Questions in „Advanced fluid dynamics”

1. Derive the evolution equation of the elementary fluid line, and show it’s analogy with the vorticity transport. What conclusions can be drawn? Formulate and explain the vorticity transport equation! For what reasons may the vorticity of a fluid parcel change in incompressible flow? Please classify the terms.

2. How can the pressure field be calculated from the velocity field, in the case of irrotational flows of an ideal fluid and in the case of Darcy flow? From what equation can the velocity potential of a constant density irrotational fluid flow be obtained? Define the vector potential for the velocity field of a constant density fluid flow! Show its relation to the stream function and explain the physical meaning of the stream function.

3. Define the complex potential and prove that the Couchy-Riemann conditions are fulfilled! Show the complex velocity is related to the stream function!

4. Explain the Joukowskiy transformation and the way it is used for calculating the lift coefficient of an arched plate!

5. Define the displacement thickness! How is it related to the boundary layer thickness for laminar flow past a flat plate of zero angle of inclination? Derive the relation between δ/x and Re_x for laminar boundary layers!

6. Derive the boundary-layer equation from the 2D Navier-Stokes equation! How do you determine the pressure gradient from the far field velocity?

7. Show the self-similar form of the boundary layer equation for laminar flow!

8. Derive the velocity profile for the laminar sub-layer and for the fully turbulent layer by assuming constant shear stress! Describe the structure of the turbulent boundary layer!

9. Explain the numerical method for solving the boundary layer equation of turbulent flow!

10. Derive the relation between the relative velocity increase (dv/v) and the relative increase of the channel cross-section (dA/A)! What conclusions can be drawn from this relation?

11. Derive the temperature ratio (T/Tt) and the cross-sectional area ratio (A/A*) as functions of the Mach number (M) for an isentropic flow!

12. Derive the quadratic equation for the square of upstream and the downstream Mach numbers from the conservation laws applied to a steady normal shock! Draw qualitatively correct graphs of the pressure, density, temperature, Mach number and stagnation pressure ratios for a normal shockwave!

13. What are the major differences between a Mach wave and an oblique shock? Prove that the tangential velocity component does not change and that the normal velocity component will change according to the laws valid for normal shocks!

14. Draw the qualitatively correct contour graph of the change of the angle of the flow direction (δ) as a function of the upstream Mach number (M_1) and the angle of the oblique shock (β)! What conclusions can be drawn from this graph?

15. Show the variation of pressure in a convergent-divergent nozzle as a function of the streamwise coordinate for different pressure ratios!
16. Describe the Cross method that is used for calculating the flow rates in looped networks and derive the loop correction formula!
17. Derive the reduced elasticity modulus for liquids contained by thin walled pipelines of finite elasticity modulus!
18. Derive the characteristic variables from the 1D form of the continuity equation and the equation of motion (including wall friction) by applying acoustic assumptions. Describe the method of characteristics! What are the boundary conditions for a closed end, for an open end and for a pipe junction?
19. Derive the vertical component of the equation of motion for the perturbation quantities in atmospheric flow using the Boussineq approximation for the buoyancy force!
20. Specify the x,y,z components of the Coriolis force in atmospheric flow! Which terms are negligible and why? Show the relation between the pressure gradient and the wind direction for a geostrophic wind! Explain the variation of wind direction in the boundary layer!

31th of May 2018.