Reflected Waves

- Already examined what happens when normal shock “hits” a boundary
  - if incident shock hits solid wall, get reflected (normal) shock - required to satisfy velocity boundary condition (v=0)
  - if it hits open end, get reflected expansion waves - satisfy pressure boundary condition (p=p_a<p_2)
- Wave reflections “impose” boundary (pressure or velocity) on flow

Oblique Shock Reflection From Wall

- Consider “weak” (M_2>1) oblique shock wave impinging on a flat wall
  - incident shock wave turns flow toward the lower wall
  - flow can not pass through boundary, must turn back parallel to lower wall - velocity boundary condition
  - flow turns back on itself \( \Rightarrow \) compression \( \Rightarrow \) in this case, reflected wave is oblique shock
- Reflected shock weaker than incident shock
  - M_2<M_1
Example: Oblique Shock Reflection

- **Given:** Mach 3.2 flow with static pressure of 25 psia approaching a 17° ($\delta_1$) turn produces oblique shock wave at 33° ($\theta_1$). Oblique shock then “hits” bottom wall, producing reflected oblique shock.

- **Find:**
  $\theta_i$, $\theta_r$, $M_2$, $M_3$, $p_2$, $p_3$

- **Assume:** TPG/CPG with $\gamma=1.4$, steady, adiabatic, no work, inviscid except shocks, ….
Mach Reflection

- If $M_2$ low enough, required turning angle for reflected wave may exceed maximum oblique shock angle
  - no simple reflected wave possible, get something like detached shock
  - IO: incident oblique shock
  - OW: strong curved shock, normal at wall
  - OR: weak oblique shock

Oblique Shock and Pressure BC

- If oblique shock “hits” a pressure boundary condition, reflected wave must adjust flow pressure to match boundary pressure
- Type of reflected wave will depend on whether pressure must drop or rise
  - pressure rise $\Rightarrow$ compression: flow will “turn back on itself”
  - pressure drop $\Rightarrow$ expansion: flow will “open up”
**Reflection From Expansion on Wall**

- Consider PM fan impinging on a flat wall
  - incident expansion waves tend to turn flow away the lower wall
  - can not create vacuum, flow must be turned back parallel to lower wall - velocity boundary condition
  - flow “opens up” ⇒ expansion ⇒ in this case, reflected waves are expansions (Mach waves)

- For case shown above (flow returning to original angle)
  - \( v_3 = \delta_2 + v_2 = \delta_2 + (\delta_1 + v_1) = 2\delta + v_1 \) (use to get \( M_3 \))

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**Non-Simple Region**

- In region where incident and reflected waves interact, can not use our simple quasi-1D theory

- In this *non-simple* region, get curved waves
  - flow still isentropic

- Outside this region, our quasi-1D methods still valid
Summary of Reflected Waves

• “Reflections” from supersonic waves represent information from a boundary being transmitted into supersonic flow
  – reflections “impose” boundary condition on flow
• Generally, pressure or velocity boundary conditions
• Type of reflected wave will depend on whether compression or expansion is needed to meet boundary conditions