Fluid Mechanics BMEGEÁTAG11
Topics Regarding the Applied Theory

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1. Derive Newton's law of viscosity. Use sketches, depicting the fluid flow between surfaces which are at rest and moving, respectively. Provide the definition and units of each parameter. What can be deduced from Newton's law of viscosity? Depict the character of kinematic viscosity as a function of temperature for a Newtonian liquid and gas (give examples) with the help of a diagram.

2. Define the two ways of describing fluid flow (Lagrangian and Euler description) using sketches. Give examples for practical uses. Define the following terms with the help of examples: pathline, streakline, streamline, streamsurface, streamtube. Under what condition would a pathline, streakline, and streamline align?

3. Depict the typical range of vapor, superheated vapor, saturated steam and liquid on a pressure volume diagram of water. Define the ideal gas law. Define all parameters and provide their units. Sketch the vapor pressure diagram of water, including characteristic points. Describe cavitation and erosion, providing methods for avoiding them. Draw sketches and write practical uses for each.

4. Derive the differential form of the hydrostatic equation and give the conditions for which it is valid. Define each parameter and provide units. Under what conditions can the equation be simplified? Provide the simplified form of the hydrostatic equation, along with definitions and units for the parameters. Provide examples and engineering applications for which the differential as well as the simplified form of the hydrostatic equation should be applied.

5. Derive the integral form of the continuity equation and provide its physical meaning. Define the parameters and provide their units. Apply the equation for a streamtube. Under what conditions can the equation be simplified? Provide the simplified form of the continuity equation for a streamtube, defining each parameter and providing units. Give examples for practical uses. Derive the differential form of the continuity equation, taking into consideration possibilities for simplification.

6. Derive the Euler equation and give the conditions for which it is valid. Define all parameters and provide their units. Mark the components of local and convective acceleration within the equation. Give examples for cases when the local and convective acceleration play and don't play a role in describing the flow, respectively.

7. Give the integral form of the Bernoulli equation for inviscid flow (lossless). Define each parameter and provide their units. What conditions have to be satisfied in order to simplify the equation? Derive the simplified form of the Bernoulli equation and write

down its physical meaning. Describe the static, dynamic and total pressure and the connection between them with the help of examples.

8. Define the natural coordinate system. Derive the tangential, normal and binormal pressure gradient components of the Euler-equation in the natural coordinate system for the following conditions: steady flow and the effects of the fields of force are negligible. Define each parameter and provide their units. Examine the streamwise component of Euler equation for a convergent as well as a divergent nozzle. Examine the normal component of the Euler equation if R is finite (curved arc) or infinite, respectively. Give examples for practical uses.

9. Derive the Thomson (Lord Kelvin) theorem (Kelvin's circulation theorem). Give the simplification conditions required for deriving the theorem. Define each parameter and provide their units. Based on the theorem, give the necessary conditions for vorticity to form. Give an example for a practical engineering use of the theorem with the help of a sketch.

10. Derive Helmholtz's I. and II. Theorems with the help of sketches. Define each parameter and provide their units. Write down the consequences of the theorems with the help of relevant engineering examples.

11. Derive the general form on the integral momentum equation, making the assumption that there is a solid body within the control volume. Describe its physical meaning. Define each parameter and provide their units. Provide information regarding the simplifications which can be made when applying the integral momentum equation for the case of a free jet of water having a constant velocity interacting with a still flat plate which is oriented perpendicular to it. Give examples and practical engineering applications for the integral momentum equation.

12. Based on the Allievi theory, derive the equation for pressure change within a pipe for the case of a suddenly closed valve. As related to Allievi theory, derive the wave propagation velocity as a function of the reduced bulk modulus. Define each parameter and provide their units. Give examples and practical engineering applications for the theory.

13. Draw the rheological curves of Non-Newtonian fluids as compared to Newtonian fluids. Describe the properties of the fluids. Give examples for each type of fluid. Define each parameter and provide their units.

14. Write down the Navier-Stokes Equation and compare it to the Euler Equation. Define each parameter and provide their units. List the assumptions made in deriving the equation. Give examples for its use (number of unknowns, and number of equations to be solved).

15. Draw a sketch of and describe the Reynolds experiment. Define the Reynolds number and derive its meaning (ratio of forces). By evaluating the results of the Reynolds experiment, compare the characteristics of laminar and turbulent flow. Describe the components of the velocity and pressure field in a turbulent flow?

16. In deriving pipe friction loss, the relationship between which dimensionless parameters needs to be investigated? Provide the universal equation of pipe friction loss for a pipe having a round cross-section. Show how this equation can be modified for use in determining friction losses of a non-circular pipe? Define each parameter and provide their units.

17. Derive the friction factor for laminar flow of a pipe having a round cross-section. Provide information regarding the application limits of this formula. Define the nth degree polynomial velocity profile and show the connection between the average and maximum velocity. Sketch the velocity distribution for a typical laminar and turbulent flow, providing the typical exponent of each profile.

18. Sketch the Nikuradze diagram, indicating its typical domains. Describe the meaning of a „hydraulically smooth pipe". With the help of sketches, compare hydraulically smooth and rough pipes. Give the Blasius formula and the conditions for its use. In engineering practice, which diagram is used for determining the friction pipe loss as a function of Reynolds number and relative pipe roughness?

19. Using a sketch, define the boundary layer and its main characteristics. Provide the five main properties of the boundary layer, with examples. Provide, with examples, the two requirements for boundary layer separation and methods for mitigating it. List examples for fluid system components for which the boundary layer cause losses as a result of the following properties: a) boundary layer separation b) the boundary layer causes secondary losses.

20. Give the Bernoulli Equation with the loss term. Give the general formula of the equation often used in hydraulics for determining the relationship between the total pressure loss and the dynamic pressure. Using sketches and equations, characterize the following types of losses: a) diffuser, expanding nozzle loss b) sudden expansion, Borda-Carnot sudden-expansion loss c) outlet loss d) valve and throttle loss e) sudden reduction of cross-section loss f) inlet loss g) pipe bend and elbow loss.

21. Derive the Energy Equation. Define each parameter and provide their units. What conditions have to be satisfied in order to simplify the equation? Define the relationship between the static, dynamic, and stagnation temperature.

22. Derive the speed of sound in gasses. Discuss the isentropic change of state applied in the derivation and the simplifying conditions assumed in applying it. Define the Mach number.

23. Derive the critical temperature, density, and pressure ratios for flow out of the simple tank. Illustrate the example with the help of a sketch.

24. Using sketches and equations, analyze the flow out of a simple tank for following cases (the smallest cross-section is located at the exit of the opening): I) The p_e/p_t pressure ratio is between 0.95 and 1. II) The p_e/p_t pressure ratio is between the critical pressure ratio and 0.95. III) The p_e/p_t pressure ratio is under the critical pressure ratio. Take into account the following considerations: a) the range of the pressure ratio, b) pressure at the smallest cross-section, c) approximate nature of the isentropic change of state, d) density at the smallest cross-section, e) velocity at the smallest cross-section.

25. Describe the role of a Laval nozzle with the use of an example. Using sketches and equations, analyze the characteristics of a properly designed Laval nozzle. Take into account the following considerations: a) the range of the pressure ratio, b) pressure at the outlet cross-section, c) approximate nature of the isentropic change of state, d) density at the outlet cross-section e) velocity at the outlet cross-section.

26. With the help of an example, using sketches and equations, derive the criteria for the similarity of flows. Take into account the following considerations: a) conditions resulting from the system of dimensionless differential equations, b) conditions resulting from the boundary conditions, c) conditions resulting from the initial conditions (including unsteady effects). Provide further criteria for cases when the density is not constant.

27. Define the components of the force acting on a body placed in flow. Define the static pressure coefficient and the local friction coefficient and use them in characterizing the forces acting on a body. Compare blunt bodies and streamlined bodies with regard to the extent of the wake and the main source of drag force. Define the lift and drag coefficients. With the help of a diagram, describe the lift and drag coefficients of an airfoil (an example of a streamlined body) as the function of the angle of attack. Provide sketches in describing the characteristic points of the diagram.

28. Using sketches and the example of a cylinder placed in a flow which is perpendicular to its axis (a typical example of a blunt body), define the dimensionless parameters which are important during the investigation of the drag force. Using a diagram, describe the drag coefficient of an infinitely long and smooth cylinder as a function of the Reynolds number. Characterize the typical domains of the diagram. Describe the effect of surface roughness and finite length on the drag coefficient.