Final exam questions

Subject group name: **Fluid Mechanics elective – Flow Stability**

Neptun code: ZVEGEVGNX27

Credit points: 3

Subject in this subject group:

- **Flow Stability** (BMEGEVGNX27)

Program: Mechanical Engineering Modelling, MSc (2N-MW0)

Specialization: Fluid Mechanics

Responsible person:

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You can check the current subject forms at the Educational Portal of the Faculty of Mechanical Engineering.

https://oktatas.gpk.bme.hu/

Always check the for updates at edu.gpk.bme.hu before preparing for the exam, especially if the subject group contains at least one subject from your final semester!

Valid from 01 September 2022

Dr. Péter Nagy

research fellow

Flow Stability (BMEGEVGNX27)

1. Please describe the D'Alambert's paradox. Please show a possible explanation. Please introduce the properties of a turbulent flow briefly.
2. Please define various stability properties of a physical system. Please select a fundamental flow configuration and show its various limits.
3. Please derive the kinetic energy change of the perturbation in a parallel flow. Please conclude the Sommerfeld paradox from the expression. What is the solution of the paradox?
4. Please describe the Orr-Sommerfeld equation! What kind of flows does the Orr-Sommerfeld equation describe? What are the boundary conditions for the Orr-Sommerfeld equation for channel flow, jet flow, and wall boundary layer flow?
5. What is the difference between an initial value and a boundary value problem? Please give a simple example for both of them. What is a Strum-Liouville problem?
6. Introduce the idea of orthogonal projection (with the vector analogy) of the best approximation. Define the inner product for the continuous and discrete function approximation. How can we approximate function derivatives by the collocation method?
7. Define the suitable grid points for the Chebyshev spectra collocation method. Please illustrate the answer also via a diagram. Illustrate the features of the Cardinal functions graphically. Define their obvious/classic form. Why the classic form cannot be used during numerical simulations?
8. Please compare the spatial and temporal stability analysis! (Physical meaning, unknowns/parameters, eigenvalues, form of the eigenvalue problem.) What is the critical Reynolds number according to linear stability analysis?
9. Please define the phase velocity and group velocity. What is the difference between a dispersive and a non-dispersive system. Please describe the Gaster transformation!
10. The Orr-Sommerfeld equation has the form:
$$(U-c)(D^2-k^2)\,\hat{v}+U''\hat{v}-\frac{1}{i\alpha Re}(D^2-k^2)^2\hat{v}=0$$
for a three-dimensional perturbation, where k is the wavenumber. Please show the Squire transformation. From the result, please conclude the Squire theorem.

11. Draw and explain a thumb curve for a wall boundary layer with zero pressure gradient. What happens along an F = constant line? Describe the e^N method for the transition prediction.
12. Please describe the Sommerfeld paradox! (Equations are not necessary) Please explain why a perturbation can grow in a linearly stable system? (Formula is necessary) What is a necessary condition for it? (In which cases can the classical stability analysis used and in which cases cannot?) Please given an example (physical system) when this condition holds and does not hold.
13. Which method can predict the limit (Reynolds-number) for a globally stable flow? Please describe the steps of derivation!
14. Please select a flow, in which transition is subcritical. Please draw the simplified bifurcation diagram as the function of initial kinetic energy and the Reynolds number. Please show the limits (with an estimated numerical value) on the diagram for the selected flow. How can the kinetic energy of the perturbation change in various cases?