(1) Regime Permanente

$\dot{m} = 50\ kg/s$ $\quad \bar{v}_{1,2} = ?$ $\quad d_1 = 0{,}20\ m$

$\rho = 1000\ kg/m^3$ $\quad Q = ?$ $\quad d_2 = 0{,}10\ m$

sol.: $\dot{m} = \rho . \overbrace{A . \bar{v}}^{Q}$

$50 = 1000 . Q \longrightarrow \boxed{Q = 0{,}05\ m^3/s}$

$Q_1 = \bar{v}_1 . A_1$

$0{,}05 = v_1 . \dfrac{\pi . 0{,}2^2}{4} \longrightarrow \boxed{\bar{v}_1 = 1{,}6\ m/s}$

$Q = \bar{v}_2 . A_2$

$0{,}05 = \bar{v}_2 . \dfrac{\pi . 0{,}1^2}{4} \longrightarrow \boxed{\bar{v}_2 = 6{,}4\ m/s}$

(2) Bernoulli entre A e C

$$\frac{P_A}{\gamma} + z_A + \cancel{\frac{v_A^2}{2g}}^{0} = \cancel{\frac{P_C}{\gamma}}^{0} + \cancel{z_C}^{NR} + \frac{v_C^2}{2g}$$

$z_C = 0$ (NR)

$v_A > v_C \rightarrow v_A \cong 0$

$P_C = P_{atm} \rightarrow P_A = P_{man} \rightarrow P_{atm} = 0$

$200\ mmHg - x$

$760\ mmHg - 101325\ Pa \longrightarrow x = 26664{,}47\ Pa$

$$\frac{26664{,}47}{9810} + 8 = \frac{v_C^2}{2 . 9{,}81}$$

$$10{,}718 . 19{,}62 = v_C^2$$

$$v_C = 14{,}5\ m/s$$

$$Q = A \cdot v$$

$$Q = \frac{\pi \cdot 0,04^2}{4} \cdot 14,5 \longrightarrow \boxed{Q = 0,018 \, m^3/s}$$

Bernoulli entre A e B

$$\frac{P_A}{\gamma} + z_A + \cancel{\frac{v_A^2}{2g}}^{\,0} = \frac{P_B}{\gamma} + z_B + \frac{v_B^2}{2g} \qquad \begin{cases} v_A >>> v_B \rightarrow v_A = 0 \\ v_B = v_C \end{cases}$$

$$\frac{26664,47}{9810} + \cancel{0} = \frac{P_B}{9810} + 4 + \frac{14,5^2}{2 \cdot 9,81}$$

$$10,718 = \frac{P_B}{9810} + 14,716$$

$$\boxed{P_{B_{man}} = -39221,42 \, P_A}$$

$$\boxed{P_{abs} = 62103,58 \, P_A}$$

4) Bernoulli entre A e B

$$\frac{P_A}{\gamma} + z_A + \frac{v_A^2}{2g} = \frac{P_B}{\gamma} + \cancel{z_B}^{\,NR} + \frac{v_B^2}{2g}$$

Manometria:

$$P_A = P_B + \cancel{x \cdot \gamma_{H_2O}} + 0,3 \cdot \gamma_{Hg} - 0,3 \cdot \gamma_{H_2O} - \cancel{x \cdot \gamma_{H_2O}} - z_A \cdot \gamma_{H_2O}$$

$$P_A - P_B = 0,3 \cdot \gamma_{Hg} - 0,3 \cdot \gamma_{H_2O} - z_A \cdot H_2O$$

$$Q = A \cdot v \longrightarrow v = \frac{Q \cdot 4}{\pi \cdot d^2}$$

$$\frac{P_A - P_B}{\gamma_{H_2O}} + z_A + \frac{Q^2 \cdot 4^2}{\pi^2 \cdot d_A^2} \cdot \frac{1}{2g} = \frac{Q^2 \cdot 4^2}{\pi^2 \cdot d_B^2} \cdot \frac{1}{2g}$$

$$\left(\frac{0{,}3\ \gamma_{Hg} - 0{,}3 .\ \gamma_{H_2O} - \cancel{z_A\,\gamma_{H_2O}}}{\gamma_{H_2O}}\right) + \cancel{z_A} = \left(\frac{Q^2 .\ 16}{\pi^2 .\ 0{,}05^4} - \frac{Q^2 .\ 16}{\pi^2 .\ 0{,}08^4}\right) . \frac{1}{2g}$$

$$0{,}3 . (13{,}6 . 9810) - 0{,}3 . 9810 = (259645{,}4\,Q^2 - 39618{,}45\,Q^2) . \frac{1}{2g} . 9810$$

$$\frac{1}{9810} . 37081{,}8 . 19{,}62 = 220026{,}7\,Q^2$$

$$Q^2 = 3{,}3066 . 10^{-4} \longrightarrow \boxed{Q = 1{,}83 . 10^{-2}\ m^3/s}$$

5) Bernoulli entre 1 e 2:

$$\cancel{\frac{P_1}{\gamma}}^{0} + z_1 + \cancel{\frac{v_1^2}{2g}}^{0} = \frac{P_2}{\gamma} + \cancel{z_2}^{NR} + \frac{v_2^2}{2g}$$

$$\begin{cases} P_1 = P_{atm} = 0 \\ v_1 >>> v_2 \rightarrow v_1 \cong 0 \end{cases} \qquad z_2 = 0\ (NR)$$

$$3{,}66 = \frac{P_2}{9810} + \frac{v_2^2}{19{,}62}$$

Manometria:

$$P_2 = \cancel{P_{atm}}^{0} + 0{,}15 . \gamma_{Hg} - 0{,}61 . \gamma_{H_2O}$$

$$P_2 = 0{,}15 . (13{,}6 . 9810) - 0{,}61 . 9810 \longrightarrow P_2 = 14028{,}3\ Pa$$

$$3{,}66 = \frac{14028{,}3}{9810} + \frac{v_2^2}{19{,}62}$$

$$2{,}23 . 19{,}62 = v_2^2 \longrightarrow \boxed{v_2 = 6{,}61\ m/s}$$

$$Q = A_2\ v_2$$

$$Q = \frac{\pi . 0{,}05^2}{4} . 6{,}61$$

$$\hookrightarrow Q = 13 . 10^{-3}\ m^3/s$$

$$\boxed{Q = 13\ L/s}$$

3) Bernoulli entre 1 e 2:

$$\frac{P_1}{\gamma} + z_1 + \cancel{\frac{v_1^2}{2g}} = \cancel{\frac{P_2}{\gamma}} + \cancel{z_2} + \frac{v_2^2}{2g}$$

NR

$z_2 = 0$ (NR)

$v_1 >>> v_2 \rightarrow v_1 \cong 0$

$P_2 = P_{atm} = 0$

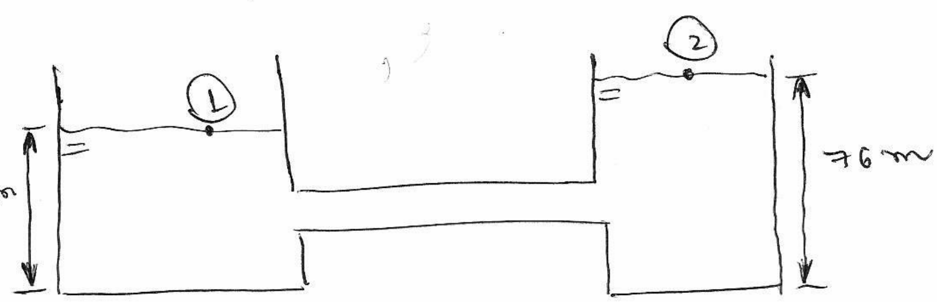
$$\frac{101325}{9810} + 5 = \frac{v_2^2}{19,62}$$

$$v_2^2 = 300,75$$

$$\boxed{v_2 = 17,34 \text{ m/s}}$$

6) Uma tubulação de ferro fundido ($\varepsilon = 2{,}5 \cdot 10^{-4}$ m) que tem 0,3 m de diâmetro e 300 m de comprimento comunica dois recipientes que tem seus níveis de superfícies a uma altura de 60 m e 76 m. Calcular a vazão através desta tubulação, supondo-se que a água se encontra a uma temperatura de 10 °C ($\nu = 1{,}3 \cdot 10^{-6}$ m²/s) e que a entrada no tubo é normal.

Dados: $K_e = 0{,}5$ (entrada e saída da tubulação)
$K_s = 1{,}0$



2ª situação

Bernoulli entre 1 e 2:

Sol.
$$\cancel{\frac{P_1}{\gamma}} + z_1 + \cancel{\frac{v_1^2}{2g}} + h_{p\,2-1} = \cancel{\frac{P_2}{\gamma}} + z_2 + \cancel{\frac{v_2^2}{2g}}$$

$\begin{cases} P_1 = P_2 = P_{atm} \\ v_1 = v_2 \cong 0 \end{cases}$ fluxo de 2 p/ 1

$60 + (hd + hl) = 76$

$hd + hl = 16$

(1.

$$\begin{cases} h_d = f \cdot \dfrac{l}{d} \cdot \dfrac{v^2}{2g} \\ h_l = h_{le} + h_{ls} = (K_e + K_s) \cdot \dfrac{v^2}{2g} \end{cases}$$

$$\left(f \cdot \frac{l}{d} + K_e + K_s\right) \cdot \frac{v^2}{2g} = 16$$

$$\left(f \cdot \frac{300}{0,3} + 0,5 + 1,0\right) \cdot \frac{v^2}{19,62} = 16$$

$$v = \sqrt{\frac{313,92}{1000 f + 1,5}}$$

Cálculo de f:

$$\boxed{f = 0,030} \longrightarrow v = 3,16 \ m/s$$

$$Re = \frac{v \cdot d}{\nu} = \frac{3,16 \cdot 0,3}{1,3 \cdot 10^{-6}} \longrightarrow Re = 7,3 \cdot 10^5$$

$$\frac{D}{\varepsilon} = \frac{0,3}{2,5 \cdot 10^{-4}} \longrightarrow \frac{D}{\varepsilon} = 1\,200$$

Diagrama Rouse - Moody : $f = 0,019$

Recalculando:

$v = 3,91 \ m/s$

$$Re = \frac{3,91 \cdot 0,3}{1,31 \cdot 10^{-6}} \longrightarrow Re = 9,02 \cdot 10^5$$

$$\frac{D}{\varepsilon} = \frac{0,3}{2,5 \cdot 10^{-4}} \longrightarrow \frac{D}{\varepsilon} = 1200$$

: Diagrama Rouse . Moody: $f \cong 0,019$

$$\boxed{v = 3,91 \ m/s}$$

$$Q = A \cdot v = \frac{\pi \cdot 0,3^2}{4} \cdot 3,91 \longrightarrow \boxed{Q = 0,277 \ m^3/s}$$

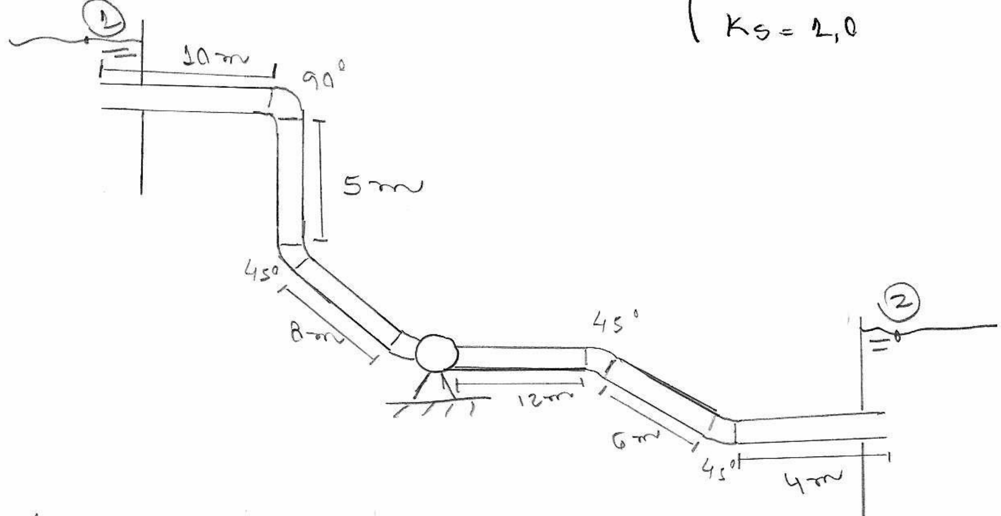
7) Determinar a perda de carga da instalação abaixo e a vazão, sabendo-se que o seu diâmetro é de 0,5 m e que a velocidade é de 4 m/s.

Dados: $\varepsilon = 5 \cdot 10^{-5} \ m$

$\nu = 1,3 \cdot 10^{-6} \ m^2/s$

$$\begin{cases} K_e = 1,0 \\ K_{90^\circ} = 0,4 \\ K_{45^\circ} = 0,2 \\ K_S = 1,0 \end{cases}$$

1ª situação



Sol.:

$$h_{p_{1 \to 2}} = h_d + h_l$$

$$h_l = K \cdot \frac{v^2}{2g} = \left(K_e + K_{90^\circ} + K_{45^\circ} \cdot 3 + K_S\right) \cdot \frac{v^2}{2g}$$

$$h_l = (1,0 + 0,4 + 3 \cdot 0,2 + 1,0) \cdot \frac{4^2}{19,62} \rightarrow \boxed{h_l = 2,45 \ m}$$

$$h_d = f \cdot \frac{l}{d} \cdot \frac{v^2}{2g} = f \cdot \frac{(10+5+8+12+6+4)}{0,5} \cdot \frac{4^2}{2 \cdot 9,81}$$

$$h_d = f \cdot 90 \cdot 0,82 \longrightarrow \boxed{h_d = 73,8 \cdot f}$$

$$\left\{ \begin{array}{l} Re = \dfrac{v \cdot d}{\nu} = \dfrac{4 \cdot 0,5}{1,3 \cdot 10^{-6}} \rightarrow Re = 1,50 \cdot 10^{6} \\[2ex] \dfrac{D}{\varepsilon} = \dfrac{0,5}{5 \cdot 10^{-5}} \longrightarrow \dfrac{D}{\varepsilon} = 1 \cdot 10^{4} \end{array} \right.$$

Diagrama de Rouse - Moody: $f = 0,0122$

$$h = 73,8 \cdot 0,0122 \longrightarrow \boxed{h_d = 0,9000\ m}$$

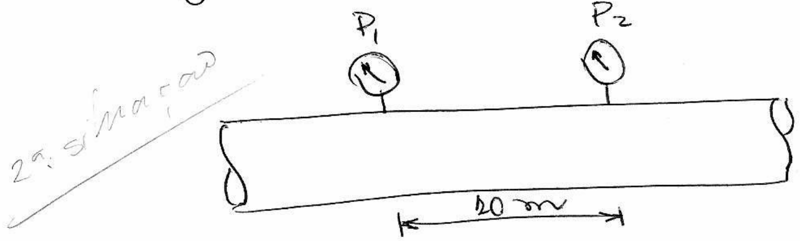
$$h_{p_{1 \to 2}} = 2,45 + 0,9000$$

$$\boxed{h_{p_{1 \to 2}} = 3,35\ m}$$

$$Q = A \cdot v = \frac{\pi \cdot 0,5^2}{\cancel{4}} \cdot \cancel{4} \longrightarrow \boxed{Q = 0,785\ m^3/s}$$

8) Calcular a vazão de água num conduto de ferro fundido, sendo dados $D = 10\ cm$, $\nu = 0{,}7 \cdot 10^{-6}\ \frac{m^2}{s}$ e sabendo-se que dois manômetros instalados a uma distância de 10 m indicam, respectivam., 1,5 kgf/cm² e 1,45 kgf/cm². Dados: $\gamma_{H_2O} = 10^3\ Kgf/m^3$

$\varepsilon = 2{,}59 \cdot 10^{-4}\ m$



$\left\{ \begin{array}{l} l \\ d \\ \nu \\ \varepsilon \\ h_p \end{array} \right. \longrightarrow$ 2º caso $\downarrow$ $Q = ?$

Sol.: Bernoulli entre 1 e 2:

$$\frac{P_1}{\gamma} + \cancel{z_1} + \cancel{\frac{v_1^2}{2g}} = \frac{P_2}{\gamma} + \cancel{z_2} + \cancel{\frac{v_2^2}{2g}} + h_{p_{1\to 2}}$$

$\left\{ \begin{array}{l} z_1 = z_2 = NR \\ v_1 = v_2 \end{array} \right.$

0,05 $\frac{\cancel{Kgf}/\cancel{cm^2}}{\cancel{Kgf}/\cancel{cm^3}}$ cm $\cdot \frac{}{100\ cm}$

$$h_{p_{1\to 2}} = \frac{P_1 - P_2}{\gamma} = \frac{(1{,}5 - 1{,}45)\ \cancel{Kgf/cm^2} \cdot \frac{10^4\ \cancel{cm^2}}{1\ m^2}}{\cancel{10^3}\ \frac{\cancel{Kgf}}{m^3}}$$

0,05 kgf . 10 = 0,5 kgf.

$h_{p_{1\to 2}} = 0{,}5\ m$

$\frac{\cancel{Kgf}}{\cancel{cm^2}} \cdot \frac{\cancel{cm^3}}{\cancel{Kgf}} \cdot \frac{1\ m}{100\ \cancel{cm}}$

$$Q = A \cdot v = \frac{\pi \cdot d^2}{4} \cdot v \ ?$$

$$h_{p_{1\to 2}} = hd = f \cdot \frac{l}{d} \cdot \frac{v^2}{2g} \longrightarrow v = \sqrt{\frac{hd \cdot d \cdot 2g}{f \cdot l}}$$

$$Re \cdot \sqrt{f} = \sqrt{\frac{hd \cdot d \cdot 2g}{l \cdot \cancel{v^2}}} \cdot \frac{\cancel{v} \cdot d}{\nu}$$

$\frac{\cancel{Kgf}/cm^2}{\cancel{Kgf}/m^3} \cdot \frac{}{10^4\ cm^2}$

$$Re\sqrt{f} = \sqrt{\frac{0{,}5 \cdot 0{,}1 \cdot 19{,}62}{10}} \cdot \frac{0{,}1}{0{,}7 \cdot 10^{-6}}$$

$Re \cdot \sqrt{f} = 4,5 \cdot 10^4$

$\frac{D}{\varepsilon} = \frac{0,1}{2,59 \cdot 10^{-4}} \rightarrow \frac{D}{\varepsilon} = 386 \cong 400$

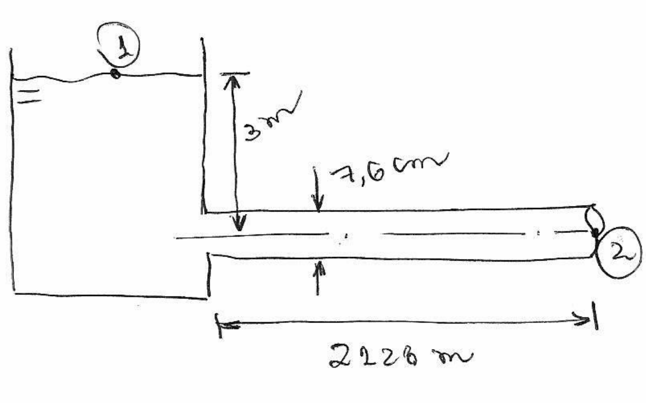
Diagrama Rouse - Moody: $f \cong 0,027$

$v = \sqrt{\frac{0,5 \cdot 0,1 \cdot 19,62}{0,027 \cdot 10}} \rightarrow v = 1,91 \, m/s$

$Q = A \cdot v = \frac{\pi \cdot 0,1^2}{4} \cdot 1,91 \rightarrow \boxed{Q = 15 \cdot 10^{-3} \, m^3/s}$

9) Um grande reservatório de óleo tem um tubo de 7,6 cm e 2228 m de comprimento a ele conectado como mostrado na figura a seguir. A superfície livre do reservatório está a 3 m acima da linha do centro do tubo e pode ser considerada fixa nesta elevação. Admitindo escoamento laminar, calcule a velocidade média de escoamento e posteriormente verifique o nº. de reynolds.

Dado: $\nu_{óleo} = 9,2 \cdot 10^{-6} \, m^2/s$



(G.)

Sol: Bernoulli entre 1 e 2:

$$\cancel{\frac{P_1}{\gamma}} + z_1 + \cancel{\frac{v_1^2}{2g}} = \cancel{\frac{P_2}{\gamma}} + \cancel{z_2} + \frac{v_2^2}{2g} + hp_{1\to 2}$$

$\begin{cases} z_2 = 0 \ (NR) \\ v_1 >>> v_2 \to v_1 \cong 0 \end{cases}$ $\quad P_1 = P_2 = P_{atm}$

$$z_1 = \frac{v_2^2}{2g} + hd$$

?

$$hd = f \cdot \frac{l}{d} \cdot \frac{v_2^2}{2g}$$

Admitindo fluxo laminar: $f = \frac{64}{Re}$

$$hd = \frac{64 \cdot \nu}{v_2 \cdot d} \cdot \frac{l}{d} \cdot \frac{v_2^2}{2g} = \frac{64 \cdot 9{,}2 \cdot 10^{-6}}{\cancel{v_2} \cdot 0{,}076} \cdot \frac{2128}{0{,}076} \cdot \frac{v_2^{\cancel{2}}}{2 \cdot 9{,}81}$$

$$hd = 11{,}06\, v_2$$

$$13 = \frac{v_2^2}{2 \cdot 9{,}81} + 11{,}06\, v_2$$

$$0{,}05\, v_2^2 + 11{,}06\, v_2 - 13 = 0$$

$$v_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-11{,}06 \pm \sqrt{11{,}06^2 - 4 \cdot 0{,}05(-13)}}{2 \cdot 0{,}05}$$

$$v_2 = \frac{-11{,}06 \pm 11{,}09}{0{,}1}$$

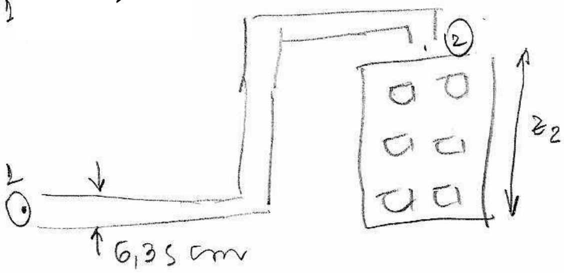
$\boxed{v_2 = 0{,}3 \text{ m/s}}$

$v_2 = \cancel{-222{,}1} \text{ m/s}$

$$Re = \frac{v \cdot d}{\nu} = \frac{0{,}3 \cdot 0{,}076}{9{,}2 \cdot 10^{-6}} \to \boxed{Re = 2478}$$

Pode ser considerado laminar! (7.)

10)



$\nu = 1{,}32 \cdot 10^{-6}\ m^2/s$

$l = 152\ m$

$Q = 9{,}46\ L/s$

$z_2 = 26\ m$

$P_1 = 7\ kgf/cm^2 = 664634{,}1\ Pa$

tubo liso

Sol: Bernoulli entre (1) e (2):

$$\frac{P_1}{\gamma} + \cancel{z_1} + \cancel{\frac{v_1^2}{2g}} = \frac{P_2}{\gamma} + z_2 + \cancel{\frac{v_2^2}{2g}} + h_{p_{1\to 2}}$$

$z_1 = 0$ (NR) $\qquad A_1 \cdot v_1 = A_2 \cdot v_2 \to A_1 = A_2 \Rightarrow v_1 = v_2$

$h_{p_{1\to2}} = h_d \to$ pois $h_l = 0$ (desprezível) $\quad 0{,}5$

$$\frac{9{,}81\ N}{1{,}0332\ \cancel{kgf}} \cdot \frac{7\ \cancel{kgf}/cm^2}{9810} = \frac{P_2}{9810} + 26 + f \cdot \frac{l}{d} \cdot \frac{v^2}{2g}$$

$$h_d = f \cdot \frac{l}{d} \cdot \frac{v^2}{2g} = f \cdot \frac{152}{0{,}0635} \cdot$$

$$Q = A \cdot v \Rightarrow v = \frac{9{,}46\ \cancel{dm^3}/s \cdot 4}{\pi \cdot (0{,}0635)^2} \cdot \frac{1\ m^3}{10^3\ \cancel{dm^3}} \to v = 2{,}99\ m/s \quad 0{,}5$$

$$Re = \frac{v \cdot d}{\nu} = \frac{2{,}99 \cdot 0{,}0635}{1{,}32 \cdot 10^{-6}} \Rightarrow Re = 1{,}4 \cdot 10^5 \text{ (turbulento)} \quad 0{,}5$$

$$f = \frac{0{,}316}{Re^{0{,}25}} = \frac{0{,}316}{(1{,}4 \cdot 10^5)^{0{,}25}} \to f = 0{,}016 \quad 0{,}5$$

$$h_d = 0{,}016 \cdot \frac{152}{0{,}0635} \cdot \frac{2{,}99^2}{2 \cdot 9{,}81} \to h_d = 17{,}45\ m \quad 0{,}5$$

$$\frac{10^4\ \cancel{cm^2}}{1\ m^2} \cdot 0{,}0067 75\ N/\cancel{cm^2} = \frac{P_2}{9810} + 26 + 17{,}45$$

$$\boxed{P_2 = 238383{,}0\ Pa} \quad 0{,}5$$

11) $P_{8_{man}} = ?$ $\quad \varepsilon = 0{,}15 \cdot 10^{-3}\, m$

$Q = 40\ L/s$

$d_S = 15\ cm$

$d_R = 10\ cm$

$\nu = 10^{-6}\ m^2/s$

$\gamma = 10^3\ kgf/m^3$

$$\begin{cases} K_1 = 15 \\ K_2 = K_4 = K_7 = 0{,}9 \\ K_3 = K_6 = 10 \\ K_5 = 0{,}5 \\ K_8 = 1{,}0 \end{cases}$$

sol: $$\cancel{\frac{P_0}{\gamma}} + \cancel{\frac{v_0^2}{2g}} + \cancel{z_0} = \frac{P_8}{\gamma} + \cancel{\frac{v_8^2}{2g}} + z_8 + h_{p_{0\to 8}}$$

$$\begin{cases} P_1 = P_{atm} = 0 \ (P_{8_{man}}) \\ v_0 = v_8 \simeq 0 \\ z_0 = 0 \ (NR) \end{cases}$$

0,5 $\quad h_{p_{0\to 8}} = h_d + h_l$

$$\boxed{P_8 = -(z_8 + h_{p_{0\to 8}})\gamma}$$

Como os diâmetros são diferentes divide-se em 2 partes:

$d_S = 0{,}15\ m$

- D_S: $$h_p = \left(f \cdot \frac{l}{d_S} + \Sigma K\right)\frac{v_S^2}{2g}$$

$$Q = A \cdot v_S \rightarrow v_S = \frac{40 \cdot 10^{-3} \cdot 4}{\pi \cdot 0{,}15^2} \rightarrow v_S = 2{,}26\ m/s$$ 0,25

$$\Sigma K = 0{,}5 + 10 + 0{,}9 + 1{,}0 = 12{,}4$$

$$f = ? \longrightarrow Re = \frac{v \cdot d_S}{\nu} = \frac{2{,}26 \cdot 0{,}15}{10^{-6}} \rightarrow Re = 3{,}4 \cdot 10^5$$

$$\frac{d_S}{\varepsilon} = \frac{\cancel{0{,}15}}{\cancel{0{,}15} \cdot 10^{-3}} \rightarrow \frac{d_S}{K} = 1000$$

Diagrama $f \simeq 0{,}021$

0,5

$$h_{p_{d_S}} = \left(0{,}021 \cdot \frac{36}{0{,}15} + 12{,}4\right)\frac{2{,}26^2}{19{,}62} \rightarrow h_{p_{d_S}} = 4{,}54\ m$$

0,3

• D_R: $h_p = \left(f \cdot \frac{l}{d_R} + \Sigma K\right) \frac{v_R^2}{2g}$

$Q = A \cdot v_R \rightarrow v_R = \frac{40 \cdot 10^{-3} \cdot 4}{\pi \cdot 0{,}10^2} \rightarrow v_R = 5{,}1 \text{ m/s}$ 0,25

$\Sigma K = 15 + 0{,}9 + 10 + 0{,}9 = 26{,}8$

$f = ?$ $\begin{cases} Re = \frac{v \cdot d_R}{\nu} = \frac{5{,}1 \cdot 0{,}10}{10^{-6}} \rightarrow Re = 5{,}1 \cdot 10^5 \\ \frac{d_R}{\varepsilon} = \frac{0{,}10}{0{,}15 \cdot 10^{-3}} \longrightarrow \frac{d_R}{K} = 666{,}66 \cong 700 \end{cases}$ diagrama $f = 0{,}0225$ 0,5

$h_{p\,d_R} = \left(0{,}0225 \cdot \frac{10{,}5}{0{,}1} + 26{,}8\right) \cdot \frac{5{,}1^2}{19{,}62} \rightarrow h_{p\,d_R} = 38{,}66 \text{ m}$ 0,25

$h_{p\,0 \to 8} = 4{,}54 + 38{,}66 \rightarrow h_{p\,0 \to 8} = 43{,}2 \text{ m}$ 0,25

$P_8 = -(6{,}5 + 43{,}2) \cdot 10^3 \text{ kgf/m}^2$

$\boxed{P_8 = -4{,}9 \cdot 10^4 \text{ kgf/m}^2}$ 0,5