Multiphase Flows – WS 2022/23
Problem Session 3: Phase Change & Phase Equilibrium

Aranya Dan, M. Tech.

Institute for Combustion Technology
RWTH Aachen University

Problem Session 3: Phase Change & Phase Equilibrium

Agenda

- Problem Session 1: Navier-Stokes Equations and Single-Phase Shock Tube
- Problem Session 2: Multiphase Shock Tube
- Problem Session 3 (Today): Multiphase Shock Tube with Phase Change

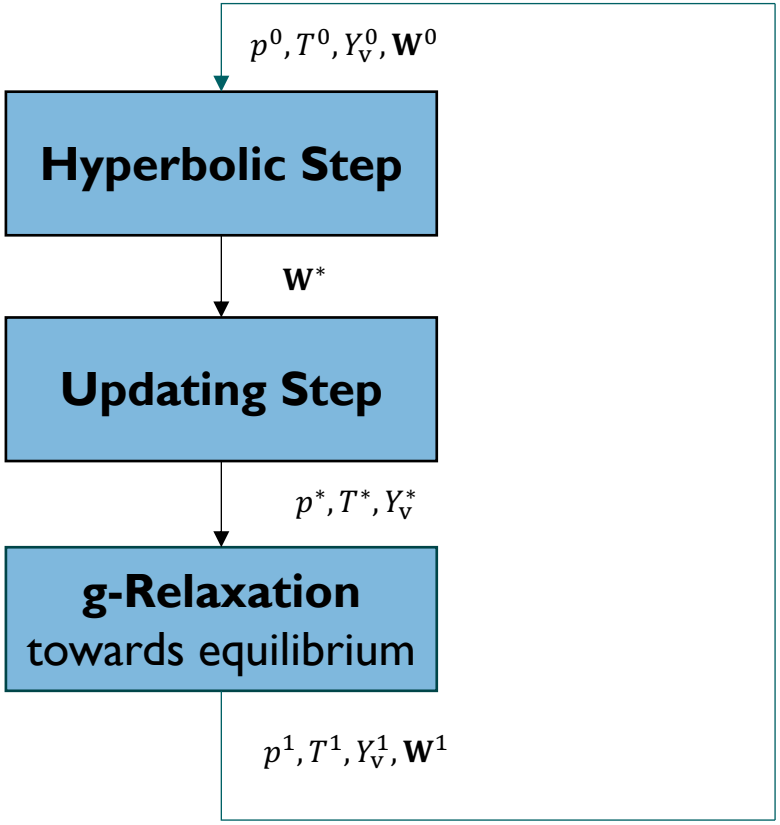
Problem Session 3: Phase Change & Phase Equilibrium

Step-Wise Solution

Solution of hyperbolic part (HLLC solver)

Updating of pressure by means of mixture SG-EOS

Bisection method for relaxation of Gibbs free energies (Phase change model)



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Phase Change Step in Multiphase Euler-Euler Model

- Condition for phase equilibrium: $g_{\mathrm{v}}(p,T) = g_{\mathrm{l}}(p,T)$

➢ During phase change step: mixture density ρ and mixture internal energy e are constant

➢ Only vapor mass fraction Y_{v} changes

- Relations for $p(\rho, e, Y_{\mathrm{v}})$ and $T(p, \rho, Y_{\mathrm{v}})$ already derived in Problem Session 2

➢ To be solved: $g_{\mathrm{v}}(Y_{\mathrm{v}}) = g_{\mathrm{l}}(Y_{\mathrm{v}})$ (iteratively by bisection or Newton method)

- Stiffened-gas equation for Gibbs free energy:

$$g(p,T) = (\gamma c_v - q')T - c_v T \ln\left(\frac{T^{\gamma}}{(p+p_{\infty})^{\gamma-1}}\right) + q$$

$$(q' \, given \; as \; qvp \; or \; qvl \; in \; code)$$

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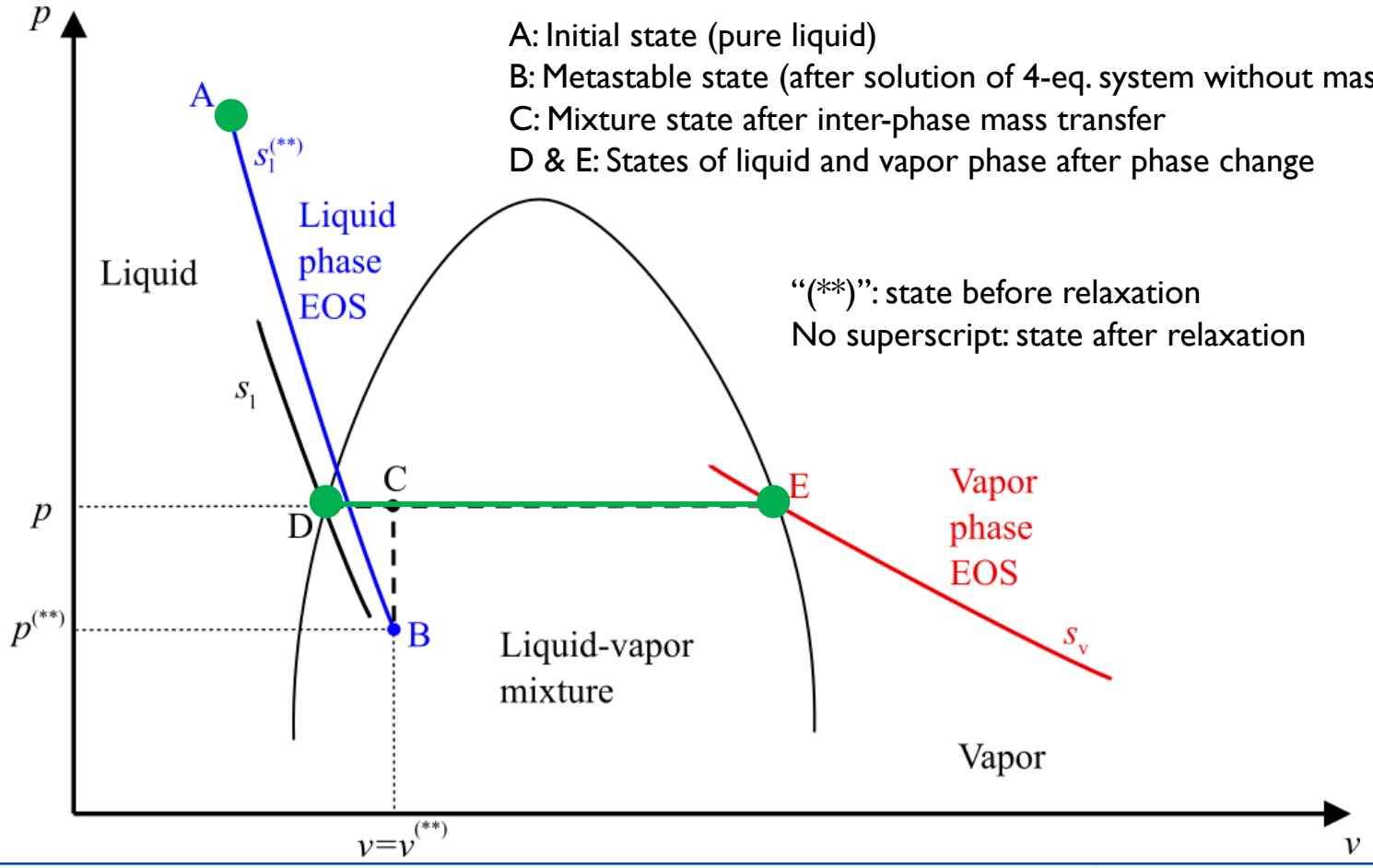
Solution Steps in $p - v$ Diagram



A: Initial state (pure liquid)
B: Metastable state (after solution of 4-eq. system without mass transfer)
C: Mixture state after inter-phase mass transfer
D & E: States of liquid and vapor phase after phase change

"(**)": state before relaxation
No superscript: state after relaxation

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Problem 1: Multiphase Shock Tube with Phase Change

The two-phase solver tube from Problem Session 2 does not yet include phase change.

a) Include phase change by means of inter-phase mass transfer. Assume instantaneous phase equilibrium. Update the equilibrium mass fraction Y_V directly using the bisection method (already contained in the functions gibbsRelaxation and bisectionGibbsEnergies).

b) Simulate the shock tube with the initial conditions of Problem Session 2. Which differences do you observe? Characterize the new wave pattern. Where does the phase change occur?

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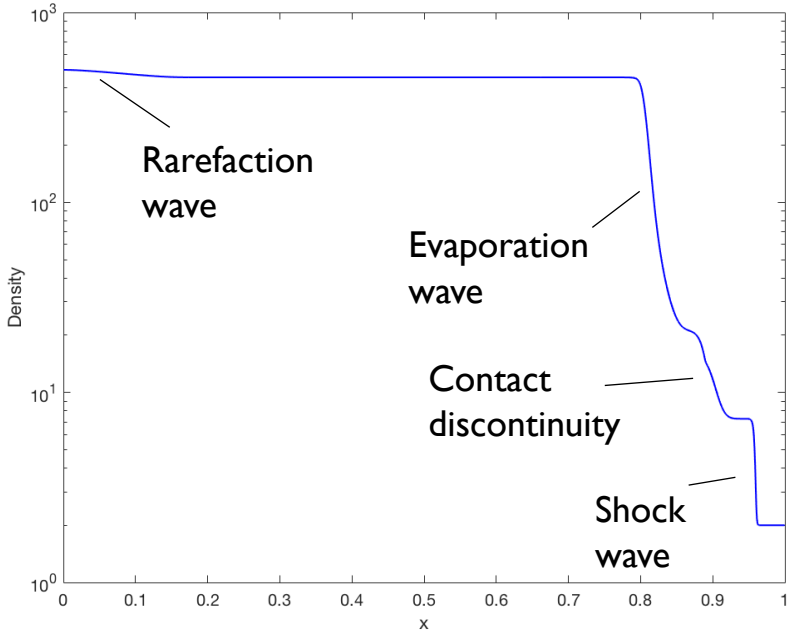
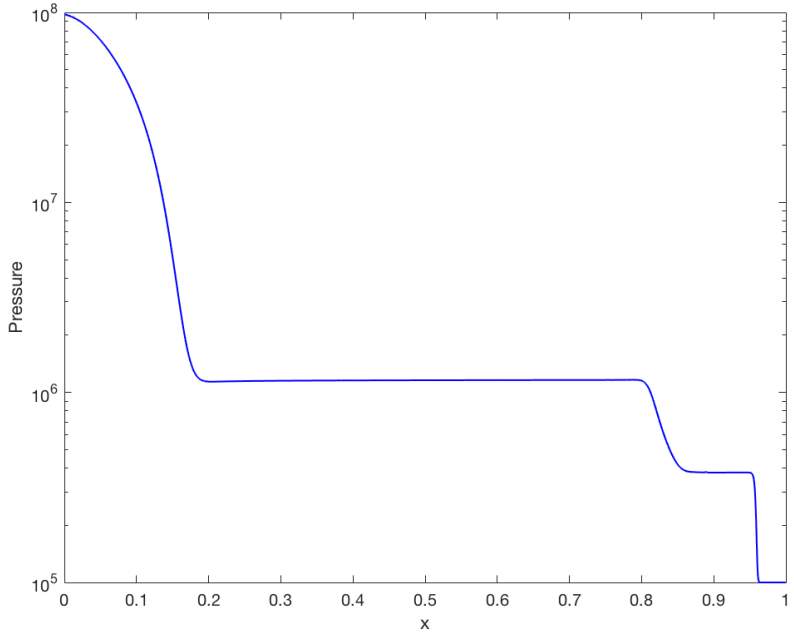
Problem 1: Wave Propagation





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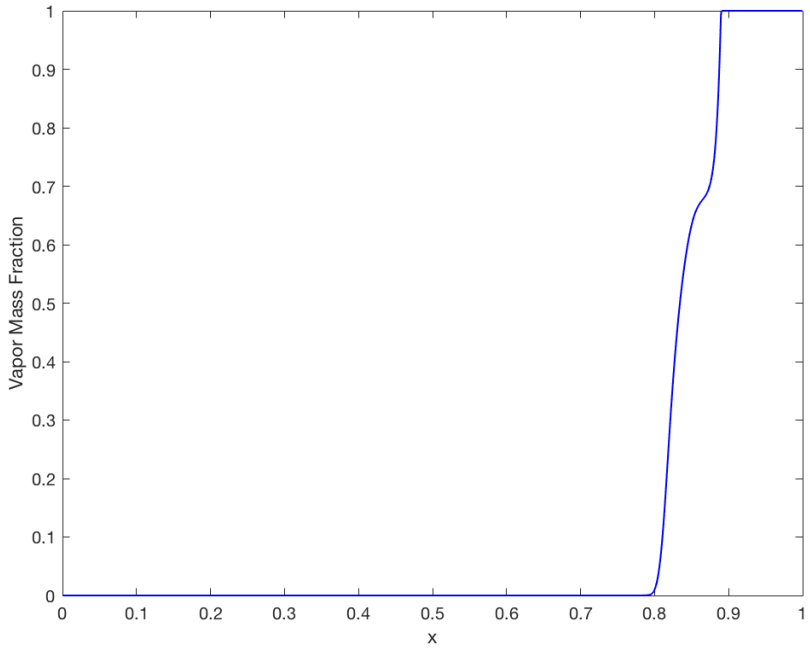
Problem 1: Wave Propagation



Thank you for your attention

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