Department of Whole Vehicle Engineering
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TOPICS for the STATE EXAM from the course titled

„Computational Fluid Dynamics in Vehicle Engineering”

15 January 2020

General philosophy of questions:

1. The Examiner aims to check,
    a. whether the student has a good engineering thinking in the given topic
    b. whether he/she can have a good discussion about the given topic in a dialogue format
    c. whether he has clues about the key figures (for example: typical values for drag, typical hot-spot temperatures, etc.) in the area of vehicle development
2. The student draws a certain topic from the list below, in which area 3-5 questions will be asked by the Examiner
3. The Examiner’s questions will be provided in „layers”, with:
    a. top layer (first question): easiest, foundation-knowledge based question
    b. bottom layer (last question): hardest, detailed understanding based question
4. Preparation for the questions:
    a. The top level question will be given to the student in writing and the student will be asked to work it out in the preparation time.
    b. The deeper level questions *might be* listed in writing, or *can be* asked by the Examiner on the spot, i.e. as a response to the top level question’s answer from the student.
5. The student will be evaluated on the basis on how deep he/she could go in the layers with successfully answering the questions.
    a. Answering all layers successfully: oustanding result
    b. Answering only the top layer question correctly (and not being able to answer any other questions): minimum expectation to get a passing grade
    c. Not being able to answer even the top layer question: fail

- **Fundamentals of CFD:** Fluid as a continuum, Lagrangian and Eulerian viewpoints, Control Volume principle and applications, conservation of mass, momentum and energy, Bernoulli equations and its limitations

- **Governing equations in CFD 1:** Navier-Stokes equations, Flux vector formulation of the N-S equations, Conservative vs. primitive forms, Euler equations, Model equations

- **Numerical solution of PDE's:** Selection of mathematical model, Selection of discretization method (Finite Difference, Finite Volume, Finite Element, Spectral Method)

- **Classification of differential equations:** ODE's vs. PDE's, Linear vs. non-linear equations, First-order vs. higher-order equations, Conservative vs. non-conservative forms

- **Classification of Partial Differential Equations (PDE's):** Determining the nature of PDE's (elliptic, parabolic, hyperbolic), Physical meaning for fluid flows, Computational meaning for fluid flows, Boundary and initial conditions for PDE's

- **Turbulence 1:** Sources and physics of turbulence, Integral, Taylor and Kolmogorov scales, Differences between turbulence modelling, Large Eddy Simulation (LES) and Direct Numerical Simulations (DNS).

- **Turbulence 2:** Turbulence modeling in CFD, Wall functions and implications for grid generation

- **Grid generation:** Structured vs. unstructured grids, Grid transformation, Cartesian grids, Zonal or block-structured grids, Hybrid grids, Moving mesh techniques (Sliding mesh, CHIMERA grids) Deforming mesh techniques, Adaptive grids, Multigrid methods and their relation to grid generation, Basic guidelines for grid generation

- **Boundary treatment:** Boundary conditions, Boundary treatment (Changing the numerical method at edges, Changing the computational domain at edges), Solid Wall boundary treatment, Far-field boundary treatment, Non-reflecting boundaries

- **Solution techniques for the discretized equations:** Explicit vs. implicit formulations, Solutions techniques for explicit and implicit methods

- **Errors and uncertainty in CFD:** Sources of error, Sources of uncertainty, Stability analysis of numerical errors (Discrete Perturbation analysis, Von Neumann Stability Analysis, Multidimensional considerations), The Courant-Friedrich-Loewy number (CFL), Stability vs. accuracy, Local vs. Global time stepping, Evaluation of convergence (Iterations convergence: residuals, Grid convergence, Time step convergence)