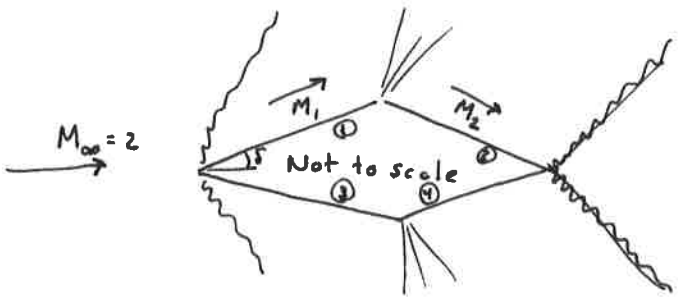
0°



Flow

①

$$\delta = \operatorname{atan}\left(\frac{\frac{0.0335}{2}}{0.5-0}\right) = 1.92°$$

$$\frac{P_\infty}{P_{t_\infty}} = 0.1278$$

$\theta = 31.58°$ $\quad M_1 = 1.93$ $\quad P_1/P_\infty = 1.113$ $\quad \frac{P_{t_1}}{P_{t_\infty}} = 0.9999 \approx 1.0$

② $\nu(M=1.93) = 24.43°$ $\quad \theta = 2\delta = 3.84°$ $\Rightarrow$ $\nu_2 = \nu_1 + \theta$ $\Rightarrow$ $\nu_2 = 28.27 = M_2 = 2.069$

$$\frac{P_2}{P_{t_1}} = 0.1147 \qquad P_2 = \frac{P_2}{P_{t_1}} \cdot \frac{P_{t_1}}{P_{t_\infty}} \cdot \frac{P_{t_\infty}}{P_\infty} \cdot P_\infty = 0.1147 \cdot 0.9999 \cdot \frac{1}{0.1278} = 0.8966\, P_\infty$$

③ same as ①

④ same as ②

Normals

$$\hat{n}_1 = [-\sin(\delta) \quad \cos(\delta)] = [-0.0333 \quad 0.999] \approx [\delta^{rad}, 1.0]$$

$$\hat{n}_2 = [-\hat{n}_{x_1} \quad \hat{n}_{y_1}] = [0.0333 \quad 0.999]$$

$$\hat{n}_3 = [-0.0333 \quad -0.999]$$

$$\hat{n}_4 = [0.0333 \quad -0.999]$$

Lengths

$$L_1 = \sqrt{0.5^2 + 0.0334^2} = 0.501 \approx 0.5$$

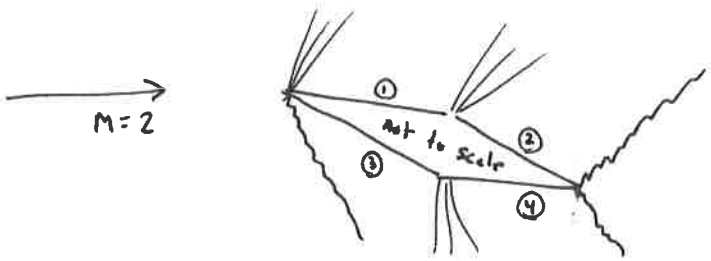
Pressure

$$F = -P \cdot L \cdot \hat{n} = -P_\infty\, 1.113 \cdot 0.501 \cdot (-0.0333 \quad 0.999) - P_\infty\, 1.113 \cdot 0.501 (-0.0333 \quad -0.999)$$
$$+ -P_\infty\, 0.8966 \cdot 0.501 \cdot (0.0333 \quad 0.999] - P_\infty\, 0.8966 \cdot 0.501 (0.0333 \quad -0.99$$
$$\pm \; 0.00724\, P_\infty\, \hat{x} + 0\, \hat{z}$$

$$\begin{pmatrix} L \\ D \end{pmatrix} = \begin{pmatrix} -\sin\alpha & \cos\alpha \\ \cos\alpha & \sin\alpha \end{pmatrix} \begin{pmatrix} F_x \\ F_z \end{pmatrix} = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} \begin{pmatrix} 0.00724 \\ 0 \end{pmatrix} P_\infty$$

$$C_\ell = \frac{L}{\frac{1}{2}\gamma M^2 P_\infty c} = \frac{2L}{\gamma M^2 P_\infty c} = 0 \qquad C_d = \frac{D}{\frac{1}{2}\gamma M_\infty^2 P_\infty c} = 0.00258 \approx 26 \text{ counts}$$

5°



at $M=2$

$$\frac{P_\infty}{P_{t_\infty}} = 0.1278$$

Flow:

① $\nu_\infty = 26.38°$ $\quad \theta = -(1.92° - 5°) = 3.08°$ $\Rightarrow$ $\nu_1 = 26.38 + 3.08 = 29.46°$

$\frac{P_1}{P_{t_\infty}} = 0.10705$ $\Rightarrow$ $P_1 = 0.10705 P_{t_\infty} \cdot \frac{P_\infty}{P_{t_\infty}} \cdot \frac{1}{0.1278} = 0.10705 \cdot 0.1278^{-1} = \underline{0.8376\, P_\infty}$ $\quad M_1 = 2.114$

② $\theta = 3.08° + 2(1.92°) = 6.92$ $\quad \nu_2 = 26.38 + 6.92$ $\Rightarrow$ $M_2 = 2.261$

$\frac{P_2}{P_{t_\infty}} = 0.08499$ $\quad P_2 = \frac{P_2}{P_{t_\infty}} \frac{P_{t_\infty}}{P_\infty} P_\infty = 0.08499 \cdot \frac{1}{0.1278} \cdot P_\infty = \underline{0.665\, P_\infty}$

③ $\delta = 1.92 + 5.0 = 6.92°$ $\quad \theta = 36.13°$ $\quad M_2 = 1.753$

$\frac{P_3}{P_\infty} = 1.4558$ $\quad \frac{P_{t_2}}{P_{t_\infty}} = 0.9946$ $\quad P_3 = \frac{P_3}{P_\infty} P_\infty = \underline{1.4558\, P_\infty}$

④ $\nu_{M=1.753} = 19.351$ $\quad \theta = 2 \cdot (1.92°) = 3.84°$ $\quad \nu_4 = 23.191$

$M_4 = 1.886$ $\quad \frac{P_4}{P_{t_3}} = 0.15248$

$$P_4 = \frac{P_4}{P_{t_3}} \frac{P_{t_3}}{P_{t_\infty}} \frac{P_{t_\infty}}{P_\infty} P_\infty = 0.15248 \cdot 0.9946 \cdot \frac{1}{0.1278} P_\infty = \underline{1.1866\, P_\infty}$$

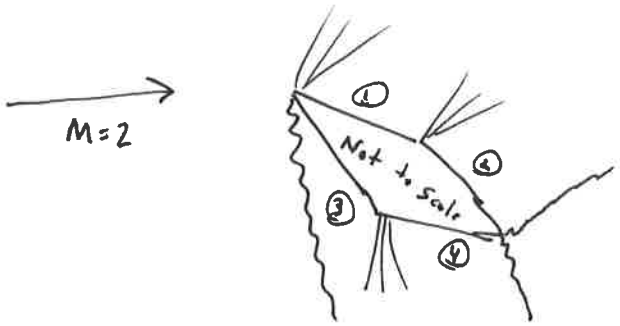
Forces

$$\begin{pmatrix} D \\ L \end{pmatrix} = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \begin{pmatrix} F_x \\ F_z \end{pmatrix} \Rightarrow \qquad C_d = \frac{D}{\frac{1}{2}\gamma M^2 c}$$

$C_l = 0.202$

$C_d = 0.0204 = 204$ counts

10°



at $M=2$

$$\frac{P_\infty}{P_{t_\infty}} = 0.1278$$

Flow:

① $\nu_\infty = 26.38°$ $\quad \theta = -(1.92 - 10) = 8.08° \Rightarrow \nu_1 = 34.46°$

$M_1 = 2.307$

$$\frac{P_1}{P_{t_\infty}} = 0.0791 \Rightarrow P_1 = \frac{0.0791}{0.1278} P_\infty = \underline{0.6189\, P_\infty}$$

② $\theta = 8.08° + 2(1.92°) = 11.92° \Rightarrow \nu_2 = 11.92 + 26.38 = 38.3 \Rightarrow M_2 = 2.485$

$$\frac{P_2}{P_{t_\infty}} = 0.0618 \Rightarrow P_2 = \frac{0.0618}{0.1278} P_\infty = \underline{0.4837\, P_\infty}$$

③ $\delta = 1.92° + 10° = 11.92°$ $\quad \theta = 41.48°$ $\quad M_2 = 1.568$

$$\frac{P_3}{P_\infty} = 1.8808 \qquad \frac{P_{t_3}}{P_{t_\infty}} = 0.9748 \qquad \underline{P_3 = 1.8808\, P_\infty}$$

④ $\nu_{M=1.568} = 13.92°$ $\quad \theta = 3.84°$ $\quad \nu_4 = 17.76° \Rightarrow M_4 = 1.698$

$$\frac{P_4}{P_{t_3}} = 0.20311$$

$$P_4 = \frac{P_4}{P_{t_3}} \frac{P_{t_3}}{P_{t_\infty}} \frac{P_{t_\infty}}{P_\infty} P_\infty = 0.20311 \cdot 0.9748 \cdot \frac{1}{0.1278} P_\infty$$

$$= \underline{1.549\, P_\infty}$$

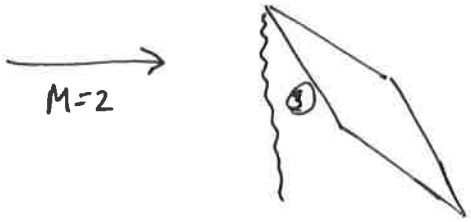
Forces

Same process, except $\alpha = 10°$

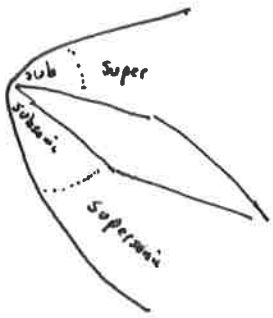
$C_\ell = 0.409$

$C_d = 0.07498 \approx 750$ counts

25°



③ $\delta = 1.92° + 25° = 26.92°$ Detached Shock.



No tools available!

CFD?

$C_l = ?$

$C_d = ?$