c)]$ for $0 \leq x/c \leq 0.2025$ and

$y/c = 0.02208 (1-x/c)$ for $0.2025 \leq x/c \leq 1$ where c is the chord of the aerofoil, x and y are axes parallel and perpendicular to the chord respectively.

Calculate (a) angle of attack at zero lift (b) the lift coefficient when $\alpha = 4^0$, (c)the moment coefficient about the quarter chord, and (d) the location of the centre of pressure.

Q7: A vortex of strength 'Γ' is in the shape of a closed circular loop of radius 'R'. (a) Obtain an expression for velocity induced at the centre of the loop in terms of Γ and R. (b) for the same vortex what is the velocity induced at a pointl from the centre.

Q8: A circular cylinder of 2.0 m diameter and 12 m length is rotated at 300 rpm about its axis when it is kept in an air stream of 40 m/s velocity, with its axis perpendicular to the flow. Determine (i) circulation around the cylinder, (ii) theoretical lift, (iii) position of stagnation points and (iv) actual drag, lift and resultant force on the cylinder, take $C_D = 0.52$, $C_L = 1.0$ and $\rho = 1.208$ kg/m^3.

UNIT-5

1. Derive Navier Stokes equations for a real fluid flow.

2. Derive laminar boundary layer equations for a flat plate set at zero incidence. What are the boundary conditions?

3. Define the terms displacement thickness, momentum thickness and energy thickness for boundary layer. Derive expressions for each one of them.

4. Derive momentum integral equation for two dimensional steady flow.

5. Derive the classical Blasius solution for laminar boundary layer over a flat plate.

6. Explain lifting line theory and give its limitations.

7. Explain the types of drag produced due to the effects of viscosity.

8. Derive Navier-Stokes equations for an unsteady, compressible, three dimensional viscous flow.

9. What is boundary layer separation?

10. Explain displacement thickness and momentum thickness in boundary layer theory.