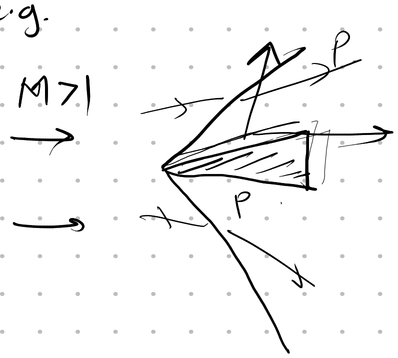
Quiz 2 Instruction

① Download the gas Tables from website (Prof. Vinoth)

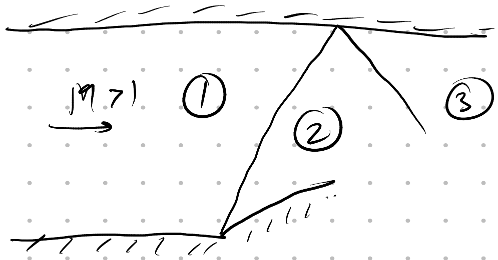
② Objective type question
→ Everything has to be written down on a paper & then uploaded. No marks without explanation.

③ Numericals
→ Grading scheme will change based on the conceptual difficulty of the problem.

For e.g.



Calculate the lift & drag for this airfoil for $\alpha = 0^\circ$ & $\alpha = 3^\circ$.



Calculate $\underline{M_3}$, $\underline{P_3}$, $\underline{T_3}$ etc.

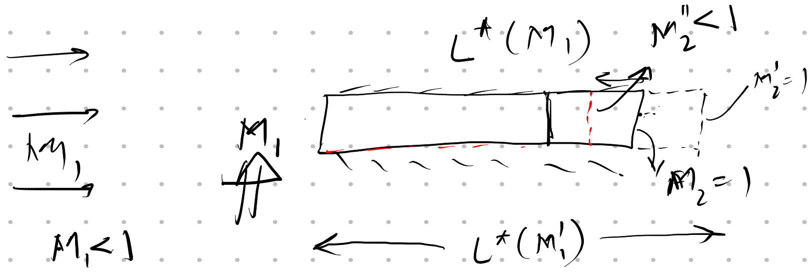
Conceptually easy. so steps will have less weightage. correct numerical answer required.

④ Derivations.

→ Starting point will be specified. You are expected to remember isentropic relations only.

→

Fanno Flow

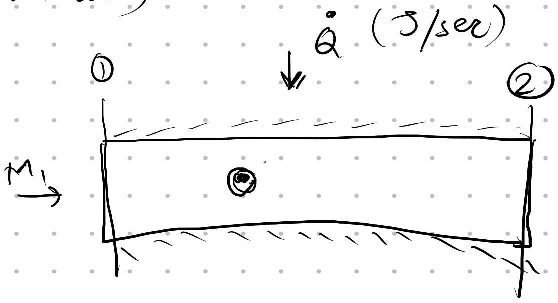


$M_1 < 1$

subsonic

1D Flow with heat addition (Rayleigh Flow)

→ 1D
steady
Inviscid
$\frac{dA}{dx} = 0$



→ Composition of the flow is going to remain constant

→ perfect gas model. (γ, C_p, C_v) $\quad \frac{dc_p}{dT} = 0, \ \frac{dc_v}{dT} = 0$

Mass conservation

$$\rho_1 u_1 = \rho_2 u_2$$

$$\frac{d\rho}{\rho} + \frac{du}{u} = 0 \qquad \text{—①}$$

Momentum

$$p_1 + \rho_1 u_1^2 = p_2 + \rho_2 u_2^2$$

$$dp + \rho u du = 0 \qquad \text{—②}$$

Energy.

$$h_{o_1} + \frac{\overset{J/sec}{\dot{Q}}}{\underset{Kg/sec}{\dot{m}}} = h_{o_2}$$

$$h_{o_1} + \underset{(J/Kg)}{q} = h_{o_2}$$

$$T_{o_2} - T_{o_1} = q/c_p$$

$$dT_0 = q/c_p \qquad \text{—③}$$

Ideal gas eq^n. $\quad p = \rho R T$

$$\frac{dp}{p} = \frac{d\rho}{\rho} + \frac{dT}{T} \qquad \text{—④}$$

From ②,

$$\frac{dp}{p} = \frac{-\rho u du}{p} = -\frac{u du}{RT} = \frac{-u^2 du}{a^2 \cdot u} \cdot \gamma = -\gamma M^2 \cdot \frac{du}{u}$$

$$\frac{dp}{p} = -\gamma M^2 \frac{du}{u} \qquad \text{—⑤}$$

From ④, $\quad \frac{dT}{T} = \frac{dp}{p} - \frac{d\rho}{\rho} = (1 - \gamma M^2)\frac{du}{u} \qquad \text{—⑥}$

we know, $\quad T_0 = T + \frac{u^2}{2c_p} \Rightarrow h_0 = h + \frac{u^2}{2}$

$$dT_0 = dT + \frac{u du}{c_p}$$

$$dT_0 = T\left[\frac{dT}{T} + \frac{u\,du}{c_p T}\right]$$

$$= T\left[\left(1-\gamma M^2\right)\frac{du}{u} + \frac{u^2}{\gamma R T}\cdot(\gamma-1)\cdot\frac{du}{u}\right]$$

$$= T\cdot\frac{du}{u}\left[1-\gamma M^2 + (\gamma-1)M^2\right]$$

$$= T\cdot\frac{du}{u}\left[1-M^2\right]$$

$$\frac{dT_0}{T} = \left(1-M^2\right)\frac{du}{u} \qquad \text{— (7)}$$

Entropy:—

$$ds = c_p\frac{dT}{T} - R\frac{dp}{p}$$

$$\frac{ds}{c_p} = \left(1-M^2\right)\frac{du}{u} \qquad \text{— (8)}$$

Also from $M = \frac{u}{\sqrt{\gamma R T}}$ $\Rightarrow$ we have $\frac{dM}{M} = \frac{(1+\gamma M^2)}{2}\frac{du}{u}$ — (9)

$$\frac{dp}{p} = -\gamma M^2\frac{du}{u}, \qquad \frac{dT}{T} = \left(1-\gamma M^2\right)\frac{du}{u}$$

$$\frac{d\rho}{\rho} = -\frac{du}{u}, \qquad \frac{dM}{M} = \frac{\left(1+\gamma M^2\right)}{2}\frac{du}{u}$$

$$\frac{ds}{c_p} = \left(1-M^2\right)\frac{du}{u} = \frac{dT_0}{T}$$

	$u\uparrow$	$u\downarrow$
$M < 1/\sqrt{\gamma}$	$M\uparrow$ $p\downarrow$ $T\uparrow$ $s\uparrow$	$M\downarrow$ $p\uparrow$ $T\downarrow$ $s\downarrow$
$\frac{1}{\sqrt{\gamma}} < M < 1$	$M\uparrow$ $p\downarrow$ $T\downarrow$ $s\uparrow$	$M\downarrow$ $p\uparrow$ $T\uparrow$ $s\downarrow$
$M > 1$	$M\uparrow$ $p\downarrow$ $T\downarrow$ $s\downarrow$	$M\downarrow$ $p\uparrow$ $T\uparrow$ $s\uparrow$

for $M<1$, heat addition $\Rightarrow$ $u\uparrow$ $M\uparrow$

" removal $\Rightarrow$ $u\downarrow$ $M\downarrow$

$M>1$, heat addition $\Rightarrow$ $u\downarrow$ $M\downarrow$

removal $\Rightarrow$ $u\uparrow$ $M\uparrow$