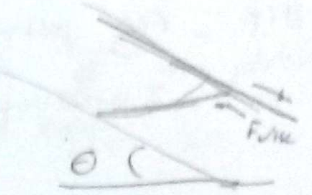
VEM ATRÁS A SOLUÇÃO COM HIPÓTESES

[illegible] desliza para baixo $V = 0{,}2\,m/s$

qual μ se $\theta = ?$ $\quad \mu = ?$ $\quad \dfrac{dh}{dx} = -\operatorname{sen}\theta$



$\dfrac{dp}{dx} = 0 \quad = -\rho g x = -\rho g \operatorname{sen}\theta$

$$u(y) = \frac{1}{2\mu}\left(\rho g \frac{dh}{dx}\right)(y^2 - ay) + \frac{V}{a}y =$$

$$= \frac{1}{\mu}\cdot\frac{9{,}81\cdot(0{,}5)}{2}\left(y^2 - 0{,}0004y\right) + \frac{0{,}2}{0{,}0004}y =$$

$$= \frac{\rho}{\mu}\ 2{,}4525\left(y^2 - 4\times10^{-4}y\right) + 500y$$

equilíbrio [illegible] da placa $\quad$ Peso placa $\times \operatorname{sen}\theta = F_{viscosa}$

$$40 \cdot 0{,}5 = \tau \cdot A_{placa} = \mu \left.\frac{\partial u}{\partial y}\right|_{y=0{,}0004} \cdot 1$$

$$\frac{20}{\mu} = \frac{\rho}{\mu}\,2{,}4525\left(2y - 4\times10^{-4}\right) + 500\Bigg|_{y=4\times10^{-4}}$$

0,0274

$\dfrac{20}{\mu} = \dfrac{\rho}{\mu}\ 9{,}81\times10^{-4} + 500 \longrightarrow$ e aí?

$\rho = 9375$

$$20 = \rho\ 9{,}81\times10^{-4} + 500\mu \longrightarrow \mu = 0{,}04\ Pa.s$$

se ~~peso~~ fluido desprezível $\rightarrow$ Resp.

$$u(y) = \frac{V}{a}y \longrightarrow \frac{\partial u}{\partial y} = \frac{V}{a}$$

$g_x = g \,\text{sen}\,\theta = \frac{dh}{dx}$

$$\frac{\partial u}{\partial t} + \cancel{u \frac{\partial u}{\partial x}} + \cancel{v \frac{\partial u}{\partial y}} = -\frac{\partial p}{\partial x} + \mu\left(\cancel{\frac{\partial^2 u}{\partial x^2}} + \frac{\partial^2 u}{\partial y^2}\right) + \rho g_x$$

0 $\qquad$ 0 desenvol. $\qquad$ 0 $\qquad$ 0 desenvolvido

Hip.: - reg. permanente $\qquad$ - Newtoniano $\qquad$ - laminar $\rightarrow$ dir y $= 0$

- Incompressível $\qquad$ - 2D $\qquad$ - desenvolvido

então $\frac{1}{\mu}\left(\frac{dp}{dx} - \rho g_x\right) = \frac{\partial u^2}{\partial y^2}$

integra 2x $\rightarrow$ $u(y) = \frac{1}{\mu}\left(\frac{dp}{dx} - \rho g_x\right)\frac{y^2}{2} + C_1 y + C_2$

C.C. $\quad u(0) = 0 \longrightarrow C_2 = 0$

$\quad u(a) = V \longrightarrow C_1 = \frac{1}{\mu}\left(\frac{dp}{dx} - \rho g_x\right)\frac{a}{2}$

então

8.122

Ar $\rho = 1{,}2$ kg/m³ $\nu = 1{,}51 \times 10^{-5}$ m²/s TAB. B2 T=20°C

$U_\infty = 60$ km/h . . C.L. começa a 100km da praia

$= 16{,}67$ m/s

ASSUMINDO → TURBULENTO: QUAL δ e τ na praia?

→ Reg. Perm. → INCOMP → CAMADA LIMITE $dP/dx = 0$, $U_\infty = c^{te}$ DE PLACA PLAN

(a) LEI POTÊNCIA $n = 7$

$$Re_L = \frac{U_\infty \cdot L}{\nu} = \frac{16{,}67 \cdot 100 \times 10^3}{1{,}51 \times 10^{-5}} = 1{,}1 \times 10^{11}$$

$\delta = 0{,}38 \times Re_x^{-1/5}$ em L=100 km → $\delta = 235$ m

$C_f = 0{,}059\, Re_x^{-1/5}$ em L.. $C_f =$ ~~...~~ $3{,}65 \times 10^{-4}$

$\tau_w = C_f \cdot \frac{1}{2} \rho U_\infty^2 \cong \boxed{0{,}0609 \text{ Pa}}$

(b) LOGARÍTMICA

$$C_f = \frac{0{,}455}{(\ln 0{,}06 Re_x)^2} \Rightarrow \text{em } L = 100\text{km} \quad C_f = 8{,}9 \times 10^{-4}$$

↳ $\boxed{\tau = 0{,}148 \text{ Pa}}$ → $u_* = \sqrt{\frac{\tau}{\rho}} = 0{,}351$ m/s

$$\frac{U_\infty}{u_*} = 2{,}44 \ln \frac{u_* \cdot \delta}{\nu} + 7{,}4$$

TAMANHO $\frac{16{,}67}{0{,}351} = 2{,}44 \ln \frac{0{,}351 \cdot \delta}{1{,}51e{-5}} + 7{,}4$ → $\boxed{\delta = 589 \text{ m}}$

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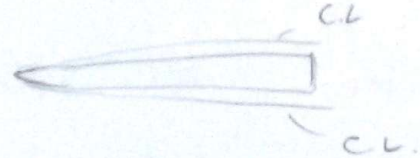
$\boxed{8.126}$

Navio



10 m/s

10 m prof.

100 m compr.

$\boxed{\text{VER HIP. CAMADA LIMITE!!}}$

ÁGUA $\rho = 10^3\ kg/m^3$ $\nu = 1\times10^{-6}\ m^2/s$

$$Re_L = \frac{V_\infty \cdot L}{\nu} = 10^9$$

VER HIPÓTESES p/ C.L.

transição ocorre em

$x_{cr} \rightarrow Re_{cr} = 5\times10^5$

$\boxed{x_{cr} = 0{,}05\ m}$

então vou considerar todo turbulento

LOG.

$$C_{F_L} = \frac{0{,}523}{(\ln 0{,}06\, Re_L)^2} = 0{,}00163$$

$$F_{TOTAL} = 2F_D = 2 \cdot C_{F_L} \cdot \frac{1}{2}\rho V_\infty^2\ p \cdot L = 163\ kN$$

C.L. TAMANHO MÁXIMO NO FIM DO CASCO. $x = L$

LOG $\rightarrow$ preciso de u_τ

$$C_f = \frac{0{,}455}{(\ln 0{,}06\, Re_L)^2} = 0{,}00142 \rightarrow \tau = C_f \cdot \frac{1}{2}\rho V_\infty^2 = 70{,}92\ Pa$$

$$u_\tau = \sqrt{\frac{\tau_w}{\rho}} = 0{,}266\ m/s$$

$$\frac{V_\infty}{u_\tau} = 2{,}44 \ln \frac{u_\tau \cdot \delta}{\nu} + 7{,}4 \rightarrow \boxed{\delta = 0{,}89\ m}$$

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$\boxed{8.108}$, $\boxed{110}$ e $\boxed{116}$

EQ. VON KÁRMAN

$$\tau_0 + \delta \frac{\partial p}{\partial x} = U(x) \frac{d}{dx}\int_0^\delta \rho u \, dy - \frac{d}{dx}\int_0^\delta \rho u^2 dy$$

se $\frac{dp}{dx} = 0$ e $U(x) = U$

$$\boxed{\tau_0 = \frac{d}{dx}\int_0^\delta \rho u (U-u)\, dy} \quad \text{I}$$

EXEMPLO $\boxed{108}$ $u(y) = U \operatorname{sen}(\pi y / 2\delta)$

na EQ. I $\tau_0 = \rho U^2 \frac{d}{dx}\int_0^\delta \operatorname{sen}(\pi y/2\delta)\left(1 - \operatorname{sen}(\pi y/2\delta)\right) dy =$

integrando $\longrightarrow = \rho U^2 \frac{d}{dx}\left[\left(-\frac{2\delta}{\pi}\cos\left(\frac{\pi x}{2\delta}\right) + \frac{1}{2}\frac{\delta \operatorname{sen}\left(\frac{\pi x}{\delta}\right)}{\pi} - \frac{x}{2}\right)_0^\delta\right] =$

$= -\rho U^2 \frac{d}{dx}\left[+\frac{2\delta}{\pi} - \frac{\delta}{2}\right] = \rho U^2 \frac{d}{dx}\left(+\frac{(4-\pi)\delta}{2\pi}\right) = \frac{+\rho U^2 (4-\pi)}{2\pi}\frac{d\delta}{dx}$

e $\tau_0 = \mu \left.\frac{du}{dy}\right|_{y=0} = \mu \cdot U \frac{\pi}{2\delta} \cos\left(\frac{\pi y}{2\delta}\right)\Big|_0 = \frac{\mu \pi U}{2\delta}$

igualando

$$\frac{\mu \pi U}{2\delta} = \frac{(4-\pi)\rho U^2}{2\pi}\frac{d\delta}{dx}$$

$$\int_0^x \frac{\mu \pi^2}{(4-\pi)\rho U} dx = \int_0^\delta \delta \, d\delta \longrightarrow \delta(x) = \sqrt{\frac{2\mu\pi^2}{(4-\pi)}\frac{x}{\rho U}} =$$

$\frac{\delta^2}{2}$

$$\boxed{\delta(x) = 4{,}795 \sqrt{\frac{x \nu}{U}}}$$

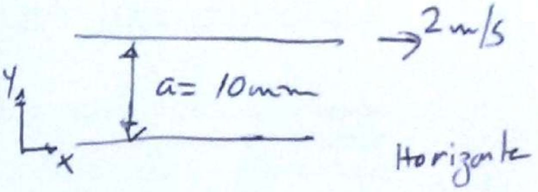
então

$$\tau_0 = \frac{\mu \pi U}{2\delta} = \frac{\mu \pi U}{2 \cdot 4{,}795 \sqrt{\frac{\nu x}{U}}} = 0{,}328\, \mu U \sqrt{\frac{U}{\nu x}}$$

(I)

$\boxed{7.59}$ → Reg. perm. – Incompr. – Newtoniano – Laminar
– desenvolvido

Aplicar hip. à Navier-Stokes dir. x
(NÃO FIZ AQUI, FAZER!)
↳ chega-se a



Horizontal

$\mu = 0{,}4\ Ns/m^2$

$$u(y) = \frac{1}{2\mu}\frac{dp}{dx}(y^2 - ay) + \frac{V}{a}y$$

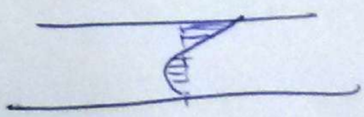
VEJA OUTROS EXEMPLOS OU LIVRO OU ANOTAÇÃO AULA!

(a) $u(y) = \dfrac{1}{0{,}8}\dfrac{dp}{dx}(y^2 - 0{,}01y) + 200y$

(b) qual $\dfrac{dp}{dx}$ que $u(0{,}005) = 0$
↑
$y = 0{,}005\,m$ (meio entre placas)

$$\frac{1}{0{,}8}\frac{dp}{dx}(0{,}005^2 - 0{,}01\cdot 0{,}005) + 200(0{,}005) = 0$$

↳ $\dfrac{dp}{dx} = 32000\ Pa/m$



$\tau = \mu\dfrac{du}{dy} = \dfrac{32000}{0{,}8}(2y - 0{,}01) + 200$

$Q = ?$ $\;Q = \displaystyle\int_0^{0{,}01} u(y)\,dy = \frac{1}{300}\ m^3/s$

em $y = 0$ $\;\tau|_{y=0} = -200\,Pa$
$y = 0{,}01\,m$ $\;\tau|_{y=a} = 600\,Pa$

$\boxed{8.108}$ FIZ EM AULA

$\boxed{8.98}$

Assumir que transição ocorre para $Re_{cr} = 5\times 10^5$

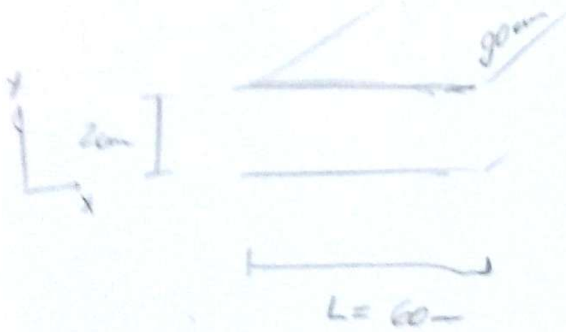
$V = 800\ km/h$
altitude 9000 m

TAB. B3 Livro → altitude 9000 m $\;\rho_{ar} \cong 0{,}47\ kg/m^3$

TAB. B2 Livro $\;T \cong -43°C \longrightarrow \mu_{ar} \cong 1{,}5\times 10^{-5}\ Ns/m^2$

→ $Re_{cr} = \dfrac{\rho V x_{cr}}{\mu}$ ⇒ $5\times 10^5 = \dfrac{0{,}47\cdot 222{,}22\cdot x_{cr}}{1{,}5\times 10^{-5}}$ ⇒ $\boxed{x_{cr} \cong 0{,}072\,m}$

7.54



CANAL AR 20°C

$\Delta P = -50\,Pa$

FLOW RATE E Reynolds?

Canal $Re = \frac{\rho \bar{V} \cdot a}{\mu}$

SOLUÇÃO PLACA PLANA

→ Reg. Perm. → Desenvolv.
→ Incompr. → Newtoniano
→ LAMINAR

VER DEDUÇÃO EM ANOTAÇÕES E OUTROS EXERCÍCIOS

$$u(y) = \frac{1}{2\mu}\frac{d}{dx}(P+\gamma h)(y^2 - ay) + \frac{V}{a}y$$

Neste caso horizontal $\frac{d(\gamma h)}{dx} = 0$ e $V = 0$ (canal parado)

temos $a = 0{,}02\,m$, $\mu_{ar} = 1{,}81 \times 10^{-5}\,Pa \cdot s$ (TAB B2), $\rho_{ar} = 1{,}204\,kg/m^3$

dados $\frac{dP}{dx} = \frac{\Delta P}{L} = -\frac{50}{60}\,Pa/m$

então $u(y) = -2{,}3 \times 10^5\,(y^2 - 0{,}02y)$

$$\text{VAZÃO} = Q = \int (\vec{V} \cdot \vec{n})\,dA = \int_0^{0{,}9}\int_0^{0{,}02} u(y)\,dy\,dz =$$

$$= 0{,}9 \int_0^{0{,}02} -2{,}3 \times 10^5\,(y^2 - 0{,}02y)\,dy = 0{,}9 \cdot (-2{,}3 \times 10^5)\left(\frac{y^3}{3} - \frac{0{,}02y^2}{2}\right)\Big|_0^{0{,}02} =$$

$$= \boxed{0{,}276\,m^3/s}$$

7.42 Solução do duto (Ver como chegar na eq. 7.3-11 e anotações de aula)

$$u(r) = \frac{1}{4\mu}\frac{d}{dx}(p+\gamma h)(r^2 - r_o^2)$$

- incomp.
- Reg. Perm.
- LAM.
- Newtoniano
- Desenvolvido
- AXISSIMÉTRICO

Velocidade média $\bar{V} = \frac{Q}{A} = \frac{1}{\pi r_o^2}\int_0^{r_o} u(r)\, 2\pi r\, dr =$

$$= \frac{-r_o^2}{8\mu}\frac{d(p+\gamma h)}{dx}$$

(a) $r_a = ?$ quando $u(r_a) = \bar{V}$

$$\frac{1}{4\cancel{\mu}}\cancel{\frac{d(p+\gamma h)}{dx}}(r_a^2 - r_o^2) = \frac{-r_o^2}{8\cancel{\mu}}\cancel{\frac{d(p+\gamma h)}{dx}}$$

$$r_a^2 = r_o^2 - \frac{r_o^2}{2} = \frac{r_o^2}{2} \Rightarrow \boxed{r_a = \frac{r_o}{\sqrt{2}}}$$

(b) $\tau|_{parede\ r=r_o} \Rightarrow \tau = \mu\frac{du(r)}{dr} = \frac{1}{2}\frac{d(p+\gamma h)}{dx} r$

$$\tau_{parede}(r=r_o) = \frac{1}{2}\frac{d(p+\gamma h)}{dx} r_o$$

onde é metade $r = r_b$ $\quad \frac{1}{2}\frac{d(p+\gamma h)}{dx} r_b = \frac{1}{2}\tau_{parede} = \frac{1}{2}\cdot\frac{1}{2}\frac{d(p+\gamma h)}{dx} r_o$

$$\boxed{r_b = \frac{r_o}{2}}$$

7.57

ver dedução para placas planas

θ HORIZONTAL

Solução eq. 7.4.13 $u(y) = \frac{1}{2\mu}\frac{d(p+\cancel{\gamma h})}{dx}(y^2 - ay) + \frac{U}{a}y$

(a) $\tau|_{y=a} = 0 \Rightarrow \mu \left.\frac{du}{dy}\right|_{y=a} = 0$

$$\mu\left(\frac{1}{2\mu}\frac{dp}{dx}(2y-a) + \frac{U}{a}\right)\Bigg|_{y=a} = 0$$

isolando $\boxed{\frac{dp}{dx} = \frac{2U}{\mu}}$

(b) idem mas calcula $\tau|_{y=0} = 0$

(c) $Q = \int_0^a u(y)\cdot 1\cdot dy = 0$

calcule a integral e isole $\frac{dp}{dx}$

(d) $u(y = 4mm) = 4 m/s$ (substitui este y em [m] na fórmula e isole $\frac{dp}{dx}$)

8.97

TABELA B3

		kg/m³	K	TAB B2 → $\mu \sim$ Pa·s
0 ft	0 m	$\rho = 1{,}225$	288	$1{,}78\times10^{-5}$
12×10^3 ft	≈ 4000 m	0,8194	262	$1{,}67\times10^{-5}$
30×10^3 ft	~ 10000 m	0,4136	223	$1{,}46\times10^{-5}$

↑ VARIA POUCO

$Re_{cr} = 6\times10^5 = \dfrac{\rho U_\infty x_{cr}}{\mu}$ $\qquad x_{cr} = \dfrac{Re\cdot\mu}{\rho U}$

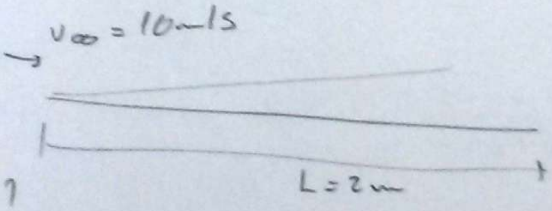
300 ft/s = 100 m/s

(a) $x_{cr} = \dfrac{6\times10^5 \cdot 1{,}78e^{-5}}{1{,}225\cdot 100} = 0{,}087\ m$

(b) $x_{cr} = \qquad = 0{,}122\ m$

(c) $x_{cr} = \qquad = 0{,}212\ m$

8.117



$\rho = 1000\ kg/m^3$

$\nu = 1\times10^{-6}\ m^2/s$

$w = 4\ m$

δ e F_{FRIC}?

(a) TUDO LAMINAR

Solução Blasius $\quad Re_L = \dfrac{U_\infty\cdot L}{\nu} = 2\times10^7$ $\quad$ (OBS: errado! $Re_{cr} \simeq 5\times10^5$)

$\delta = \dfrac{5x}{\sqrt{Re_x}}$ em $x = L$ → $\delta_L(L) = \dfrac{5\cdot2}{\sqrt{Re_L}} = \boxed{2{,}24\times10^{-3}\ m}$

Fricção Blasius $\quad C_{f_L} = \dfrac{1{,}32}{\sqrt{Re_L}} = \dfrac{1{,}32}{\sqrt{2\times10^7}} = 2{,}952\times10^{-4}$

DEF. $C_{f_L} = \dfrac{F}{\frac{1}{2}\rho U_\infty^2\, w\cdot L}$ ⇒ $F_{FRIC} = C_{f_L}\cdot\frac{1}{2}\rho U_\infty^2\, w\cdot L \cong \underline{118\ N}$

(b)

TUDO TURBULENTO → Usar C.C. LOGARÍTMICA

TAMANHO $\frac{U_\infty}{u_\tau} = 2{,}44 \ln \frac{u_\tau \delta}{\nu} + 7{,}4$ $\qquad u_\tau = \sqrt{\frac{\tau_w}{\rho}}$

Cisalho $\frac{0{,}455}{(\ln 0{,}06 Re_x)^2}$

Força $\frac{0{,}523}{(\ln 0{,}06 Re_L)^2}$

para o tamanho, precisamos de u_τ, então calculamos τ_w em $x = L$

$$C_f = \frac{0{,}455}{(\ln 0{,}06 Re_L)^2} = 2{,}322 \times 10^{-3} \qquad C_f = \frac{\tau_w}{\frac{1}{2}\rho U_\infty^2} \Rightarrow \tau_w = 116 \text{ kPa}$$

$$u_\tau = 0{,}341 \text{ m/s}$$

TAMANHO $\frac{10}{0{,}341} = 2{,}44 \ln\left(\frac{0{,}341 \cdot \delta}{1 \times 10^{-6}}\right) + 7{,4} \Rightarrow \boxed{\delta = 2{,}343 \times 10^{-2} \text{ m}}$

Força $C_{FL} = \frac{0{,}523}{(\ln 0{,}06 Re_L)^2} = 2{,}669 \times 10^{-3}$

$$F = C_{FL} \cdot \frac{1}{2}\rho U_\infty^2 \, L \cdot W \rightarrow \boxed{F = 1068 \text{ N}}$$