**Code Generalization**

* **Fork/branch your quasi-1D HW#4 code for 2D development**
* **Add mesh‐reader for curvilinear structured grids**
* **Define metric terms (Jacobian, face normals)**

**2. Spatial Discretization Schemes**

* **Implement van Leer flux‐vector splitting**
* **Implement Roe’s approximate Riemann solver**
* **Add MUSCL reconstruction (linear extrapolation)**
* **Integrate a flux limiter (e.g. minmod or van Albada)**

**3. Time Integration & Convergence**

* **Embed a 2-stage RK integrator**
* **(Or) Embed a 4-stage RK integrator**
* **Hook up L₂ residual norm monitoring**
* **Validate “practical residual→error” method in class**

**4. MMS Verification**

* **Set up subsonic MMS case (Roy et al. 2002)**
* **Set up supersonic MMS case (Roy et al. 2004)**
* **Run on Cartesian grids → debug fluxes & BCs**
* **Run on curvilinear grids → collect L₁/L₂ norms**
* **Perform grid‐refinement study → compute observed order**

**5. Physical Test Case A: 30° Inlet**

* **Load inlet geometry grids (Canvas)**
* **Run M = 4.0, p = 12 270 Pa, T = 217 K**
* **Post-process outlet total pressure → average**
* **Compute total pressure loss**

**6. Physical Test Case B: NACA 64A006 Airfoil**

* **Load O-grid meshes (Canvas)**
* **Enforce periodic BC at the TE cut**
* **Run α = 0°, M = 0.84, p = 65 855.8 Pa, T = 300 K**
* **Run α = 8°, M = 0.75, p = 67 243.5 Pa, T = 300 K**
* **Extract Cp distribution → plot vs. experiment**
* **Integrate L′, D′ → compute CL, CD → compare to data**

**7. Reporting & Submission**

* **Draft Introduction & Numerical Methods section**
* **Include MMS results (plots & convergence tables)**
* **Include inlet case results (flow‐field snapshots & loss)**
* **Include airfoil Cp and CL/CD comparisons**
* **Write Conclusions & error analysis**
* **Package code + README for running all cases**
* **Submit PDF report and code bundle by 5/7/2025 (or 5/12/2025 late)**

**1. ​Starting Point**

You already have a **quasi-1D Euler solver** from HW #4. Your job is to **generalize that** into a **2D finite-volume solver** on curvilinear structured meshes.

**Key pieces to carry over and extend**

* Data structures for conserved variables
* Flux‐evaluation routines
* Time‐marching (you’ll swap your 1D RK integrator for a 2D version)

**2. ​Numerical Methods to Implement**

1. **Spatial discretization**
   * Two upwind schemes:
     + **van Leer flux-vector splitting**
     + **Roe’s approximate Riemann solver**
   * **Second-order accuracy** via MUSCL extrapolation + flux limiters
     + (Note: you may need to turn limiters off for formal-order MMS studies.)
2. **Time integration**
   * Explicit Runge–Kutta (2-stage or 4-stage) to march to steady state.
3. **Convergence monitoring**
   * Track L₂ norms of the residuals.
   * Use the “practical method” from class to relate those residuals to error norms in your global outputs (e.g. total pressure loss, lift, drag).

**3. ​Verification: Method of Manufactured Solutions (MMS)**

* Run two canonical MMS cases (one subsonic, one supersonic) from Roy et al.
* Compute L₁ and L₂ norms of your solution variables at cell centers.
* Use grid-refinement studies (available grids on Canvas) to **measure your observed order of accuracy**.
* **Tip:** start on Cartesian grids to shake out bugs, then move to curvilinear.

**4. ​Physical Test Cases**

**A. Supersonic “30° inlet”**

* **Freestream:** M = 4.0, p = 12 270 Pa, T = 217 K
* Use the Canvas curvilinear grids for this ramp/inlet geometry.
* Compute the **averaged total pressure** at the outlet → quantify total pressure loss.

**B. NACA 64A(006) airfoil**

* Two cases:
  1. **α = 0°**, M = 0.84, p ₀ = 65 855.8 Pa, T = 300 K
  2. **α = 8°**, M = 0.75, p ₀ = 67 243.5 Pa, T = 300 K
* Meshes on Canvas include O-type structured grids with periodic trailing edge.
* Modify boundary treatment to enforce periodicity at the TE cut.
* Compute:
  1. **Pressure coefficient** distribution → compare to experimental Cp(θ) for α = 0°
  2. **Lift coefficient** L′
  3. **Drag coefficient** D′  
     – Compare CL and CD for α = 0° to the experimental data.

**5. ​Report Deliverables**

* **Formal write‐up** (AIAA‐style or similar):
  + Introduction & problem statement
  + Numerical methods (schemes, limiters, RK details)
  + MMS verification (grids, convergence plots, observed orders)
  + Inlet case (flowfield snapshots, pressure‐loss curves)
  + Airfoil case (Cp plots, CL/CD tables vs. experiment)
  + Conclusions & error analysis
* **Code package** with clear instructions for running each test.