Solution Assignment #5

Summer 2016

9.10 / 9.11 / 9.16 / 9.17 / 9.18 / 9.19 / 9.40 / 9.78 / 9.81 / 9.90 / 12.23 / 12.27 / 12.28 / 12.30 / 12.31 / 12.68 / 12.70 / 13.13

*** 9.10**

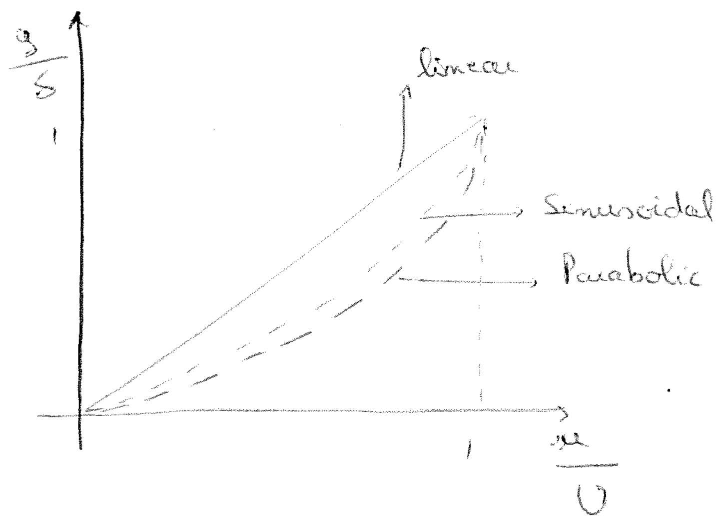
Velocity profiles in laminar BL:

Linear: $\frac{u}{U} = \frac{y}{\delta}$

Sinusoidal: $\frac{u}{U} = \sin\left(\frac{\pi}{2}\frac{y}{\delta}\right)$

Parabolic: $\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$

Plot $\frac{y}{\delta}$ vs $\frac{u}{U}$ and compare.



9.11

Velocity profile in laminar BL is:

$$\frac{u}{U} = \frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3$$

a) Satisfy BC?

b) Evaluate δ^*/δ and $\frac{\theta}{\delta}$

a) BC for laminar BL:

(2)

$$u(0) = 0 \quad \text{and} \quad \left.\frac{du}{dy}\right|_{y=\delta} = 0$$

we know that $u(y) = U\left(\frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3\right)$

$$u(0) = U(0-0) = 0 \checkmark$$

$$\frac{du}{dy} = U\left(\frac{3}{2}\times\frac{1}{\delta} - \frac{3}{2}\frac{y^2}{\delta^3}\right)$$

$$\left.\frac{du}{dy}\right|_{y=\delta} = U\left(\frac{3}{2}\times\frac{1}{\delta} - \frac{3}{2}\frac{\delta^2}{\delta^3}\right) = U\left(\cancel{\frac{3}{2\delta}} - \cancel{\frac{3}{2\delta}}\right) = 0 \checkmark$$

Satisfy BC $\checkmark$

b) $\delta^* = \int_0^\infty \left(1 - \frac{u}{U}\right) dy = \int_0^\delta \left(1 - \frac{u}{U}\right) dy$

$$\Rightarrow \delta^* = \int_0^\delta \left(1 - \frac{3}{2}\times\frac{y}{\delta} + \frac{1}{2}\left(\frac{y}{\delta}\right)^3\right) dy$$

$$\Rightarrow \delta^* = \left[y - \frac{3}{4}\frac{y^2}{\delta} + \frac{1}{2\times 4}\frac{y^4}{\delta^3}\right]_0^\delta$$

$$\Rightarrow \delta^* = \delta - \frac{3}{4}\frac{\delta^2}{\delta} + \frac{1}{8}\frac{\delta^4}{\delta^3} = \delta - \frac{3}{4}\delta + \frac{1}{8}\delta = \frac{3}{8}\delta$$

$$\Rightarrow \boxed{\frac{\delta^*}{\delta} = \frac{3}{8}}$$

$$\Theta = \int_0^\infty \frac{u}{U}\left(1 - \frac{u}{U}\right) dy = \int_0^\delta \frac{u}{U}\left(1 - \frac{u}{U}\right) dy$$

$$\Rightarrow \Theta = \int_0^\delta \left(\frac{3}{2}\frac{y}{\delta} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3\right)\left(1 - \frac{3}{2}\frac{y}{\delta} + \frac{1}{2}\left(\frac{y}{\delta}\right)^3\right) dy$$

$$= \int_0^\delta \frac{3}{2}\frac{y}{\delta} - \frac{9}{4}\frac{y^2}{\delta^2} + \frac{3}{4}\frac{y^4}{\delta^4} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3 + \frac{3}{4}\frac{y^4}{\delta^4} - \frac{1}{4}\frac{y^6}{\delta^6}\, dy$$

$$= \int_0^\delta \frac{3}{2}\frac{y}{\delta} - \frac{9}{4}\frac{y^2}{\delta^2} + \frac{3}{2}\frac{y^4}{\delta^4} - \frac{1}{2}\left(\frac{y}{\delta}\right)^3 - \frac{1}{4}\frac{y^6}{\delta^6}\, dy$$

$$= \left[\frac{3}{4}\frac{y^2}{\delta} - \frac{9}{4\times 3}\frac{y^3}{\delta^2} + \frac{3}{2\times 5}\frac{y^5}{\delta^4} - \frac{1}{2\times 4}\frac{y^4}{\delta^3} - \frac{1}{4\times 7}\frac{y^7}{\delta^6}\right]_0^\delta$$

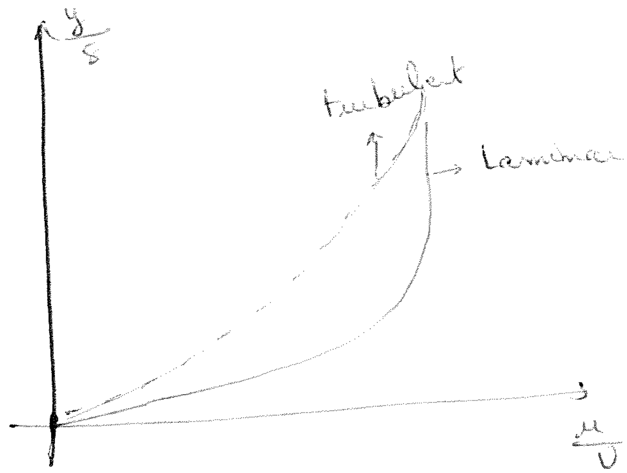
$$= \frac{3}{4}\delta - \frac{3}{4}\delta + \frac{3}{10}\delta - \frac{1}{8}\delta - \frac{1}{28}\delta \Rightarrow \boxed{\frac{\Theta}{\delta} = 0{,}139}$$

9.14

Velocity profile turbulent BL:

$$\frac{u}{U} = \left(\frac{y}{\delta}\right)^{1/7}$$

Compare shape of profile with laminar BL: $\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$
by plotting y/δ vs. $\frac{u}{U}$



$\Rightarrow \frac{du}{dy} \to \infty$ when $y \to 0$

9.17

δ^*/δ and $\frac{\Theta}{\delta}$ for turbulent 1/7 power law profile

compare with laminar values.

– turbulent

$$\delta^* = \int_0^\delta \left(1 - \frac{u}{U}\right) dy = \int_0^\delta 1 - \frac{y^{1/7}}{\delta^{1/7}}\, dy = \left[y - \frac{1}{1/7+1}\,\frac{y^{1/7+1}}{\delta^{1/7}} \right]_0^\delta$$

$$= \delta - \frac{7}{8}\,\frac{\delta^{8/7}}{\delta^{1/7}} = \delta - \frac{7}{8}\delta \Rightarrow \frac{\delta^*}{\delta} = 1 - \frac{7}{8} = \frac{1}{8} = \boxed{0{,}125 = \frac{\delta^*}{\delta}}$$

$$\Theta = \int_0^\delta \frac{u}{U}\left(1 - \frac{u}{U}\right) dy = \int_0^\delta \frac{y^{1/7}}{\delta^{1/7}}\left(1 - \frac{y^{1/7}}{\delta^{1/7}}\right) dy = \int_0^\delta \frac{y^{1/7}}{\delta^{1/7}} - \frac{y^{2/7}}{\delta^{2/7}}\, dy$$

$$\Theta = \left[\frac{7}{8}\,\frac{y^{8/7}}{\delta^{1/7}} - \frac{1}{\frac{2}{7}+1}\,\frac{y^{2/7+1}}{\delta^{2/7}} \right]_0^\delta = \frac{7}{8}\delta - \frac{7}{9}\delta \Rightarrow \frac{\Theta}{\delta} = \frac{7}{8} - \frac{7}{9} = \boxed{0{,}0972 = \frac{\Theta}{\delta}}$$

Laminar: (same analysis with $\frac{u}{U} = \frac{2y}{\delta} - \left(\frac{y}{\delta}\right)^2$

$$\frac{\delta^*}{\delta} = 0{,}33$$

$$\frac{\theta}{\delta} = 0{,}133$$

	Turbulent	Laminar
$\frac{\delta^*}{\delta}$	0,125	0,33
$\frac{\theta}{\delta}$	0,0972	0,133

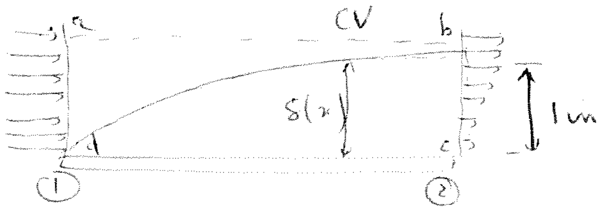
9.18

Fluid $\rho = 1{,}5$ slug/ft^3 $U = 10$ ft/s $L = 10$ ft, $b = 3$ ft $\delta|_{x=L} = 1$ in

Velocity profile linear

a) $\dot{m}$ in control system ?

b) Drag force on upper surface ? How this drag can be computed from given data



a) Assumptions: * steady flow
* No pressure force
* uniform flow at ①

Mass conservation: $0 = \cancel{\frac{\partial}{\partial t}\int_{CV} \rho \, dV} + \int_{SC} \rho \vec{V} \cdot d\vec{A}$ (steady)

$$\Rightarrow -\rho U b \delta + \int_0^\delta \rho u \, b \, dy + \dot{m}_{ab} = 0$$

Velocity profile linear $\Rightarrow \frac{u}{U} = \frac{y}{\delta}$

$$\Rightarrow -\rho U b \delta + \left[\frac{\rho U y^2}{2\delta} b\right]_0^\delta + \dot{m}_{ab} = 0$$

$$\Rightarrow \dot{m}_{ab} = \rho U b \delta - \frac{\rho}{2}\delta b U = \frac{\rho \delta b U}{2} = 1{,}5 \times \frac{1}{12} \times \frac{3 \times 10}{2} = \boxed{1{,}875 \ \frac{\text{slug}}{s} = \dot{m}_a}$$

b) Drag?

$$\Sigma \vec{F} = \cancel{\frac{\partial}{\partial t}\int_{VC} \rho \vec{V}\, dV} + \int_{SC} \rho \vec{V}\,\vec{V}\cdot d\vec{A}$$

$u = U\frac{y}{\delta}$

$$R_x = (-\rho U b \delta)U + \dot{m}_{ab} \times U + \int_0^{\delta} (\rho u b)\, u\, dy$$

$$= -\rho U^2 b\delta + \dot{m}_{ab} U + \int_0^{\delta} \rho U^2 \frac{y^2}{\delta^2}\, b\, dy$$

$$= -\rho U^2 b\delta + \dot{m}_{ab} U + \left[\rho \frac{U^2 b}{\delta^2} \times \frac{1}{3} y^3\right]_0^{\delta}$$

$$= -\rho U^2 b\delta + \dot{m}_{ab} U + \frac{\rho U^2 b}{3}\delta$$

$$\Rightarrow \boxed{R_x = -6{,}25\ \text{lbf}}$$

9.19

turn over plate in 9.18 $\Rightarrow$ $L = 3$ ft $\quad b = 10$ ft

a) Drag increases or decreases, why?

b) $\delta|_{x=L} = 0{,}6$ in, repeat analysis of 9.18 $\Rightarrow$ $\dot{m}$ and Drag

Same assumptions as in 9.18

b) $\dot{m}_{ab} = \frac{1}{2}\rho U b \delta = 3{,}75$ slug/s (from mass conservation as previously)

$$R_x = -\rho U^2 b\delta + \dot{m}_{ab} U + \frac{\rho U^2 b \delta}{3} = -12{,}5\ \text{lbf}$$

a) Drag is larger than for problem 9.18 as expected since the viscous friction is near the leading edge $\Rightarrow$ (3 ft in 9.18 and 10 ft in 9.19)
The BL is small $\Rightarrow$ $\tau = \mu\frac{\partial u}{\partial y} = \frac{\mu U}{\delta}$ is large.

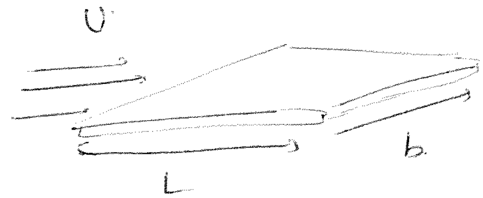
9.40

Thin flat plate installed in water tunnel as a splitter

$U = 1{,}6\ m/s \qquad L = 0{,}3\ m \qquad b = 1m$

Parabolic laminar BL

Determine viscous drag on plate (no pressure drag) ?



$\Rightarrow \rho_{water} = 1000\ kg/m^3$

$\mu = 10^{-3}\ Pa \cdot s$

The flow is laminar but calculate Re

$$Re|_{x=L} = \frac{\rho V L}{\mu} = \frac{1000 \times 1{,}6 \times 0{,}3}{10^{-3}} = 4{,}8\,10^5 \Rightarrow \text{laminar} \checkmark$$

viscous drag $\Rightarrow F_D = \int_0^L \tau_w\, b\, dx$ for one side

$$\Rightarrow F_{D\,total} = 2\int_0^L \tau_w\, b\, dx$$

$$c_f = \frac{\tau_w}{\frac{1}{2}\rho V^2} \qquad \text{and } \tau_w = \mu \frac{\partial u}{\partial y} = \frac{2\mu U}{\delta} \quad \text{where } \delta = \frac{5{,}48}{Re_x^{1/2}}\, x$$

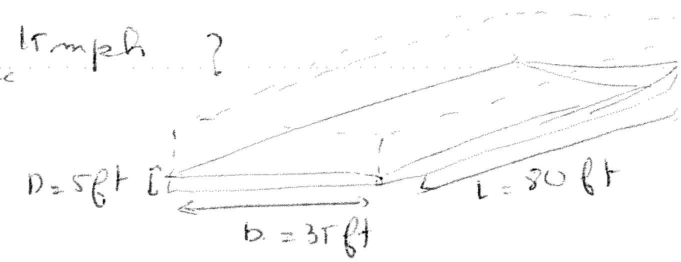
$$\Rightarrow F_{D\,total} = 2b\int_0^L \frac{2\mu U}{\mu^{1/2}} \times \frac{\rho^{1/2} U^{1/2} x^{1/2}}{5{,}48\, x}\, dx = \frac{4 b\, U^{3/2} \rho^{1/2} \mu}{\mu^{1/2}\, 5{,}48}\left[2\, x^{1/2}\right]_0^L$$

$$F_{D\,total} = \frac{4 b U^{3/2} \rho^{1/2} \mu}{5{,}48\ \mu^{1/2}} \times 2 L^{1/2} \Rightarrow \boxed{F_{D\,total} = 1{,}617\ N}$$

9.78

Flat bottomed barge $L = 80\,ft$, $b = 35\,ft$, $d = 5\,ft$ $T = 60°F \Rightarrow$ water

Power required to overcome drag for $V_{max} = 15\,mph$?



P?

F_D ? $\Rightarrow$ $F_D = C_D \times \frac{1}{2} \rho V^2 A_{wetted}$

$A_{wetted} = L(b + 2d) = 3600\,ft^2$

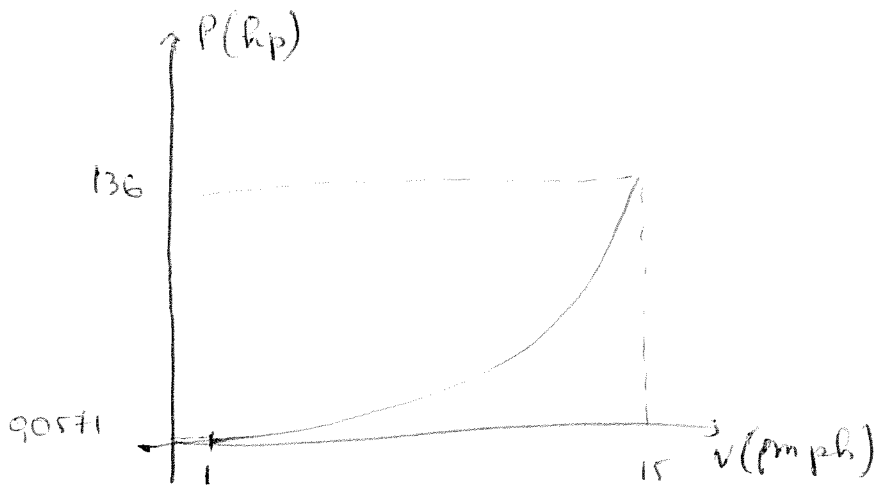
(table A.7) $T = 60°F \Rightarrow \rho = 1{,}94\,slug/ft^3$, $\nu = 1{,}321\,10^{-5}\,ft^2/s$

$\Rightarrow C_D$? $\Rightarrow$ check Re $\Rightarrow$ $Re = \frac{\rho V L}{\nu} = 1{,}45\,10^3$

$\Rightarrow C_D = \frac{0{,}455}{(\log Re_L)^{2,58}} - \frac{1610}{Re_L}$

Power $= F_D \times V = C_D \times \frac{1}{2} \rho V^3 L(b + 2d)$ where $C_D = \frac{0{,}455}{\left(\log\left(\frac{\rho V L}{\nu}\right)\right)^{2,58}} - \frac{1610}{\left(\frac{\rho V L}{\nu}\right)}$

for V varying from 1 mph to 15 mph $\Rightarrow$ P varies from 0,0571 hp to 136 hp



9,81

Jet transport aircraft $\cancel{M}$= 12 km , V= 800 km/h
circular cylinder D= 4m , L= 38m
⇒ Skin friction drag and Power to overcome drag

$$C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A}$$

⇒ Assume flat ~~flat~~ plate with Area $A = L\pi D$

For H= 12 km ⇒ $\frac{\rho}{\rho_{SL}} = 0{,}2546$ where $\rho_{SL} = 1{,}225\ kg/m^3$

⇒ $\rho = 0{,}3119\ kg/m^3$ T= 216,7 k

μ? use expression $\mu(T)$ ⇒ $\mu = \frac{bT^{1/2}}{1+\frac{S}{T}}$ $b = 1{,}458\ 10^{-6}\ kg/m\,s\,k^{1/2}$ S= 110,4 k

⇒ $\mu = 1{,}42\,10^{-5}$ Pa.s

$Re = \frac{\rho V L}{\mu} = 1{,}85\,10^8$ ⇒ turbulent ⇒ $C_D = \frac{0{,}455}{(\log Re_L)^{2{,}58}} = 0{,}00196$

⇒ $\boxed{F_D = 7189\,N}$

⇒ Power = $F_D \times V$ = $\boxed{1{,}598\ 10^6\ W = \text{Power}}$

9.90

American flag ⇒ 194 ft high (H), 367 ft wide (W ⇒ length) ⇒ no holes
V= 10 mph = 14,67 ft/s
Estimate the wind force on flag ⇒ should they have been surprised ?
$\rho_{air} = 0{,}00234\ slug/ft^3$ $\nu = 1{,}62\,10^{-4}\ ft^2/s$

Re? ⇒ $\frac{\rho V L}{\mu} = \frac{VL}{\nu} = \frac{14{,}67 \times 367}{1{,}62\,10^{-4}} = 3{,}32\,10^7$

$F_D = C_D \times \frac{1}{2} \rho V^2 A$ ⇒ $A = H \times W$

C_D ⇒ fig 9.10 ⇒ $C_D = 1{,}15$

⇒ $\boxed{F_D = 2{,}06\,10^4\ lbf}$ ⇒ very large ⇒ failure should have been expected!

12.23

speed of sound at 20° for :

a) hydrogen,

b) helium

c) methane

d) nitrogen

e) carbon dioxide

a) $c = \sqrt{kRT}$ $T = 20+273 = 293\,k$

$k_{hydrogen} = 1{,}41$
$R = 4124\ J/kg\,k$ $\Big\} \Rightarrow c = \sqrt{kRT} = 1305\ m/s$

b) $k_{helium} = 1{,}66$
$R_{helium} = 2077\ J/kg\,k$ $\Big\} \Rightarrow c = \sqrt{kRT} = 1005\ m/s$

c) $k_{methane} = 1{,}31$ ~~J/kg k~~
$R_{methane} = 518{,}3\ J/kg\,k$ $\Big\}$ $c = \sqrt{kRT} = 446\ m/s$

d) $k_{nitrogen} = 1{,}4$
$R_{nitrogen} = 296{,}8\ J/kg\,k$ $\Big\} \Rightarrow c = \sqrt{kRT} = 349\ m/s$

e) $k_{carbon\ dioxide} = 1{,}29$
$R_{carbon\ dioxide} = 188{,}9\ J/kg\,k$ $\Big\} \Rightarrow c = \sqrt{kRT} = 267\ m/s$

12.27

Submarine sends a sonar signal to detect enemy
⇒ Reflected wave returns after 3,25 s
Separation between submarines? for $T = 20°$ in seawater

→ we know that $t = 3{,}25\,s \Rightarrow d$? $V = \frac{d}{t}$

$\Rightarrow c = V$ for water we know that $c = \sqrt{\frac{E_v}{\rho}}$

At $T = 20°$ in seawater : $S = 1{,}025$, $E_v = 2{,}42\ \frac{GN}{m^2}$ $\rho_{water} = 1000\ kg/m^3$

$$c = \sqrt{\frac{E_v}{\rho_{water} S}} = \sqrt{\frac{2,42 \cdot 10^9}{1000 \times 1,025}} = 1537 \text{ m/s}$$

(10)

$\Rightarrow$ Since the wave is reflected $\Rightarrow$ the distance between both submarines is $\boxed{d = 2500 \text{ m}}$

and $d = ct \simeq 5000 \text{ m}$

12.28

Airplane $\Rightarrow$ $V = 550$ km/hr at $H = 1500$ m on standard day (1)

Now $\Rightarrow$ $V = 1200$ km/hr at $H = 15000$ m (2)

Mach ~~number~~ number for (1) and (2) ?

(1) $\Rightarrow$ $H = 1500$ m $\Rightarrow$ $T = 278,4$ K , $V = 550$ km/hr $= 152,778$ m/s

$\Rightarrow M = \frac{V}{c} = \frac{V}{\sqrt{kRT}}$ Air $\Rightarrow$ $k = 1,4$ and $R = 287$ J/kgK

$\Rightarrow \boxed{M_1 = 0,457}$

(2) $\Rightarrow H = 15000$ $\Rightarrow$ $T = 216,7$ K , $V = 1200$ km/hr $= 333,33$ m/s

$\Rightarrow M = \frac{V}{\sqrt{kRT}} = \boxed{1,13 = M_2}$

12.30

Aircraft performance never released but it was thought to cruise at $M = 3,3$ at $H = 85000$ ft

Speed of sound ? flight speed ? compare to muzzle speed of 30-06 rifle bullet (700 m/s)?

@ $H = 85000$ ft $\Rightarrow$ $T = 222$ K Air $\Rightarrow$ $k = 1,4$ $R = 287$ J/kgK

$\Rightarrow c = \sqrt{kRT} = \sqrt{1,4 \times 287 \times 222} = 299$ m/s

$\Rightarrow M = \frac{V}{c} \Rightarrow V = M \times C = 3,3 \times 299 = 987$ m/s

$\Rightarrow \frac{V_{aircraft}}{V_{bullet}} = \frac{987}{700} = 1,41$ $\Rightarrow$ larger than V_{bullet}

12.31

Boeing 727 aircraft of Fig. 9.8 ⇒ V = 520 mph at 33000 ft on standard day

a) M ?

b) If Max Mach number is 0,9 what is V ?

a) $M = \frac{V}{c} = \frac{V}{\sqrt{kRT}}$

@ H = 33000 ft ⇒ T = 223 K air k = 1,4 , R = 287 J/kg K

⇒ $c = \sqrt{kRT} = 299 \ m/s$

⇒ V = 520 mph = 232 m/s

⇒ $M = \frac{232}{299} = \boxed{0,776 = M}$

b) for $M = 0,9 = \frac{V}{c}$ ⇒ $V = c \times M = 299 \times 0,9 = \boxed{269 \ m/s = V}$

12.68

Anglo - French concorde supersonic transport ⇒ M = 2,2 at 20 km altitude.

a) c ? V ? and α ?

b) Maximum air Temperature at stagnation point on aircraft ?

a) $c = \sqrt{kRT}$?

@ H = 20 km ⇒ T = 216,7 K Air ⇒ k = 1,4 , R = 287 J/kg K

⇒ $c = \sqrt{1,4 \times 286,9 \times 216,7} = \boxed{295 \ m/s = c}$

$M = \frac{V}{c}$

⇒ $V = Mc = 2,2 \times 295 = \boxed{649 \ m/s = V}$

we know for supersonic Mach cone ⇒ $\alpha = \sin^{-1}\left(\frac{1}{M}\right) = \sin^{-1}\left(\frac{1}{2,2}\right) = \boxed{27^\circ = \alpha}$

b) we know that T_0 stagnation temperature :

$\frac{T_0}{T} = 1 + \frac{k-1}{2} M^2 \Rightarrow T_0 = T\left(1 + \frac{k-1}{2} M^2\right) = 216,7\left(1 + \frac{1,4-1}{2} 2,2^2\right) = \boxed{426 \ K = T_0}$

12.70

Supersonic tunnel test section designed to have $M = 2{,}5$ @ $T = 15°C$ and $P = 35\ kPa$ (abs)

$\Rightarrow$ Air

a) T_0? P_0?

b) Mass flow rate for test section area of $0{,}175\ m^2 = A$

a) we know $\frac{T_0}{T} = 1 + \frac{k-1}{2} M^2$

$$\frac{P_0}{P} = \left(1 + \frac{k-1}{2} M^2\right)^{\frac{k}{k-1}}$$

$$T_0 = \overset{?}{T}\left(1 + \frac{k-1}{2} M^2\right) \qquad T = (15 + 273)\ k = 288\ k$$

$$\Rightarrow T_0 = 288\left(1 + \frac{1{,}4-1}{2} 2{,}5^2\right) = \boxed{645\ k = T_0}$$

$$P_0 = P\left(1 + \frac{k-1}{2} M^2\right)^{\frac{k}{k-1}} = 35\,10^3\left(1 + \frac{1{,}4-1}{2} 2{,}5^2\right)^{\frac{1{,}4}{1{,}4-1}}$$

$$\Rightarrow \boxed{P_0 = 598\ kPa}$$

b) $\dot{m} = \rho V A$ $\qquad V$? ρ? $\quad k = 1{,}4 \quad R = 287\ J/kg\,k$ (air)

$$M = \frac{V}{c} \Rightarrow V = M \times c \qquad c = \sqrt{kRT}$$

$$\Rightarrow V = 2{,}5 \times \sqrt{1{,}4 \times 287 \times 288} = 850\ m/s$$

$$P = \rho R T \Rightarrow \rho = \frac{P}{RT} = \frac{35\,10^3}{287 \times 288} = 0{,}424\ kg/m^3$$

$$\Rightarrow \dot{m} = 0{,}424 \times 850 \times 0{,}175 = \boxed{63\ kg/s = \dot{m}}$$

13.13

Air at ① ②

$\Rightarrow k = 1{,}4$ $\quad P_1 = 60\,kPa$ (abs) $\quad P = 78{,}8\,kPa$ (abs)

$R = 287\ J/kg\,k$ $\quad T_1 = 27°C$ $\quad M_2$?

$V_1 = 486\ m/s$ $\quad$ Assuming isentropic flow

$A_1 = 0{,}02\ m^2$

Sketch passage ?

since isentropic $\Rightarrow P_{o_1} = P_{o_2}$

we know $\Rightarrow \dfrac{P_o}{P} = \left(1 + \dfrac{k-1}{2} M^2\right)^{\frac{k}{k-1}}$ $\quad M_1 ? \Rightarrow M_1 = \dfrac{V_1}{C_1} = \dfrac{V_1}{\sqrt{kRT}} = \dfrac{486}{\sqrt{1{,}4 \times 287 \times 27 + 273}} = \dfrac{486}{347\ m/s} = 1{,}4$

$$\frac{P_{o_1}}{P_1} = \left(1 + \frac{k-1}{2} M_1^2\right)^{\frac{k}{k-1}} \Rightarrow P_{o_1} = P_1\left(1 + \frac{k-1}{2} M_1^2\right)^{\frac{k}{k-1}} \Rightarrow P_o = 60\,10^3\left(1 + \frac{1{,}4-1}{2}\,1{,}4^2\right)^{\frac{1{,}4}{1{,}4-1}}$$

$\Rightarrow P_{o_1} = 191\,10^3\,Pa$

$$P_{o_1} = P_{o_2} = P_2\left(1 + \frac{k-1}{2} M_2^2\right)^{\frac{k}{k-1}} \Rightarrow M_2 = \sqrt{\frac{2}{k-1}\left(\left(\frac{P_{o_2}}{P_2}\right)^{\frac{k-1}{k}} - 1\right)} = \boxed{1{,}2 = M_2}$$

$M_1 = 1{,}4$
$M_2 = 1{,}2$ $\Big\}$ $\Rightarrow$ fluid being slowed down and $M > 1 \Rightarrow$ supersonic diffuser