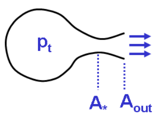
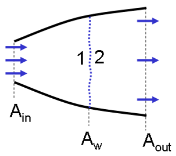
Gas dynamics

1. Derive the formula for calculating the speed of sound in ideal gases!
2. Explain the formation of shock wave from a series of small compression waves! What are the major characteristics of shocks?
3. Derive the relation between the relative velocity increase (dv/v) and the relative increase of the channel cross-section (dA/A)!
4. Derive the relation between the temperature ratio (Tt/T) as a function of the Mach number (M) for an isentropic flow!
5. 

   a) What is the optimum A_{out}/A_* ratio of the nozzle of a rocket thruster designed for near ground flight, if the chamber pressure p_t=10 bar_A , and γ=1.3. Please, use the gas tables!

   b) Calculate the mass flow-rate for T_t=1300 K a, R=462 J/kg-K and A_{out}=20 cm²!
6. Derive the quadratic equation for the square of upstream and the downstream side Mach numbers from the conservation lows applied to a steady normal shock!
7. Draw qualitatively correct graphs of the pressure, density, temperature, Mach number and stagnation pressure ratios for a normal shockwave!
8. 

   There is a strong stationary normal shock in a divergent channel at the cross-section characterized by A_w.

   $\gamma = 1.4$ $M_{in} = 2$

   $p_{in} = 100\, kPa_A$ $T_{in} = 270\, K$

   $A_w / A_{in} = 2$ $A_{out} / A_{in} = 3$

   a) Calculate the Mach number at the outlet (M_{out})!

   b) Please, determine the outlet pressure (p_{out})!
9. What are the major differences between a Mach wave and an oblique shock? Prove that, the tangential velocity component does not change, and the normal velocity component will change according to the laws valid for normal shocks!
10. Draw the qualitatively correct contour graph of the change of the angle of the flow direction (delta) as a function of the upstream Mach number (M1) and the angle of the oblique shock (beta)! What conclusions can be drawn from this graph?

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