20. GAIA: Eremgimen aldakorra hodietan

? desberdina Erraitz

20.1)

$\phi_{barne} = 250mm$

$\varphi = 0'1 m^3/s$

$e = 10mm$

$E_H = 2'2 \cdot 10^6 kg/cm^2 \frac{10000cm^2}{m^2} = 2'2 \cdot 10^{10} kg/m^2$

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

$E_F (15^\circ C) = 22000 kg/cm^2 \frac{10000cm^2}{m^2} = 22000 \cdot 10^4 kg/m^2$

$g = 9'8 m/s^2$

$\varphi = v \cdot A \Rightarrow v = \frac{\varphi}{A} = \frac{0'1}{\frac{\pi 0'25^2}{4}} = 2'037 m/s$

Hodia zurruna bada:

$$c = \sqrt{\frac{E_f}{\rho}} = \sqrt{\frac{22000 \cdot 10^4 \cdot 98}{1000}} = 1468'33 m/s$$

- Ixte aldarra:

$$p = \rho c v = 1000 \cdot 1468'33 \cdot 2'037 = 2'991 \cdot 10^6 Pa$$

Hodia elastikoa bada:

$$c = \sqrt{\frac{E_F}{\rho\left(1 + \frac{E_F}{E_T}\frac{D}{e}\right)}} = \sqrt{\frac{22000 \cdot 10^4 \cdot 98}{1000\left(1 + \frac{22000 \cdot 10^4 \cdot 0'25}{2'2 \cdot 10^{10} \cdot 0'01}\right)}} = 1313'31 m/s$$

- Ixte aldarra:

$$p = \rho c v = 1000 \cdot 1313'31 \cdot 2'037 = 2'675 \cdot 10^6 Pa$$

$$\Delta p = p_2 - p_e = 2'99 \cdot 10^6 - 2'675 \cdot 10^6 = 3'1577 \cdot 10^5 Pa$$

$$\boxed{\Delta p = 3'22 kg/cm^2}$$

20.2)

$L = 15m$

$\Delta p = 20 atm = 2026500 Pa$

$\varphi = 30 l/min \frac{1 m^3}{1000 dm^3} \frac{1 min}{60 s} = 0'0005 m^3/s$

$\phi_{barne} = 8mm$

$e = 1mm$

$E_T = 2'2 \cdot 10^6 kg/cm^2 \frac{10000cm^2}{1m^3} = 2'2 \cdot 10^{10} kg/m^2$

$E_F = 13300 kg/cm^2 \frac{10000cm^2}{1m^3} = 1'33 \cdot 10^8 kg/m^2$

t_{min} ? $\Delta p < 20 atm$

$\rho = 860 kg/m^3$

$$v = \frac{\varphi}{A} = \frac{0'0005}{\frac{\pi 0'008^2}{4}} = 9'947 m/s$$

$$\begin{cases} \Delta p = \rho c v \\ 2026500 = 1000 \cdot c \cdot 9'947 \\ c = 203'78 m/s \\ t = \frac{2L}{c} = \frac{2 \cdot 15}{203'78} = 0'147 s \end{cases}$$

$V = 9'947 \, m/s$

Modulo elasticidad:

$$C = \sqrt{\frac{E_F}{\rho\left(1 + \frac{E_F}{E_T}\frac{D}{e}\right)}} = \sqrt{\frac{13300 \cdot 10^4 \cdot 9'8}{860\left(1 + \frac{13300 \cdot 10^4}{2'2 \cdot 10^{10}}\frac{0'008}{0'001}\right)}} = 1202'35 \, m/s$$

$$\Delta p = \rho C \Delta V = 860 \cdot 1202'35 \cdot 9'947 = 10285472'03 \, Pa > 2026500 \, Pa$$

↓ Existe cavitación, existe rotura tubería:

$$\Delta p = \rho g \Delta h \Rightarrow 2026500 = 860 \cdot 9'8 \, \Delta h$$

$$\Delta h = 240'448 \, m.c.a$$

$$\Delta h = k \frac{L V}{g t_{cierre}} \Rightarrow 240'448 = 2 \frac{15 \cdot 9'947}{9'8 \cdot t_{cierre}}$$

$$\boxed{t_{cierre} = 0'126 \, s}$$

20.3)

$L = 15 m$

$\phi = 20 \, mm$

$Q = Q_0 (1 + \text{sen}\, \omega t)$

$Q_0 = 3 \, l/s$

$\omega = 0'5 \, rad/s$

Δp?

$E_F = 22000 \cdot 10^4 \, kg/m^2$

Una vez hecho, sumamos de la superficie:

$$C = \sqrt{\frac{E_F}{\rho}} = \sqrt{\frac{22000 \cdot 10^4 \cdot 9'8}{1000}} = 1468'33 \, m/s$$

$$t = \frac{2L}{C} = \frac{2 \cdot 15}{1468'33} = 0'02 \, s$$

$$Q = Q_0 (1 + \text{sen}\, \omega t) = 3 (1 + \text{sen}(5 \cdot 0'02))$$

$$Q = 3 \, l/s = 3 \cdot 10^{-3} \, m^3/s$$

$$V = \frac{Q}{A} = \frac{3 \cdot 10^{-3}}{\pi \frac{0'02^2}{4}} = 9'55 \, m/s$$

$$\Delta p = \rho C \Delta V = 1000 \cdot 1468'33 \cdot 9'55 = 14'02 \cdot 10^6 \, Pa$$

$$\Delta p = 1382'58 \, atm$$

20.4)

$n = 0'05$

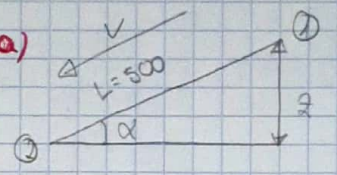
$\emptyset = 200\,mm$

$L = 500\,m$

$\rho = 860\,kg/m^3$

$f = 0'02$

a)



malda: $\frac{5}{100}$ $\quad tg\,\alpha = \frac{5}{100}$

$\alpha = 2'86°$

$\sin\alpha = \frac{z}{500} \Rightarrow \boxed{z = 24'968\,m}$

b) $H_1 = H_2 + h_{e_{1\to2}} \Rightarrow z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} = z_2 + \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + \frac{8 f L Q^2}{g\pi D^5}$

$$24'968 = \frac{v_2^2}{2\cdot 9'8} + \frac{8\cdot 0'02\cdot 500\cdot \left(v_2\cdot \frac{\pi 0'2^2}{4}\right)^2}{9'8\cdot\pi^2 0'2^5}$$

$$\boxed{v_2 = 3'097\,m/s}$$

c) $t_{ixte} = 30\,s$ ixte motela dela suposatuta:

$$\Delta h = k\frac{L v}{g\, t_{ixte}} = (2)\frac{500\cdot 3'097}{9'8\cdot 30} = 10'53\,m\,H_2O$$

$\Delta p = \rho g h = 860\cdot 9'8\cdot 10'53 = 88720'6\,Pa$

$\boxed{\Delta p = 0'8762\,atm}$

? Emaitza desberdina

20.5) Fibro-zementuzko hodia $\Rightarrow k = 5/6$

$Q = 4500\,l/min \quad \frac{1m^3}{1000dm^3}\,\frac{1min}{60s} = 0'075\,m^3/s$

$\emptyset = 250mm$ Denbora finkatua:

$z = 30m$ $\quad t = c + k\frac{L v}{g H_m}$

$f = 0'016$

$L = 500m$ Tanteatu: $\frac{z}{L} = \frac{30}{500} = 0'06 \Rightarrow 1.6 \Rightarrow c = 1$

$e = 15mm$ $\quad \Rightarrow k = 1'75$

$H_1 + H_m = H_2 + h_{f_{1\to2}}$

$$z_1 + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + H_m = z_2 + \frac{v_2^2}{2g} + \frac{8 f L Q^2}{g\pi^2 D^5}$$

$$H_m = 30 + \frac{8\cdot 0'016\cdot 500\cdot 0'075^2}{9'8\cdot\pi^2 0'25^5}$$

$H_m = 33'81\,m\,H_2O$

$$t = c + k\frac{L v}{g H_m} = 1 + 1'75\,\frac{500\cdot \frac{0'075}{\pi 0'25^2/4}}{9'8\cdot 33'81} = 5'0348\,s$$

$$c = \frac{9900}{\sqrt{48'3 + \frac{5}{6}\frac{0'25}{0'015}}} = 1255'39\,m/s$$

$\frac{2L}{c} = \frac{2\cdot 500}{1255'39} = 0'79\,s \Rightarrow 5'03 >> 0'79\,s \Rightarrow$ Ixte motela

$$\Delta h = k\frac{L v}{g\, t_{ixte}} = 2\,\frac{500\cdot\left(0'075/\frac{\pi 0'25^2}{4}\right)}{9'8\cdot 5'03} = \boxed{30'99\,m\,H_2O = \Delta h}$$

20.6) Fibro-zemetz egunkoa → $k = \frac{5}{6}$

$\phi = 2500$ l/min

$\varnothing = 250$ mm

$l = 120$ m

$f = 0'016$

$L = 150$ m

$e = 0'015$ m

$L_m = L - \frac{ct}{2}$

$t = c + k \frac{LV}{g\,Hm}$ $\begin{cases} c = 0 \\ k = 1'85 \end{cases}$ $120/150 = 0'8$

$\phi = 2500$ l/min $\frac{1m^3}{1000dm^3} \frac{1min}{60s} = 0'0416$ m³/s

$H_1 + Hm = H_2 + h_{e\,1-D2}$

$\frac{p_1}{\delta} + \frac{V_1^2}{2g} + z_1 + Hm = \frac{p_2}{\delta} + \frac{V_2^2}{2g} + z_2 + \frac{8 f L Q^2}{g \pi^2 D^5}$

$Hm = 120 + \frac{8 \cdot 0'016 \cdot 150 \cdot 0'0416^2}{9 \cdot \pi^2 \cdot 0'25^5} = 120'35$ mH₂

$t = c + k \frac{LV}{g\,Hm} = 0 + 1'85 \frac{150 \cdot \left(0'0416 / \frac{\pi 0'25^2}{4}\right)}{9'8 \cdot 120'35} = 0'199$ s

$\frac{2L}{c} = \frac{2 \cdot 150}{1255'14} = 0'239$ s $\Rightarrow 0'199$ s $< 0'239$ s Ixte ozbarra

$c = \frac{9900}{\sqrt{48'3 + k \frac{D}{e}}} = \frac{9900}{\sqrt{48'3 + \frac{5}{6} \frac{0'25}{0'015}}} = 1255'39$ m/s

$L_m = L - \frac{ct}{2} = 150 - \frac{1255'39 \cdot 0'199}{2} = 25'088$ m

20.7) Hormigoi armatu → $k = 5$

$L = 15'4$ m

$\varnothing = 1'5$ m

$e = 50$ cm

$\phi = 287$ m³/s

$t = 20$ s

a) $c = \frac{9900}{\sqrt{48'3 + k \frac{D}{e}}} = \frac{9900}{\sqrt{48'3 + 5 \frac{1'5}{0'5}}} = 891'566$ m/s

$\frac{2L}{c} = \frac{2 \cdot 15'4}{891'566} = 33'64$ s $\Rightarrow 20$ s $< 33'64$

Ixte ozbarra:

$\Delta h = -\frac{c \Delta V}{g} = \frac{891'566 \left(287 / \frac{\pi 1'5^2}{4}\right)}{9'8} = 5911'01$ mH₂ $= \Delta h$

b) $\Delta p = \delta c \Delta V = 1000 \cdot 891'566 \frac{287}{\frac{\pi 1'5^2}{4}} = 57919251'764$ Pa

$\Delta p = 59'06$ kg/cm²

20.8)

$\phi = 50mm$

$e = 8mm$

$p = 10 bar$

Φ ? [m^3/h]

$k = 0'5$

$$C = \frac{9900}{\sqrt{48'3 + k\frac{D}{e}}} = \frac{9900}{\sqrt{48'3 + 0'5\,\frac{0'05}{0'008}}} = 1380'537 m/s$$

$$\Delta p = \rho C \Delta v = \rho C \frac{\Phi}{A}$$

$$10 \cdot 10^5 = 1000 \cdot 1380'537 \cdot \frac{\Phi}{\frac{\pi\, 0'05^2}{4}}$$

$$\Phi = 1'422 \cdot 10^{-3} m^3/s$$

$$\Phi = 1'422 \cdot 10^{-3} m^3/s \; \frac{3600 s}{1h} = \boxed{5'12 m^3/h = \Phi}$$

20.9)

$v = 2 m/s$

$L = 3000m$

$t = 5s$

$c = 1000 m/s$

$$\frac{2L}{c} = \frac{2 \cdot 3000}{1000} = 6s \rightarrow 5s < 6s \rightarrow \text{Ixte actiona}$$

a) $\Delta p = \rho C \Delta v = 1000 \cdot 1000 \cdot 2 = \boxed{2 \cdot 10^6 Pa = \Delta p}$

b) $L_m = L - \frac{ct}{2} = 3000 - \frac{1000 \cdot 5}{2} = \boxed{500 m = L_n}$

20.10)

$$e = \left(\frac{p D}{2\sigma} + m\right) c$$

$\sigma = 12000 N/cm^2$

$\phi' = 800 mm$

$m = 2mm$

$c = 1'2$

$\Phi = 840 l/s$

$L = 700m$

$z = 80m$

$E_H = 1'5 \cdot 10^7 N/cm^2$

$e > 5mm$

$E_F = 22000 kg/cm^2$

Ixte actiona

$$\begin{cases} e = \left(\frac{p D}{2\sigma} + m\right) c \\ \Delta p = \rho C v \end{cases} \rightarrow C = \sqrt{\frac{E_F}{\rho\left(1 + \frac{E_F}{E_H}\frac{D}{e}\right)}}$$

$$\Phi = 840 l/s \; \frac{1 m^3}{1000 dm^3} = 0'84 m^3/s$$

$$v = \frac{\Phi}{A} = \frac{\Phi}{\frac{\pi D^2}{4}} = \frac{0'84}{\frac{\pi\, 0'8^2}{4}} = 1'6711 m/s$$

$$e = \left(\frac{\rho \sqrt{\frac{E_F}{\rho\left(1 + \frac{E_F}{E_H}\frac{D}{e}\right)}}\; v\, D}{2\sigma} + m\right) c$$

$$e = \left(\frac{1000 \sqrt{\frac{22000 \cdot 9'8 \cdot 10^4}{1000\left(1 + \frac{22000 \cdot 9'8 \cdot 10^4}{1'5 \cdot 10^7 \cdot 10000} \cdot \frac{0'8}{e}\right)}}\; 1'6711 \cdot 0'8}{2 \cdot 12000 \cdot 10^4} + 0'002\right) 1'2$$

$e = 8'8787 \cdot 10^{-3} m$

$\boxed{e \geq 9mm}$

20. 11)

$z = 750m$

$\varnothing = 1'2\,m$

$\varphi = 3m^3/s$

$L = 1800m$

$\sigma = 20000\,N/cm^2$

$E_H = 2'5 \cdot 10^7\,N/cm^2$

$m = 3mm$

$c = 1'15$

$E_F = 22000\,kg/cm^2$

Emalte dosbordura

a) $e = \left(\frac{p \cdot D}{2\sigma} + m\right) c$ $\quad t_{ixte} = 6s$ $\quad V = \frac{\varphi}{A} = \frac{3}{\frac{\pi 1'2^2}{4}} = 2'65$

Ixte arbana:

$$e = \left(\frac{\sqrt{\frac{E_F}{8\left(1 + \frac{E_F}{E_A}\frac{D}{e}\right)}}\, VD}{2\sigma} + m \right) c$$

$$e = \left(\frac{1000\sqrt{\frac{22000 \cdot 10^4 \cdot 9'8}{1000\left(1 + \frac{22000 \cdot 10^4 \cdot 9'8}{2'5 \cdot 10^7 \cdot 10000}\frac{1'2}{e}\right)}} \cdot \frac{3}{\frac{\pi 1'2^2}{4}} \cdot 1'2}{2 \cdot 20000 \cdot 10^4} + 0'003 \right) 1'15$$

$\boxed{e = 46'6\,mm}$

$$C = \sqrt{\frac{22000 \cdot 10^4 \cdot 9'8}{1000\left(1 + \frac{22000 \cdot 10^4 \cdot 9'8}{2'5 \cdot 10^7 \cdot 10000}\cdot\frac{1'2}{0'0466}\right)}} = 1328'405$$

$\frac{2L}{C} = \frac{2 \cdot 1800}{1328'4} = 2'7s \rightarrow 6s > 2'7s$ ixte moteda (Berat e dallit)

Si posatu moteda dida

20.12)

$z = 30m$

$\varphi = 4500\ l/min$

$\varnothing = 250mm$

$f = 0'016$

$L = 500m$

$c = 1000\ m/s$

$$t = 1 + \frac{1'75 L v}{g\ hm}$$

$$H_1 + Hm = H_2 + h_{R1-2}$$

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 + Hm = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + \frac{8 f L \varphi^2}{g \pi D^5}$$

$$Hm = \frac{v_2^2}{2g} + \frac{8 f L \varphi^2}{g \pi D^5} + z$$

$$\varphi = 4500\ l/min \cdot \frac{1m^3}{1000 dm^3} \cdot \frac{1min}{60s} = 0'075\ m^3/s$$

$$v = \frac{\varphi}{A} = \frac{0'075}{\frac{\pi\ 0'25^2}{4}} = 1'52\ m/s$$

$$Hm = \frac{v_2^2}{2g} + \frac{8 f L \varphi^2}{g \pi^2 D^5} + z = \frac{1'52^2}{2 \cdot 9'8} + \frac{8 \cdot 0'016 \cdot 500 \cdot 0'075^2}{9'8 \cdot \pi^2 \cdot 0'25^5} + 30 = 33'81133\ mH$$

$$t_{exte} = 1 + \frac{1'75 \cdot L \cdot v}{g\ hm} = 1 + \frac{1'75 \cdot 500 \cdot 1'52}{9'8 \cdot 33'81133} = 5'013s$$

$$\frac{2L}{c} = \frac{2 \cdot 500}{1000} = 1s \Rightarrow t_{exte} > \frac{2L}{c} \Rightarrow \text{Ixte molela}$$

$$\Delta h = \frac{2 L v}{g\ t_{exte}} = \frac{2 \cdot 500 \cdot 1'52}{9'8 \cdot 5'013} = \boxed{83'94m\ Va = \Delta h}$$

20.13)

$\varnothing = 0'35m$

$L = 1500m$

$\varphi = 250\ l/s$

$\Delta h = 40m\ v2$

$c = 1000 m/s$

$$\varphi = 250\ l/s \cdot \frac{1m^3}{1000 dm^3} = 0'25 m^3/s$$

$$v = \frac{\varphi}{A} = \frac{\varphi}{\frac{D^2 \pi}{4}} = \frac{0'25}{\frac{\pi\ 0'35^2}{4}} = 2'598\ m/s$$

$$\Delta h = \frac{2 L v}{g\ t_{exte}} \Rightarrow 40 = \frac{2 \cdot 1500 \cdot 2'598}{9'8\ t_{exte}}$$

$$\boxed{t_{exte} = 19'89s}$$

20.14)

$L = 2500m$

$A = 0'2 m^2$

$\varphi = 400 l/s$

$t_{exte} = 2s$

$c = 1000 m/s$

$$\frac{2L}{c} = \frac{2 \cdot 2500}{1000} = 5s$$

$t_{exte} < \frac{2L}{c} \Rightarrow$ Ixte actuara

$$\Delta p = \rho\ c\ \Delta v = 1000 \cdot 1000 \cdot \frac{0'4}{0'2} = \boxed{2 \cdot 10^6\ Pa = \Delta p}$$

$$v = \frac{\varphi}{A}$$

a) Potentzia mekanikoa?

$\eta = 1'75$

$\varphi = 50 l/s \frac{1m^3}{1000 dm^3} = 0'05 m^3/s$

$$Hm + H_1 = H_2 + h_{R_{1\to 2}} + h_{k_{1\to 2}}$$

f?

① $v = \frac{\varphi}{A} = \frac{0'05}{\frac{\pi 0'2^2}{4}} = 1'59 m/s$

$Re = \frac{vD}{\nu} = \frac{1'59 \cdot 0'2}{1'142 \cdot 10^{-6}} = 2'78 \cdot 10^5$

$\frac{\varepsilon}{D} = \frac{0'07}{200} = 0'00035$

$f_1 = 0'018$

② $v = \frac{\varphi}{A} = \frac{0'05}{\frac{\pi 0'1^2}{4}} = 6'366 m/s$

$Re = \frac{vD}{\nu} = \frac{6'366 \cdot 0'1}{1'142 \cdot 10^{-6}} = 1'115 \cdot 10^6$

$\frac{\varepsilon}{D} = \frac{0'07}{100} = 0'0007$

$f_2 = 0'018$

$$Hm + \cancel{\frac{p_1}{\gamma}}^{0} + \cancel{z_1}^{0} + \cancel{\frac{v_1^2}{2g}}^{0} = \cancel{\frac{p_2}{\gamma}}^{0} + z_2 + \cancel{\frac{v_2^2}{2g}}^{0} + \frac{8 f_1 L \varphi^2}{g \pi^2 D^5} + \frac{8 f_2 L \varphi^2}{g \pi^2 D^5} + 0'5 \frac{V_{e_1}^2}{2g} + \frac{V_{e_2}^2}{2g}$$

$$Hm = 54 + \frac{8 \cdot 0'016 \cdot 100 \cdot 0'05^2}{9'8 \cdot \pi^2 \cdot 0'2^2} + \frac{8 \cdot 0'018 \cdot 1000 \cdot 0'05^2}{9'8 \cdot \pi^2 \cdot 0'1^2} + 0'5 \frac{1'59^2}{2 \cdot 9'8} + \frac{6'366^2}{2 \cdot 9'8}$$

$Hm = 429'366 mUz$

$P_{at} = f g Hm \cdot \varphi = 999'12 \cdot 9'8 \cdot 429'366 \cdot 0'05 = 0'1 \cdot 10^5 W$

$\eta = \frac{P_{ark}}{P_{elek}} \Rightarrow P_{elek} = \frac{2'1 \cdot 10^5}{0'75} = 2'2 \cdot 10^5 W$

$Pot_{elek} = 2'8 \cdot 10^5 W \frac{1 CP}{735 W} = 381'32 CP = P_{elek}$

b) Habitatzea gorta ez dadin lehen daitekeen emaria habitatzea ez ateratzeko segurtasunetikoa = 0

Habitatzea ez emateko ⇒ TAULA 3 $P_{ab.}(15°C) = 0'0176 kg/m^2$

Habitatzea barnetan:

$$\frac{p_2 - p_3}{\gamma} + \frac{V_2^2}{2g} = \frac{p_1 - p_3}{\gamma} - z_2 - h_{R_{1\to 2}}$$

f? Gurtiz turbulentoa $\varepsilon/D = 0'07/200 = 0'00035 \to f = 0'015$

$NPSH_{segurtasunetikoa} + NPSH_{eskaturikoa} = NPSH_{erabil}$

$$\frac{-0'0176 \cdot 9'8 \cdot 10^4}{9'8 \cdot 999'12} + \frac{\left(\frac{4\varphi}{\pi 0'2^2}\right)^2}{2 \cdot 9'8} = \frac{101325}{999'12 \cdot 9'8} - 4 - \left(0'5 \frac{\left(\frac{4\varphi}{\pi 0'2^2}\right)^2}{2 \cdot 9'8} + \frac{8 \cdot 0'015 \cdot 100 \cdot \varphi^2}{9'8 \cdot \pi^2 \cdot 0'2^5}\right)$$

$\varphi = 0'1842 m^3/s$

$\varphi = 118'42 l/s$

22.7)

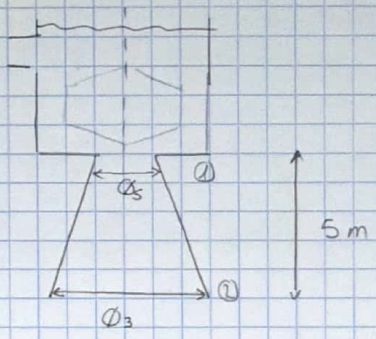
a) Tronco konikoa

$L = 5m$

$\phi_s = 0'7m$

$\phi_3 = 1'4m$

$\varphi = 1'5 m^3/s$



$$v_1 = \frac{\varphi}{A_1} = \frac{1'5}{\frac{\pi \cdot 0'7^2}{4}} = 3'9 \text{ m/s}$$

$$v_2 = \frac{\varphi}{A_2} = \frac{1'5}{\frac{\pi \cdot 1'4^2}{4}} = 0'9744 \text{ m/s}$$

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$\frac{p_1}{\gamma} + 5 + \frac{0'8976^2}{2 \cdot 9'8} = \frac{0'9744^2}{2 \cdot 9'8}$$

$$\frac{p_1}{\gamma} = -5'72 \text{ m Ur}$$

$$p_1 = -5'72 \cdot 1000 \cdot 9'8 = -56120'9 \text{ Pa}$$

$$p_1 = -0'572 \text{ kg/cm}^2 \rightarrow 1 - \text{atm} = 0'4...$$

b) $NPSH_{sag.} + NPSH_{sist.} = NPSH_{ponb.}$

Taulan begiratzen

22.8)

$\phi_e = 26cm$

$N_e = 1150 rpm$

$H_e = 12m$

$\varphi_e = 3000 \text{ l/min} = 0'05 m^3/s$

Ponpa

a) $N_p = 1750 rpm$, H, φ?

$\lambda = 1$

$$\frac{N_p}{N_m} = \left(\frac{H_p}{H_m}\right)^{1/2} \frac{1}{\lambda} \Rightarrow \frac{1750}{1150} = \left(\frac{H_p}{12}\right)^{1/2} \cdot 1$$

$$\boxed{H_p = 27'78m}$$

$$\frac{\varphi_p}{\varphi_e} = \left(\frac{H_p}{H_e}\right)^{1/2} \lambda^2 \Rightarrow \frac{\varphi_e}{3000} = \left(\frac{27'78}{12}\right)^{1/2} \cdot 1^2$$

$$\boxed{\varphi_e = 4565'2174 \text{ l/min}}$$

b) $\phi_p = 24cm$

$N_p = 1150 rpm$

$$\lambda = \frac{D_p}{D_m} = \frac{24}{26} = 0'923$$

$$\frac{N_p}{N_e} = \left(\frac{H_p}{H_e}\right)^{1/2} \frac{1}{\lambda} \Rightarrow 1 = \left(\frac{H_p}{12}\right)^{1/2} \frac{1}{0'923}$$

$$\boxed{H_p = 10'22m}$$

$$\frac{\varphi_p}{\varphi_e} = \left(\frac{H_p}{H_e}\right)^{1/2} \lambda^2 \Rightarrow \frac{\varphi_p}{3000} = \left(\frac{10'22}{12}\right)^{1/2} \left(\frac{24}{26}\right)^2$$

$$\boxed{\varphi_p = 2359'5 \text{ l/min}}$$

c) $N_s = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1150\sqrt{0'05}}{12^{3/4}} = \boxed{39'88\ rpm = N_s}$

22.9)

$\phi_1 = 25cm$

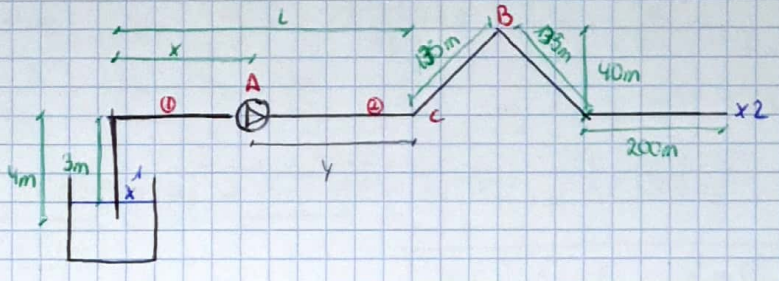
$f_1 = 0'03$

$\phi_2 = 15cm$

$h = 40m$

$f_2 = 0'02$

$h_{man} = 65m$



a) Ura $T = 21^\circ C$

u, L, x? Kabitatica agortzeko A eta B puntuen artean

Ura 21°C-tan egonda, baporitatzio faltsurea:

T[C]	p[kg/cm²]
20	0'0239
21	x
25	0'0327

$(20-25)(0'0239 - x) = (20-21)(0'0239 - 0'0327)$

$x = 0'02566$

$p_{AB} = 0'02566\ kg/cm^2 \Rightarrow p_2 = p_B = 0'2566\ m\ U_2$

$p_{atm} = 1'033\ kg/cm^2 \Rightarrow p_1 = p_A = 10'33\ m\ U_2$

- $H_B = H_2 + h_{R\ B\to 2}$

$$\frac{p_B}{\gamma} + z_B + \frac{V_B^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + f_2 \frac{L_{eq}}{D_2} \frac{V_2^2}{2g}$$

$$0'2566 + 40 = 10'33 + \frac{V_2^2}{2\cdot 9'8} + 0'02 \frac{(135+200)}{0'15} \frac{V_2^2}{2\cdot 9'8}$$

$\boxed{V_2 = 3'58\ m/s}$ Bigarren hodian

- $Q_1 = Q_2 \Rightarrow V_1 A_1 = V_2 A_2$

$$V_1 \frac{\pi D_1^2}{4} = V_2 \frac{\pi D_2^2}{4}$$

$$V_1 \frac{\pi 0'25^2}{4} = 3'58 \frac{\pi 0'15^2}{4}$$

$\boxed{V_1 = 1'29\ m/s}$ Lehenengo hodian

- $H_1 = H_A + h_{R\ 1\to A}$

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} = \frac{p_A}{\gamma} + z_A + \frac{V_A^2}{2g} + f_A \frac{L_{eq}}{D_1} \frac{V_A^2}{2g}$$

$$10'33 = 0'2566 + 3 + \frac{1'29^2}{2\cdot 9'8} + 0'03 \frac{(4+x)}{0'25} \frac{1'29^2}{2\cdot 9'8}$$

$\boxed{x = 681'93m}$

$H_1 + Hm = H_2 + h_{Q_{1\to 2}}$

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + Hm = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + f_1 \frac{L_{1A}}{D_1}\cdot\frac{v_1^2}{2g} + f_2 \frac{L_{A2}}{D_2}\frac{v_2^2}{2g}$$

$$65 = 3 + \frac{3'58^2}{2\cdot 9'8} + 0'03\ \frac{4+681'93}{0'25}\cdot\frac{1'29^2}{2\cdot 9'8} + 0'02\ \frac{4+(135+135+200)}{0'15}\cdot\frac{3'58^2}{2\cdot 9'8}$$

$y = 153'46m$

$L = x + y = 681'93 + 153'46 = \boxed{835'4m = L}$

$v_1 = 1'29 m/s$	$x = 681'93 m$
$v_2 = 3'58$	$L = 835'4 m$

b) $L = 200m$

$x = 150m$

AB kabitatio gabe

Ulerdello ihelarra

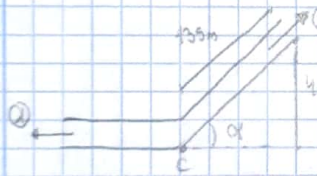
$H_1 + Hm = H_2 + H_{1\to 2}$

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + Hm = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + f_1 \frac{L_{1A}}{D_1}\frac{v_1^2}{2g} + f_2 \frac{L_{A2}}{D_2}\frac{v_2^2}{2g}$$

$$Hm = z_2 + \frac{\left(\frac{Q}{\frac{\pi D_2^2}{4}}\right)^2}{2g} + \frac{8 f_1 L_{1A} Q^2}{g\pi^2 D_1^5} + \frac{8 f_2 L_{A2} Q^2}{g\pi^2 D_2^5}$$

$$65 = 3 + \frac{\left(Q/\frac{\pi 0'35^2}{4}\right)^2}{2\cdot 9'8} + \frac{8\cdot 0'03\cdot(4+150)\,Q^2}{9'8\cdot\pi^2\cdot 0'25^5} - \frac{8\cdot 0'02\cdot 520\,Q^2}{9'8\cdot\pi^2\,0'15^5}$$

$Q = 0'07223 m^3/s$



$\sum \vec{F}_{ext} = \rho Q (\vec{v}_2 - \vec{v}_1)$

$\sin\alpha = \frac{40}{135} = 17'2353°$

$Q = v\cdot A \Rightarrow v = \frac{Q}{A} = \frac{0'07223}{\frac{\pi\,0'15^2}{4}} = 4'0874 m/s$

$F_x = -\rho Q v_{1x} + \rho Q v_{2x} = +1000\cdot 0'07223\,(-4'0874 + 4'0874\cos 17'23) = -13'75 N$

$F_y = \rho Q v_{2y} = 1000\cdot 0'07224\cdot 4'0874 \sin 17'23 = 87'45 N$

$F_x = -13'75 N$	
$F_y = 87'45 N$	

22. 10)

$\emptyset = 300mm$

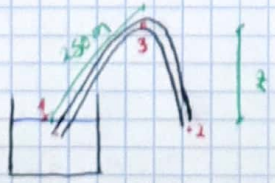
Burdin galba.

$L = 1500m$

$Q = 500 m^3/h \Rightarrow 0'138 m^3/s$

$T = 20°C$

$R = 250m$



$Q = v\cdot A \Rightarrow v = \frac{Q}{A} = \frac{Q}{\frac{\pi D^2}{4}} = \frac{4\cdot 0'138}{\pi\cdot 0'3^2} = 1'965 m/s$

$T = 20°C \Rightarrow \rho = 998'23 kg/m^3$

$\mu = 100'45\cdot 10^{-5} kg\,s/m^2$

Burdin galba $\Rightarrow \varepsilon = 0'07$

$$\begin{cases} Re = \frac{\rho v D}{\mu} = \frac{998'23\cdot 1'96\cdot 0'3}{100'45\cdot 10^{-5}} = 5'8578\cdot 10^5 \\ \frac{\varepsilon}{D} = \frac{0'07}{300} = 0'000233 \end{cases} \Rightarrow f = 0'016$$

$p_s(20^\circ C) = 0'0239\ kg/cm^2 \Rightarrow 0'239\ m\ c.a.$

$p_a = 1'033\ kg/cm^2 \Rightarrow 10'33\ m\ c.a.$

$H_1 = H_3 + h_{2\ 1\to3}$

$\frac{p_1}{\gamma} + \cancel{z_1}^{\,0} + \cancel{\frac{v_1^2}{2g}}^{\,0} = \frac{p_3}{\gamma} + z_3 + \frac{v_3^2}{2g} + f\frac{L}{D}\frac{v^2}{2g}$

$10'33 = 0'239 + z_3 + \frac{1'965^2}{2\cdot 9'8} + 0'016\ \frac{250}{0'3}\ \frac{1'965^2}{2\cdot 9'8}$

$\boxed{z_3 = 7'26\ m}$

b)

$H_1 = H_2 + h_{2\ 1\to2}$

$\cancel{\frac{p_1}{\gamma}} + \cancel{z_1}^{\,0} + \cancel{\frac{v_1^2}{2g}}^{\,0} = \cancel{\frac{p_2}{\gamma}} + z_2 + \frac{v_2^2}{2g} + f\frac{L_{12}}{D}\frac{v^2}{2g}$

$0 = z_2 + \frac{1'965^2}{2\cdot 9'8} + 0'016\ \frac{1500}{0'3}\ \frac{1'965^2}{2\cdot 9'8}$

$z_2 = -15'95\ m$

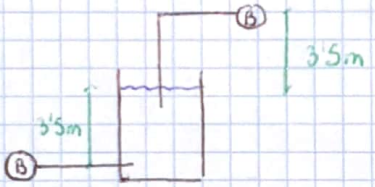
$\boxed{H = 15'95\ m}$

Et **22.11)**

$\emptyset = 60\ cm$

$h \uparrow 3'5\ m$

Habitatge:
- $Q = 0'5\ m^3/s$
- $h = 5\ m$
- $\omega = 1200\ rpm$
- $P = 45\ CV$
- $h \downarrow 3'5\ m$
- η bomba
- $T = 10^\circ C$



$T = 10^\circ C \Rightarrow \rho = 999'73\ kg/m^3$

$p_s = 0'012\ kg/cm^2$

22.12)

$r_1 = 6cm$

$r_2 = 12cm$

$b_2 = 2cm$

$\beta_1 = 30°$

$\beta_2 = 45°$

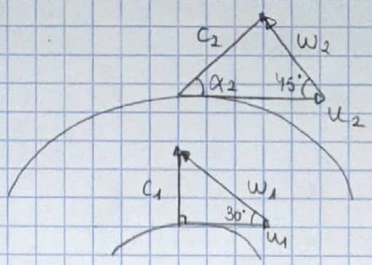
$b_1 = 3cm$

$N = 1500 rpm$

$\alpha_1 = 90°$

$\eta_H = 1.85$

$\eta_T = 1.70$



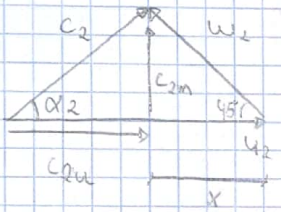
a) c_1?

$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi \cdot 1500}{60} \cdot 0'06 = 3\pi = 9'425 m/s$

$tg\ \beta_1 = \frac{c_1}{u_1} \Rightarrow tg\ 30 = \frac{c_1}{9'425}$

$\boxed{c_1 = 5'44 m/s}$

b) $k = 1$ α_2?



Inpultsore sarrerako angelua 90° direnez. $c_1 = c_{1m}$

$\begin{cases} Q = c_{1m} k_1 \pi D_1 b_1 \Rightarrow 5'44 \cdot 1 \cdot \pi\ 0'12 \cdot 0'03 = Q \\ Q = c_{2m} k_2 \pi D_2 b_2 \Rightarrow c_{2m} \cdot 1 \cdot \pi\ 0'24 \cdot 0'02 = Q \end{cases}$

$c_{2m} = 4'08104857 m/s$

$tg\ \beta_2 = \frac{c_{2m}}{x} \Rightarrow tg\ 45 = \frac{4'08105}{x}$

$x = 4'08105 m/s$

$u_2 = \omega \cdot r_2 = \frac{2\pi N}{60} \cdot r_2 = \frac{2\pi 1500}{60} \cdot 0'12 = 6\pi = 18'85 m/s$

$u_2 = x + c_{2u} \Rightarrow c_{2u} = u_2 - x = 18'85 - 4'08105$

$c_{2u} = 14'77 m/s$

$tg\ \alpha_2 = \frac{c_{2m}}{c_{2u}} = \frac{4'08105}{14'77} \Rightarrow \boxed{\alpha_2 = 15'45°}$

c) Q?

$Q = c_{1m} k_1 \pi D_1 b_1 = 5'44 \cdot 1 \cdot \pi \cdot 0'12 \cdot 0'03 = \boxed{0'0615 m^3/s = Q}$

d) Eulerren altuera?

$He = \frac{c_{1u} \cdot u_1 - c_{2u} \cdot u_2}{g} = \frac{-14'77 \cdot 18'85}{9'8} = -28'41 \Rightarrow \boxed{He = 28'41 m}$

e) Altuera manometrikoa?

$Hm = He\ \eta_H = 28'41 \cdot 0'85 = \boxed{24'15 m = Hm}$

f) Potentzia?

$W_{hidro} = W_{elek}\ \eta_T \Rightarrow W_{elek} = \frac{W_{hidro}}{\eta_T} = \frac{\rho g Hm \cdot Q}{\eta_T} = \frac{1000 \cdot 9'8 \cdot 24'15 \cdot 0'0615}{0'70}$

$W_{elek} = 20791'6 W \frac{1CP}{736 W} \Rightarrow \boxed{W_{elek} = 28'252 CP}$

22.13)

Altzairu komertziala

$L_{hod} = 20\,m$

$\varnothing = 80\,mm$

$h = 900\,m$

$\varphi = 14\,l/s \rightarrow 0'014\,m^3/s$

$NPSH_{eskaturikoa} = 2'5\,m\,Uz$.

$NPSH_{segurta} = 1'5\,m\,Uz$

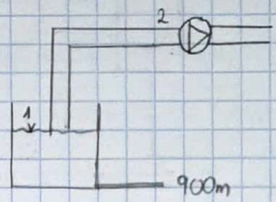
$p_{atm} = 682'4\,mmHg \rightarrow 0'92773\,kg/cm^2$

$\rho_{mer} = 13600\,kg/m^3$

$T = 15°C$

$p_{lura} = 0'0176\,kg/cm^2$

Ponparen ardatzaren altuera maximoa?



$\varphi = V \cdot A \Rightarrow V = \dfrac{\varphi}{A} = \dfrac{0'014}{\frac{\pi\, 0'08^2}{4}}$

$V = 2'785\,m/s$

$NPSH_{eskaturikoa} = \dfrac{V_2^2}{2g} = 2'5\,m\,Uz$

$NPSH_{segurta} = \dfrac{p_2 - p_s}{\gamma} = 1'5\,m\,Uz$

• $H_1 = H_2 + h_{R_{1\to2}}$

f?

Altzairu komertziala: $\varepsilon = 0'1$

$\nu\,(15°C) = 1'142 \cdot 10^{-6}\ m^2/s$

$$\begin{cases} \dfrac{\varepsilon}{D} = \dfrac{0'1}{80} = 0'00125 \\ Re = \dfrac{V\,D}{\nu} = \dfrac{2'785 \cdot 0'08}{1'142 \cdot 10^{-6}} = 1'95 \cdot 10^5 \end{cases} \Rightarrow f = 0'022$$

• $H_1 = H_2 + h_{R_{1\to2}}$

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + h_{R_{1\to2}}$$

$$\frac{p_2 - p_s}{\gamma} + \frac{V_2^2}{2g} = \frac{p_1 - p_s}{\gamma} - z_2 - h_{R_{1\to2}} + z_1$$

$$NPSH_{segur} + NPSH_{eskatu} = \frac{p_1 - p_s}{\gamma} - z_2 - \frac{8 f L \varphi^2}{g \pi^2 D^5} + z_1$$

Ez dut g kontuan hartu eta hartu behar da

$$1'5 + 2'5 = 9'2773 - 0'176 - z_2 - \frac{8 \cdot 0'022 \cdot 20 \cdot 0'014^2}{9'8 \cdot \pi^2 \cdot 0'08^5} + 900$$

$z_2 = 902'9245\,m$

22.15)

$NPSH = 2\,m\,Uz$

$Galerak = 4\,m\,Uz = h_R$

$p = 720\,mmHg$

$T = 38°C$

$p_s = 0'07\,kg/cm^2$

$z_B = 2$

kontuan izan: $NPSH_{erab} > 1'3\,NPSH_{eskatu}$

$p_1 = 720\,mm\,Hg \rightarrow 95992'128\,Pa$ $\quad p_s = 0'07\,kg/cm^2 \rightarrow 9'332568\,Pa$

$\rho\,(38°C)$

T	ρ
35	994'11
38	x
40	992'25

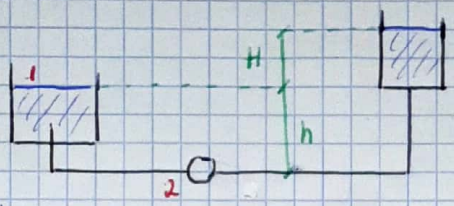
$\rho\,(38°C) = 992'994\,kg/m^3$

$$NPSH_{erab} = \frac{p_1 - p_s}{\gamma} - z_B - h_R = \frac{95992'128 - 9'3325}{992'994 \cdot 9'8} - 2 - 4$$

$NPSH_{erab} = 3'863\,m\,Uz$

$NPSH_{erab} > 1'3\,NPSH_{esk} \Rightarrow 3'864 > 1'3 \cdot 2 \Rightarrow 3'863 > 2'6$ ✓ **Betetzen da**

22.16)



a) NPSH erab.

$$H_1 = H_2 + h_{R\,1\to 2}$$

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_{R\,1\to 2}$$

$$\frac{p_2 - p_s}{\gamma} + \frac{v_2^2}{2g} = \frac{p_1 - p_s}{\gamma} + h - h_{R\,1\to 2}$$

b) NPSH erab?

$Q = 160\ l/s$

$NPSH_{esk} = 10\ mUz$

$\varnothing_{esp} = 500\ mm$

$\varnothing_{im} = 500\ mm$

$n = 5$

$L_{imp} = 30\ m$

$P_{atm} = P_1 = 1\ atm$

$T = 20^\circ C \rightarrow \gamma = 998'23\ kg/m^3$

$p_s = 0'024\ kg/cm^2 \rightarrow 3'2\ Pa$

$k_{uken} = 5$

$k_{oal} = 20$

$H = 20\ m$

$h = 4\ m$

$f = 0'02$

$NPSH_{seg} = 0'30 \cdot NPSH_{esk} = 3\ mUz$

$$Q = v \cdot A \Rightarrow v = \frac{Q}{A} = \frac{0'16}{\frac{\pi \cdot 0'5^2}{4}} = 0'815\ m/s$$

$$NPSH_{erab} = \frac{p_1 - p_s}{\gamma} + h - h_{R\,1\to 2} - k_{uk}\frac{v^2}{2g} - k_{oal}\frac{v^2}{2g}$$

$$NPSH_{erab} = 10'33 - \frac{3'2}{998'23 \cdot 9'8} + 4 - 0'02\,\frac{30}{0'5}\,\frac{0'815^2}{2 \cdot 9'8} - (5+20)\,\frac{0'815^2}{2 \cdot 9'8}$$

$$NPSH_{erab} = 13'94$$

c) Kabitatzio amiztkua h handitzen bada?

h handitzen bada NPSH erabilgarria handitu egingo da, eta beraz kabitatzioa ematzko amiztkua baxuagoa izango da.

22.17)

$N = 750$ rpm

$\beta_2 = 60°$

$b_1 = 35$ mm

$b_2 = 21$ mm

$\eta = 0'9$

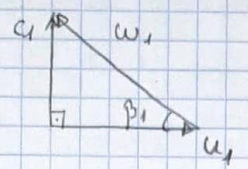
$D_1 = 200$ mm

$D_2 = 350$ mm

$\varphi = 50$ l/s

a) • Sarrera triangelua:

Sarrera erradiala: $\alpha_1 = 90°$



$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi 750}{60} \cdot 0'1 = \frac{5}{2}\pi$

$\boxed{u_1 = 7'854 \text{ m/s}}$

Hasu honetan $c_1 = c_{1m}$

$\varphi = c_{1m} \pi h_1 D_1 b_1$

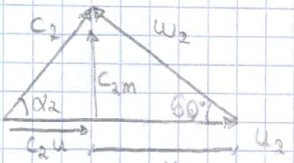
$0'05 = c_{1m} \pi 0'9 \cdot 0'2 \cdot 0'035$

$c_{1m} = \boxed{c_1 = 2'526 \text{ m/s}}$

$\text{tg}\,\beta_1 = \frac{c_1}{u_1} = \frac{2'526}{7'854} \Rightarrow \boxed{\beta_1 = 17'83°}$

$\sin\beta_1 = \frac{c_1}{w_1} \Rightarrow w_1 = \frac{c_1}{\sin\beta_1} = \frac{2'526}{\sin 17'83} = \boxed{8'25 \text{ m/s} = w_1}$

• Irteera triangelua:



$u_2 = \omega \cdot r_2 = \frac{2\pi 750}{60} \cdot \frac{0'35}{2} = \frac{35}{8}\pi = \boxed{13'744 \text{ m/s} = u_2}$

$\varphi = c_{2m} \pi h_2 D_2 b_2$

$0'05 = c_{2m} \pi 0'9 \cdot 0'35 \cdot 0'021$

$c_{2m} = 2'406 \text{ m/s}$

$\text{tg}\,\beta_2 = \frac{c_{2m}}{x} \Rightarrow x = \frac{c_{2m}}{\text{tg}\,\beta_2} = \frac{2'406}{\text{tg}\,60} = 1'39 \text{ m/s}$

$u_2 = c_{2u} + x \Rightarrow c_{2u} = u_2 - x = 13'744 - 1'39 = 12'355 \text{ m/s}$

$\text{tg}\,\alpha_2 = \frac{c_{2m}}{c_{2u}} = \frac{2'406}{12'355} \Rightarrow \boxed{\alpha_2 = 11'02°}$

$\sin\alpha_2 = \frac{c_{2m}}{c_2} \Rightarrow c_2 = \frac{c_{2m}}{\sin\alpha_2} = \frac{2'406}{\sin 11'02} = \boxed{12'59 \text{ m/s} = c_2}$

$\sin\beta_2 = \frac{c_{2m}}{w_2} \Rightarrow w_2 = \frac{c_{2m}}{\sin\beta_2} = \frac{2'406}{\sin 60} = \boxed{2'78 \text{ m/s} = w_2}$

b) Euler altuera?

$He = \frac{\cancel{c_{1u}u_1}^{0} - c_{2u}u_2}{g} = \frac{-12'355 \cdot 13'744}{9'8} = -17'33 \text{ m} \Rightarrow \boxed{He = 17'33 \text{ m } u_2}$

c) $\eta_H = \%80$

$\eta_T = \%77$

kWh = 0'1 €

$Hm = He \cdot \eta_H = 17'33 \cdot 0'8 = 13'86 \text{ m } u_2$

$W_H = W_{elek} \cdot \eta_T \Rightarrow W_{elek} = \frac{W_H}{\eta_T} = \frac{\delta g Hm \varphi}{\eta_T} = \frac{1000 \cdot 9'8 \cdot 13'86 \cdot 0'05}{0'77}$

$W_{elek} = 8821'15 \text{ W}$

$W_{elek} = 8821'15 \text{ Wh} \frac{1 \text{ kWh}}{1000 \text{ Wh}} \frac{0'1 €}{1 \text{ kWh}} = \boxed{0'8821 €/h = W_{elek}}$

22.18/

$\varphi = 300\ m^3/h$

$D_1 = 150\ mm$

$D_2 / D_1 = 3$

$b_1 = 40\ mm$

$b_2 / b_1 = 0'5$

$\beta_1 = 60^\circ$

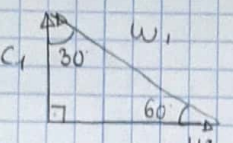
$\beta_2 = 40^\circ$

Sarrera erradiala

$\alpha_1 = 90^\circ$

$k = 1$

a) Ermaketearen barneko abiadura?



kasu honetan $c_1 = c_{1m}$

$\varphi = c_{1m} k_1 \pi D_1 b_1$

$\frac{300}{3600} = c_{1m} \cdot 1 \cdot \pi \cdot 0'150 \cdot 0'04$

$c_{1m} = 4'421\ m/s$

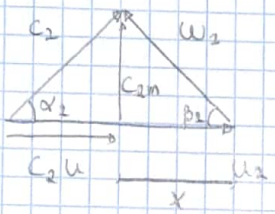
$tg\ \beta_1 = \frac{c_1}{u_1} \Rightarrow u_1 = \frac{c_1}{tg\beta_1} = \frac{4'421}{tg\ 60} = 2'552\ m/s$

$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \cdot r_1 \Rightarrow 2'552 = \frac{2\pi N}{60} \cdot \frac{0'15}{2}$

$\boxed{N = 325\ rpm}$

b) Euler altuera?

$He = \frac{c_{1u} u_1 - c_{2u} u_2}{g}$



$D_2/D_1 = 3 \Rightarrow D_2 = 3 \cdot D_1 = 3 \cdot 150 = 450\ mm$

$b_2/b_1 = 0'5 \Rightarrow b_2 = 0'5\ b_1 = 0'5 \cdot 40 = 20\ mm$

$u_2 = \omega \cdot r_2 = \frac{2\pi N}{60} \cdot r_2 = \frac{2\pi \cdot 325}{60} \cdot \frac{0'45}{2} = 7'6576\ m/s$

$\varphi = c_{2m} k_2 \pi D_2 b_2$

$\frac{300}{3600} = c_{2m} \cdot 1 \cdot \pi \cdot 0'45 \cdot 0'02$

$c_{2m} = 2'95\ m/s$

$tg\ \beta_2 = \frac{c_{2m}}{x} \Rightarrow x = \frac{c_{2m}}{tg\ \beta_2} = \frac{2'95}{tg\ 40} = 3'5124\ m/s$

$u_2 = c_{2u} + x \Rightarrow c_{2u} = u_2 - x = 7'6576 - 3'5124 = 4'145\ m/s$

$He = \frac{c_{1u} u_1 - c_{2u} u_2}{g} = \frac{-4'145 \cdot 7'6576}{9'8} = -3'24 \Rightarrow \boxed{He = 3'24\ mU_2}$

c) Indar bihotea?

$H = \dot{m}\ c_{1u} \cdot r_1 - \dot{m}\ c_{2u} \cdot r_2$

$\dot{m} = 300\ m^3/h\ \frac{1000\ dm^3}{1\ m^3}\ \frac{1\ l}{1\ dm^3}\ \frac{1\ h}{3600\ s} = 83'3\ l/s$

$H = -\dot{m}\ c_{2u} \cdot r_2 = -83'3 \cdot 4'145 \cdot \frac{0'45}{2} = 77'72\ N \cdot m \Rightarrow \boxed{H = 77'72\ Nm}$

d) Potentzia?

$Pot = \rho g H Q = 1000 \cdot 9'8 \cdot 3'24 \cdot \frac{300}{3600} = 2646\ W \Rightarrow \boxed{Pot = 2646\ W}$

e) Presio hazkundea eta presio dinamikoa

$$He = \underbrace{\frac{c_1^2 - c_2^2}{2g}}_{hd\ (altuera\ zuzkiloa)} + \underbrace{\frac{u_1^2 - u_2^2}{2g} + \frac{w_2^2 - w_1^2}{2g}}_{hp\ (presio\ aldtuera) \rightarrow \Delta p}$$

$c_2^2 = c_{2m}^2 + c_{2u}^2 = 2'95^2 + 4'145^2$

$c_2 = 5'087\ m/s$

$$hd = \frac{c_1^2 - c_2^2}{2g} = \frac{4'42^2 - 5'087^2}{2 \cdot 9'8} = -0'324 m Uz \Rightarrow \boxed{hd = 0'324 m Uz}$$

$$\sin \beta_1 = \frac{c_1}{w_1} \Rightarrow w_1 = \frac{c_1}{\sin \beta_1} = \frac{4'42}{\sin 60} = 5'104\ m/s$$

$$\sin \beta_2 = \frac{c_{2m}}{w_2} \Rightarrow w_2 = \frac{c_{2m}}{\sin 40} = \frac{2'95}{\sin 40} = 4'59\ m/s$$

$$hp = \frac{u_1^2 - u_2^2}{2g} + \frac{w_2^2 - w_1^2}{2g} = \frac{2'552^2 - 7'6576^2}{2 \cdot 9'8} + \frac{4'59^2 - 5'104^2}{2 \cdot 9'8} = -2'91 m Uz$$

Eratago:

$He = hd + hp \Rightarrow hp = He - hp = 3'24 - 0'324 = 2'92 m Uz \Rightarrow \boxed{hp = 2'92 m Uz}$

22.19)

$Q = 50\ L/s$

$r_1 = 5\ cm$

$\alpha_1 = 90°$

$b_1 = 3 cm$

$r_2 = 11 cm$

$b_2 = 2 cm$

$\beta_2 = 45°$

$\eta_H = 1'87$

$\eta_T = 1'70$

$k = 1$

$N = 1200\ rpm$

a) Sarrerako abiadura absolutua?

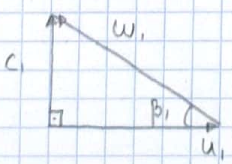
Kasu honetan $c_1 = c_{1m}$

$Q = c_{1m}\ k_1\ \pi\ D_1\ b_1$

$0'05 = c_{1m} \cdot 1 \cdot \pi \cdot 0'1 \cdot 0'03$

$c_{1m} = \boxed{c_1 = 5'305\ m/s}$

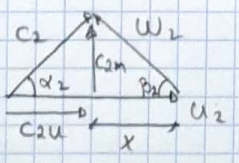
b) β_1?



$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi 1200}{60} \cdot 0'05 = 6'2832\ m/s$

$tg\ \beta_1 = \frac{c_1}{u_1} = \frac{5'305}{6'2832} \Rightarrow \boxed{\beta_1 = 40'175°}$

c) α_2?



$u_2 = \omega r_2 = \frac{2\pi N}{60} r_2 = \frac{2\pi 1200}{60} \cdot 0'11 = 13'823\ m/s$

$Q = c_{2m}\ k_2\ \pi\ D_2\ b_2 \Rightarrow 0'05 = c_{2m} \cdot 1 \cdot \pi \cdot 0'22 \cdot 0'02$

$c_{2m} = 3'62\ m/s$

$$\operatorname{tg}\beta_2 = \frac{c_{2m}}{x} \Rightarrow x = \frac{c_{2m}}{\operatorname{tg}\beta_2} = \frac{5'617}{\operatorname{tg} 45} = 5'617$$

$$u_2 = c_{2u} + x \Rightarrow c_{2u} = u_2 - x = 13'823 - 5'617 = 10'206 \text{ m/s}$$

$$\operatorname{tg}\alpha_2 = \frac{c_{2m}}{c_{2u}} = \frac{5'617}{10'206} \Rightarrow \boxed{\alpha_2 = 19'51^\circ}$$

d) Euleren altuera?

$$He = \frac{\cancel{c_{1u}} u_1 - c_{2u} u_2}{g} = \frac{-10'206 \cdot 13'823}{9'8} = -14'395 \Rightarrow \boxed{He = 14'395 \text{ mUz}}$$

e) Ponpak emandako potentzia hidraulikoa?

$$Hm = He\ \eta_m = 14'395 \cdot 0'87 = 12'524 \text{ mUz}$$

$$Pot_h = \rho g Hm Q = 1000 \cdot 9'8 \cdot 12'524 \cdot 0'05 = 6136'873 \text{ W} \Rightarrow \boxed{W_h = 6136'873 \text{ W}}$$

f) Ponpak kontsumitzeko potentzia?

$$W_h = W_{elek}\ \eta_T \Rightarrow W_{elek} = \frac{W_h}{\eta_T} = \frac{6136'873}{0'7} = 8766'96 \text{ W} \Rightarrow \boxed{W_{elek} = 8766'96 \text{ W}}$$

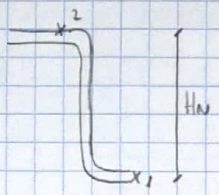
23. GAIA: Turbina hidraulikoak. Zentral hidroelektrikoak

23.1)

$H_N = 240\,m$
$C_0 = 0'98$
$d = 150\,mm$
$N = 160\,rpm$
$\varnothing_{ard} = 1800\,mm$
$\alpha_2 = 142'5^\circ$

a) Zomotadaren emaria eta sarrera abiadura?

$C_0 = 0'98$ bada, esan nahi du %2-a galtzen dela



$$H_1 = H_2$$

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

$$\frac{v_1^2}{2g} = 240$$

$$v_1 = 68'586\,m/s$$

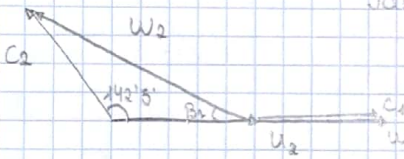
$$C_0 = \frac{V_R}{V_T} \Rightarrow V_R = C_0 \cdot V_T = 0'98 \cdot 68'586 = 67'214\,m/s$$

$$\boxed{V_R = 67'214\,m/s}$$

$$\varphi = v \cdot A = V_R \cdot \frac{\pi d^2}{4} = 67'214 \cdot \frac{\pi\, 0'15^2}{4} = 1'187\,m^3/s$$

$$\boxed{\varphi = 1'187\,m^3/s}$$

b) Indarra?



Sarrera triangeluak ere dago lema bat dalako

$$u_1 = u_2 = r_1 \cdot \omega = \frac{\varnothing_{ard}}{2} \cdot \frac{2\pi N}{60} = \frac{1'8}{2} \cdot \frac{2\pi 160}{60} = 15'08\,m/s$$

$$C_2 = V_R = 67'214\,m/s$$

$$|\vec{w}_1| = |\vec{w}_2| = C_1 - u_1 = 67'214 - 15'08 = 52'134\,m/s$$

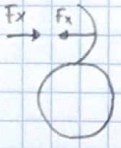
Pelton turbina denez hau da, alegia turbina bat, $u_1 = u_2$

Cosinuaren teorema erabiliz:

$$w_2^2 = u_2^2 + C_2^2 - 2 C_2 u_2 \cos\alpha$$

$$52'134^2 = 15'08^2 + C_2^2 - 2 C_2 \cdot 15'08 \cdot \cos 142'5$$

$$C_2 = 39'35\,m/s$$



$$F_x = \delta \varphi (C_1 - u_1)(1 - \cos\alpha_2) = 1000 \cdot 1'187 (67'214 - 15'08)(1 - \cos 142'5)$$

$$F_x = 110978'1888\,N \cdot \frac{1\,kg}{9'8\,N} = 11324'305\,kg$$

Besoak urari egiten dion indarra:

$$\boxed{F_x = -11324'305\,kg}$$

c) Potentzia hidraulikoa [ZP]?

$$He = \frac{C_{1u} u_1 - C_{2u} u_2}{g} = \frac{67'214 \cdot 15'08 - 39'35 \cos 142'5 \cdot 15'08}{9'8} = 151'465\,m\,u_2$$

$$Pot = \delta\, g\, He\, \varphi = 1000 \cdot 9'8 \cdot 151'465 \cdot 1'187 = 1761936'988\,W \cdot \frac{1\,ZP}{736\,W} = \boxed{2393'936\,ZP = Pot_H}$$

23.2)

$N = 300\,rpm$

$H_k = 5m$

$\eta_T = 1.70$

$Pot = 200 - 300 kW$

a) Turbinaren abiadura espezifikoa?

$$n_s = \frac{N\sqrt{P}}{H^{5/4}} \Rightarrow$$

Pot 200kW → 271'742P

$$n_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{300\sqrt{271'74}}{5^{5/4}} = 661'43\,rpm$$

Pot 300kW → 407'612P

$$n_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{300\sqrt{407'61}}{5^{5/4}} = 810'085\,rpm$$

$$\boxed{n_s = 661'43 - 810'085\,rpm}$$

b) $H_p = 3m$. P_p eta N_p?

Malura berdina denez $\lambda = 1$

$$\frac{P_p}{P} = \left(\frac{H_p}{H_k}\right)^{3/2} \lambda^2 \quad \text{eta} \quad \frac{N_p}{N} = \left(\frac{H_p}{H_k}\right)^{1/2} \frac{1}{\lambda}$$

$Pot = 200 kW$

$$\frac{P_p}{200} = \left(\frac{3}{5}\right)^{3/2} \Rightarrow P_p = 92'95 kW$$

$$\frac{N_p}{300} = \left(\frac{3}{5}\right)^{1/2} \Rightarrow N_p = 232'38\,rpm$$

$Pot = 300 kW$

$$\frac{P_p}{300} = \left(\frac{3}{5}\right)^{3/2} \Rightarrow P_p = 139'43 kW$$

$N_p = 232'38\,rpm$

$$\boxed{P_p = 92'95 - 139'43 kW}$$

$$\boxed{N_p = 232'38\,rpm}$$

c) N_p eta P?

$\eta = 1.70$

$H_k = 3'2\,m$

$Pot = 150 kW$?

$Pot = 200 kW$

$$\frac{P_p}{200} = \left(\frac{3'2}{5}\right)^{3/2} \Rightarrow P_p = 102'4 kW$$

$Pot = 300 kW$

$$\frac{P_p}{300} = \left(\frac{3'2}{5}\right)^{3/2} \Rightarrow P_p = 153'6 kW \rightarrow \text{Posible da}$$

$$\frac{N_p}{300} = \left(\frac{3'2}{5}\right)^{1/2} \Rightarrow \boxed{N_p = 240\,rpm}$$

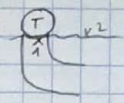
$$\boxed{P_p = 102'4 - 153'6 kW}$$

a) $h_a = 0'3 \frac{V^2}{2g}$ Gainaratzeko presioa?

V = digesorearen sarrera

A = $1m^2$

kabitatzio amitua



$$H_1 = H_2 + h_{R\,1\to2}$$

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g} + h_{R\,1\to2}$$

$$\frac{p_1}{\gamma} = (0'3 - 1)\frac{V^2}{2g} = -0'7\,\frac{Q^2}{2gA^2}$$

$Pot = \rho g H \varphi$

$300 \cdot 10^3 = 1000 \cdot 9'8 \cdot 5 \cdot \varphi$

$\varphi = 6'122\ m^3/s$

$$\frac{p_1}{\gamma} = -0'7\,\frac{6'122^2}{2 \cdot 9'8 \cdot 1^2} = \boxed{-1'34\,m\,U2 = h_{pA}}$$

23.6)

N = 375 m

$\beta_1 = 90$

$\alpha_1 = 10$

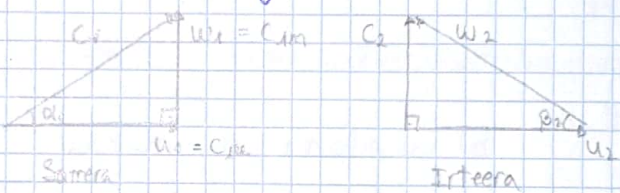
$C_{1m} = C_{2m} = 2m/s$

$D_2 = 1/2\ D_1$

$b_1 = 100$

$\eta = 1.4 \to h_1 = 0'96$

a) Abiadura triangeluak, marraztu



b) He?

$u_1 = \omega \cdot r_1$ edo $tg\,\alpha_1 = \frac{w_1}{u_1} = \frac{C_{1m}}{u_1} \Rightarrow u_1 = \frac{C_{1m}}{tg\,\alpha_1} = \frac{2}{tg\,10}$

$C_{1u} = u_1 = 11'3426\,m/s$

$$He = \frac{C_{1u}u_1 - C_{2u}u_2}{g} = \frac{11'3426 \cdot 11'3426}{9'8} = 13'128\,m\,U2$$

$\boxed{He = 13'128\,m\,U2}$

c) β_2?

$w_1 = C_{1m} = C_{2m} = C_2 = 2\,m/s$

$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} r_1 \Rightarrow 11'3426 = \frac{2\pi\,375}{60} \cdot r_1$

$r_1 = 0'288\,m$

$D_2 = 1/2\ D_1 = 1/2\ (2r_1) = 0'288\,m$

$u_2 = \omega \cdot r_2 = \frac{2\pi N}{60} \cdot r_2 = \frac{2\pi\,375}{60} \cdot \frac{0'288}{2} = 5'6713\,m/s$

$tg\,\beta_2 = \frac{C_2}{u_2} = \frac{2}{5'6713} \Rightarrow \boxed{\beta_2 = 19'425^\circ}$

d) D_2 eta D_1?

$D_1 = 2r_1 = 2 \cdot 0'2888 = \boxed{0'5776\ m = D_1}$

$D_2 = \frac{1}{2} D_1 = \frac{1}{2} 0'5776 = \boxed{0'288 m = D_2}$

e) Potentzia turbinarena?

$\varphi = c_{1m} \pi k_1 D_1 b_1 = 2 \pi 0'96 \cdot 0'5776 \cdot 0'1 = 0'35\ m^3/s$

$Pot = \rho g He \varphi = 1000 \cdot 9'8 \cdot 13'128 \cdot 0'35 = 44823'21\ W$

$\boxed{Pot = 44'823\ kW}$

23.7)

$H_N = 270 m$

3 tobera

$L = 2'4\ km$

$h_R = 24 m\ Uz$

$N_s < 38\ rpm$

$Pot_m = 18000\ ZP$

$N = 650\ rpm$

$u/c = 0'46$

$\eta_T = 0'87$

$k = 0'94$

$k_v = 0'97$

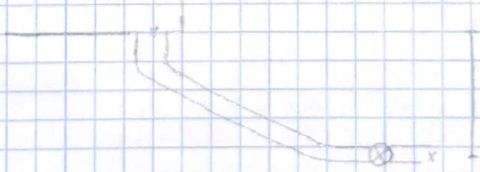
a) Zenbat Pelton turbina?

$N_s = \frac{N \sqrt{P_t}}{H^{5/4}} \Rightarrow 38 = \frac{650 \sqrt{\frac{18000}{n}}}{(270-24)^{5/4}}$

$n = 5'55$

Beraz, 6 turbina jarri behar dira $\boxed{n = 6\ turbina}$

b) Gurpilaren diametroa



$V_T = \sqrt{2g H}$

$V_T = \sqrt{2g (270-24)}$

$V_T = 69'44 m/s$

$k_v = \frac{V_2}{V_T} \Rightarrow V_2 = V_T k_v = 69'44 \cdot 0'97 = 67'355\ m/s$

$V_2 = C_1$

$\frac{u_1}{C_1} = 0'46 \Rightarrow u_1 = 0'46\ C_1 = 0'46 \cdot 67'355 = 30'98 m/s$

$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \frac{D_1}{2} \Rightarrow 30'98 = \frac{2\pi 650}{60} \frac{D_1}{2}$

$\boxed{D_1 = 0'91 m}$

c) Ixoaren diametroa? d?

$Pot_T = 18000\ ZP$ dira, $n = 6$ turbina

$Pot_{Turbina} = \frac{Pot_T}{n} = \frac{18000}{6} = 3000\ ZP \frac{736\ W}{1\ ZP} = 2208000\ W$

$Pot = \rho g H \varphi \Rightarrow 2208000 = 1000 \cdot 9'8 \cdot (270-24) \cdot \varphi$

$\varphi = 0'916\ m^3/s$

$\varphi = V \cdot A = V_2 \frac{\pi d^2}{4} \Rightarrow 0'916 = 67'355 \cdot \frac{\pi d^2}{4}$

$\boxed{d = 0'131\ m}$

d) Hodien diametroa ?

Bergatik $\varphi \times 2$? Injektoreen delako? ?

$f = 0'006$

$h_R = f \frac{L}{D} \frac{v^2}{2g} = \frac{8 f L \varphi^2}{g \pi^2 D^5}$

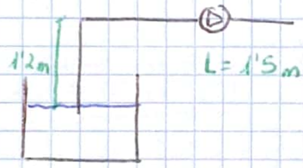
$\varphi_T = 2 \cdot \varphi_{inj} = 2 \cdot 0'916 = 1'832\ m^3/s$

$D = \sqrt[5]{\frac{8 f L \varphi_T^2}{g \pi^2 h_R}} = \sqrt[5]{\frac{8 \cdot 0'006 \cdot 2'4 \cdot 10^3 \cdot 1'832^2}{9'8 \cdot \pi^2 \cdot 24}} = 0'7\ m$

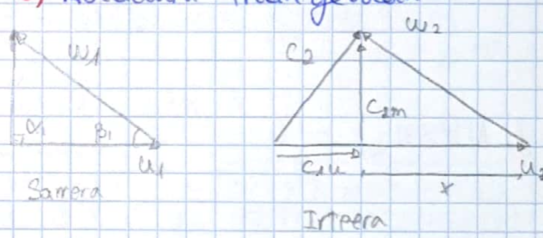
$\boxed{D_n = 0'7\ m}$

23. 8)

$N = 1000\ rpm$
$D_1 = 180\ mm$
$D_2/D_1 = 2$
$b_1 = 30\ mm$
$b_2 = 20\ mm$
$\beta_1 = 20°$
$\beta_2 = 30°$
$\alpha_1 = 90°$
$\eta_H = \%81$
$\eta_T = \%77$
→ $\varnothing_{asp} = 0'22\ m$
$\varnothing_{imp} = 0'2\ m$
$k_1 = k_2 = 0'95$



a) Abiadura triangeluak



Sarrera:

$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi 1000}{60} \cdot \frac{0'18}{2} = \boxed{9'42477\ m/s = u_1}$

$tg\ \beta_1 = \frac{c_1}{u_1} \Rightarrow c_1 = u_1\ tg\ \beta_1 = 9'42\ tg\ 20 = \boxed{3'43\ m/s = c_1}$

$\cos \beta_1 = \frac{u_1}{w_1} \Rightarrow w_1 = \frac{u_1}{\cos \beta_1} = \frac{9'42}{\cos 20} = \boxed{10'03\ m/s = w_1}$

kasu honetan $c_1 = c_{1m}$

$\varphi = c_{1m}\, \pi\, k_1\, D_1\, b_1 = 3'43 \cdot \pi \cdot 0'95 \cdot 0'18 \cdot 0'03 = 0'0553\ m^3/s$

Irteera:

$D_2/D_1 = 2 \Rightarrow D_2 = 2 D_1 = 2 \cdot 0'18 = 0'36\ m$

$u_2 = \omega \cdot r_2 = \frac{2\pi N}{60} \cdot \frac{D_2}{2} = \frac{2\pi 1000}{60} \cdot \frac{0'36}{2} = \boxed{18'85\ m/s = u_2}$

$\varphi = c_{2m}\, \pi\, k_2\, D_2\, b_2 \Rightarrow 0'0553 = c_{2m}\, \pi \cdot 0'95 \cdot 0'36 \cdot 0'02 \Rightarrow c_{2m} = 2'57\ m/s$

$tg\ \beta_2 = \frac{c_{2m}}{x} \Rightarrow x = \frac{c_{2m}}{tg\ \beta_2} = \frac{2'57}{tg\ 30} = 4'46\ m/s$

$u_2 = c_{2u} + x \Rightarrow c_{2u} = u_2 - x = 18'85 - 4'46 = 14'39\ m/s$

$\sin \beta_2 = \frac{c_{2m}}{w_2} \Rightarrow w_2 = \frac{c_{2m}}{\sin \beta_2} = \frac{2'57}{\sin 30} = \boxed{5'14\ m/s = w_2}$

$c_2^2 = c_{2m}^2 + c_{2u}^2 \Rightarrow c_2 = \sqrt{2'57^2 + 14'39^2} = \boxed{14'62 m/s = c_2}$

b) Emaria? [l/s]

$\varphi = 0'0553\ m^3/s \ \frac{1000\ dm^3}{1\ m^3} \ \frac{1\ l}{1\ dm^3} = \boxed{55'3\ l/s = \varphi}$

c) He?

$He = \frac{\cancel{c_{1u}^0} \cdot u_1 - c_{2u} \cdot u_2}{g} = \frac{-14'39 \cdot 18'85}{9'8} = -27'68m \Rightarrow \boxed{He = 27'68 m\ c.a.}$

d) $t = 6h$

kWh = 16 pts

$Hm = He\ \eta_H = 27'68 \cdot 0'81 = 22'42 m\ c.a.$

$W_H = \rho g Hm \varphi = 1000 \cdot 9'8 \cdot 0'0553 \cdot 22'42 = 12150'17 W$

$W_H = W_{elek} \cdot \eta_T \Rightarrow W_{elek} = \frac{W_H}{\eta_T} = \frac{12150'17}{0'77} = 15779'44 W$

$W_{elek} = 15779'44\ W \frac{1kW}{1000 W} \cdot 6h = 94'676\ kWh \frac{16\ pst}{1 kWh} = \boxed{1514'83 pst = W_{elek}}$

e) Abiadura espetifikoa bonbarena?

$n_{s\varphi} = \frac{N \sqrt{\varphi}}{Hm^{3/4}} = \frac{1000 \sqrt{0'0553}}{22'42^{3/4}} = \boxed{22'8 rpm = n_{s\varphi}}$

f) $NPSH_{esk} = 6$

Gogoratu: $NPSH_{erab} > 1'3 \cdot NPSH_{esk}$

Altuera galbanitatua: $\varepsilon = 0'07 mm$

$\nu (20^\circ C) = 1'007 \cdot 10^{-6}\ m^2/s$

$\rho_s (20^\circ C) = 0'0239\ kg/cm^2$

$\rho (20^\circ C) = 998'23\ kg/m^3$

$Re = \frac{D v}{\nu} = \frac{0'22 \ \frac{0'0553}{\pi 0'22^2}}{1'007\ 10^{-7}} = 3'17 \cdot 10^5$

$\frac{\varepsilon}{D} = \frac{0'07}{220} = 0'000318$

$\Big\} f = 0'017$

$NPSH_{erab} = NPSH_{esk} + NPSH_{seg}$

$NPSH_{erab} = \frac{p_1 - p_s}{\gamma} - z_2 - h_2 = 10'33 - 0'239 - 1'2 - \frac{8 \cdot 0'017 \cdot 1'5 \cdot 0'0553^2}{9'8\ \pi^2 \cdot 0'22^5}$

$NPSH_{erab} = 8'88 > 1'3 \cdot 6$

$8'88 > 7'8 \Rightarrow$ Berau ez da kabitazioik egongo.

23.9)

$D_2 = 240\,cm$

$D_1 = 300\,cm$

$\alpha_2 = 90°$

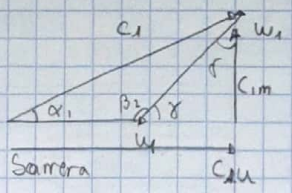
$N = 100\,rpm$

$w_1 = 15\,m/s$

$w_2 = 16\,m/s$

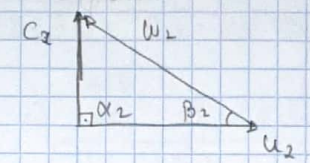
$b_1 = b_2 = 300\,mm$

a) Abiadura hirkiak?



$$u_1 = w \cdot r_1 = \frac{2\pi N}{60}\frac{D_1}{2} = \frac{2\pi 100}{60}\frac{3}{2}$$

$$\boxed{u_1 = 15'708\,m/s}$$



$$u_2 = w \cdot r_2 = \frac{2\pi N}{60} \cdot r_2 = \frac{2\pi \cdot 100}{60} \cdot \frac{2'4}{2}$$

$$\boxed{u_2 = 12'566\,m/s}$$

$$\cos \beta_2 = \frac{u_2}{w_2} = \frac{12'566}{16} \Rightarrow \beta_2 = 38'2425°$$

$$\sin \beta_2 = \frac{c_2}{w_2} \Rightarrow c_2 = w_2 \sin \beta_2 = 16 \sin 38'24 = \boxed{9'9\,m/s = c_2}$$

$$\left.\begin{array}{l} Q = c_{1m}\,\pi\,h_1\,D_1\,b_1 \\ Q = c_{2m}\,\pi\,h_2\,D_2\,b_2 \end{array}\right\} \Rightarrow c_{1m}\,\pi \cdot 3 \cdot 0'3 = 9'9 \cdot \pi \cdot 2'4 \cdot 0'3$$

$$c_{1m} = 7'923\,m/s$$

$$\sin \gamma = \frac{c_{1m}}{w_1} = \frac{7'923}{15} \Rightarrow \gamma = 31'88$$

$$\cos \gamma = \frac{x}{w_1} \Rightarrow x = w_1 \cos \gamma = 15 \cos 31'88 = 12'7367\,m/s$$

$$c_{1u} = u_1 + x = 15'708 + 12'7367 = 28'4447\,m/s$$

$$c_1 = \sqrt{c_{1m}^2 + c_{1u}^2} = \sqrt{7'923^2 + 28'4447^2} = \boxed{29'53\,m/s = c_1}$$

b) Emaria?

$$Q = c_{2m}\,\pi\,h_2\,D_2\,b_2 = 9'9 \cdot \pi \cdot 1'2'4 \cdot 0'3 = \boxed{22'39\,m^3/s = Q}$$

c) Emodenak turgaiten duen potentzia?

$$He = \frac{c_{1u} \cdot u_1 - \cancel{c_{2u}^{0}} \cdot u_2}{g} = \frac{28'447 \cdot 15'708}{9'8} = 45'6\,m\,Uz$$

$$Pot = \rho\, g\, He\, Q = 1000 \cdot 9'8 \cdot 45'6 \cdot 22'39 \Rightarrow \boxed{Pot = 10\,MW}$$

23. 10)

$D_1 = 750mm$

$D_2 = 30mm$

$N = 400 rpm$

$\alpha_1 = 15^\circ$

$C_1 = 14 m/s$

$C_{1m} = 5 m/s$

$C_{1u} = 0$

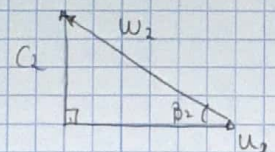
$b_1/D_1 = 0'15$

$\eta_H = 0'8$

$Q = 4 m$

$V_{sar} = 2 m/s$

a) Abiadura triangeluak



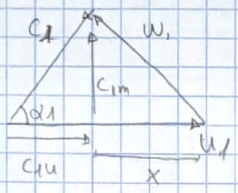
Irteera

$u_2 = \omega \cdot r_2 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi \cdot 400}{60} \cdot \frac{0'03}{2}$

$\boxed{u_2 = 0'628 m/s}$

$\boxed{C_2 = 5 m/s}$

$w_2^2 = C_2^2 + u_2^2 \Rightarrow w_2 = \sqrt{5^2 + 0'628^2} = \boxed{5'04 m/s = w_2}$



$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi 400}{60} \cdot \frac{0'75}{2}$

$\boxed{u_1 = 15'708 m/s}$

$\sin \alpha_1 = \frac{C_{1m}}{C_1} \Rightarrow C_{1m} = C_1 \sin \alpha_1 = 14 \sin 15 = 3'623 m/s$

$\cos \alpha_1 = \frac{C_{1u}}{C_1} \Rightarrow C_{1u} = C_1 \cos 15 = 14 \cos 15 = 13'523 m/s$

$x = u_1 - C_{1u} = 15'708 - 13'523 = 2'18 m/s$

$w_1 = \sqrt{x^2 + C_{1m}^2} = \sqrt{2'18^2 + 3'623^2} = \boxed{4'231 m/s = w_1}$

b) Emaria?

$b_1/D_1 = 0'15 \Rightarrow b_1 = 0'15 \cdot D_1 = 0'15 \cdot 0'75 = 0'1125 m$

$Q = C_{1m} \pi h_1 D_1 b_1 = 3'623 \pi \cdot 1 \cdot 0'75 \cdot 0'1125 = 0'96 m^3/s \Rightarrow \boxed{Q = 0'96 m^3/s}$

c) Eulerren altuera?

$He = \frac{C_{1u} w_1 - C_{2u} u_2}{g} = \frac{13'523 \cdot 15'708}{9'8} = \boxed{21'675 mU2 = He}$

d) Sarrera netoa?

$Hm = He \cdot \eta_H = 21'675 \cdot 0'8 = \boxed{17'34 mU2 = Hm}$

e) Potentzia erabilgarria?

$Pot = \rho g Hm Q = 1000 \cdot 9'8 \cdot 17'34 \cdot 0'96 = \boxed{163134'72 W = Pot}$

f) Presio manometrikoa?

$H_1 = H_2 + Hm$ Turbinarena

$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} = \frac{p_2}{\gamma}^{atm} + z_2^{0} + \frac{v_2^2}{2g} + Hm$

$\frac{p_1}{\gamma} + 4 + \frac{2^2}{2g} = 17'34$

$p_1 = 128732 Pa \rightarrow \boxed{p_1 = 1'287 bar}$

g) Turbinaren abiadura espezifikoa. Zer motatako turbina?

$$n_S = \frac{N\sqrt{P}}{H^{5/4}} = \frac{400\sqrt{\frac{1631'34}{736}}}{(17'34)^{5/4}} = \boxed{168'3\ rpm = n_S}$$

Klasean egindako

23.11)

$Q = 1\ m^3/s$

Cemento ardiarako

lodiera = 1'44m

altuera = 0'65m

$L = 10'4m$

malda = $1'44 \cdot 10^{-3}$ m/m

$h_1 = 200'11m$

$h_2 = 199'88m$

Acero galvanizado

$h = 197'8m$

$\phi = 800\ mm$

$e = 6mm$

$l = 525m$

$Q = 1m^3/s$

$h_{am} = 44'74m$

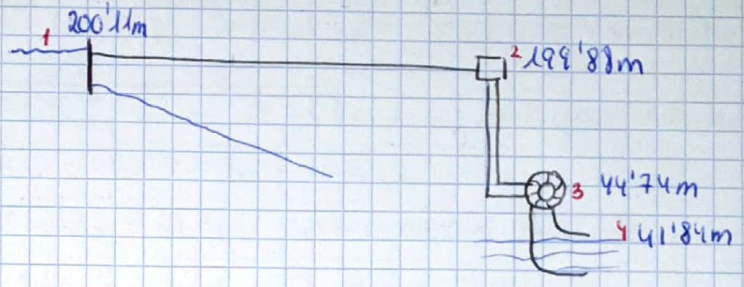
$t_{corte} = 3'5s$

$h_{jite} = 41'84m$

$N = 500\ rpm$

$\eta_T = 0'855$

$\phi_{erodo} = 0'88m$



a) Salto bruto eta salto baliagarria? (Util)

$H_B = 200'11 - 41'84 = \boxed{158'27m = H_B}$

$H_u = 199'88 - 44'74 = \boxed{155'14m = H_u}$

?? b) Profundidad del agua en el canal? Tanto

$Q = \frac{A}{n} R_H^{2/3} m^{1/2}$

Hasiera ez dagunez ur kotata joango

$$1 = \frac{1'44 \cdot 0'65}{1} \left(\frac{1'44}{1'44 + 0_4}\right)^{2/3} \sqrt{1'44 \cdot 10^{-3}}$$

$y = 0$

c) $h_{R\,sek} = 1'5 mUz$, h_{RT} eta H_{neto}?

Altzairu galbanizatua: $\varepsilon = 0'07$

$\nu(15^\circ C) = 1'142 \cdot 10^{-6}\ m^2/s$

$$Q = v \cdot A \Rightarrow v = \frac{Q}{A} = \frac{1}{\pi 0'8^2/4} = 1'989\ m/s$$

$$Re = \frac{v\,D}{\nu} = \frac{1'989 \cdot 0'8}{1'142 \cdot 10^{-6}} = 1'39365 \cdot 10^6$$

$$\frac{\varepsilon}{D} = \frac{0'07}{800} = 0'0000875$$

$\Big\} f = 0'013$

$$h_{R\,2-03} = f \frac{L}{D} \frac{v^2}{2g} = 0'013 \frac{525}{0'8} \frac{1'989^2}{2 \cdot 9'8} = 1'722 mUz$$

$$h_{RT} = h_{R\,2-03} + h_{R\,sek} = 1'722 + 1'5 = \boxed{3'222 mUz = h_{RT}}$$

$$H_N = H_u - h_{RT} = 155'14 - 3'222 = \boxed{151'92m = H_N}$$

d) Ardatzeko Pot eta par mekanikoa?

$$Pot = \rho g H_N Q \eta = 1000 \cdot 9'8 \cdot 151'92 \cdot 1 \cdot 0'855 = \boxed{1'273 MW = Pot_{ard}}$$

$$Pot = M\omega \Rightarrow M = \frac{Pot}{\omega} = \frac{1'273 \cdot 10^6}{500 \frac{2\pi}{60}} = \boxed{24311'32 Nm = M}$$

e) Txomotaren abiadura, errodetearen abiadura eta txomotaren abiadura erlatiboa errodetearen sarreran?

$C_y = 0'975$

Errodetearen abiadura: $u = \omega \cdot r = \frac{2\pi N}{60} \cdot r = \frac{2\pi \cdot 500}{60} \cdot \frac{0'88}{2} = \boxed{23'04 m/s = u}$

Txomoaren abiadura: $V_T = \sqrt{2g H_N} = \sqrt{2 \cdot 9'8 \cdot 151'92} = 54'5677 m/s$

$C_1 = V_T \cdot C_y = 54'5677 \cdot 0'975 = \boxed{53'203 m/s = c}$

Txomoaren abiadura errodetearekiko: $w = c - u = 53'203 - 23'04 = \boxed{30'1635 m/s = w}$

?? f) Txomoen Ø eta Ø tobera? $C_{CH} = 0'6$

$Q = V \cdot A = 2 \cdot C_1 \cdot A = 2 \cdot 53'203 \cdot \frac{\pi D^2}{4} = 1$

↳ injektio ditudalako

$\boxed{D_{Tx} = 0'109 m}$

(formula nondik?)

$C_{CH} = \frac{A_{txomota}}{A_{Tobera}} = \frac{\frac{\pi D_{txo}^2}{4}}{\frac{\pi D_{tob}^2}{4}} = \frac{D_{txo}^2}{D_{tob}^2} \Rightarrow D_{tob} = \sqrt{\frac{D_{txo}^2}{C_{CH}}} = \sqrt{\frac{0'109^2}{0'6}} = 0'1412 m$

$\boxed{D_{tob} = 0'1412 m}$

g) $\eta_{injec.}$?

→ bernolli $\frac{P}{\gamma} + z + \frac{V^2}{2g} = H$ (atm, 0)

$\eta_{injek} = \frac{P_{irt}}{P_{sart}} = \frac{\rho g H Q}{\rho g H_N Q} = \frac{H}{H_N} = \frac{\frac{V^2}{2g}}{H_N} = \frac{\frac{53'203^2}{2 \cdot 9'8}}{151'92} = \boxed{0'95 = \eta_{injek}}$

h) Sobrepresión producida por el golpe de ariete?

$E_F (15C) = 22000 \, kg/cm^2 \cdot 98000 = 2'156 \cdot 10^9 \, N/m^2$

Altzairua denez:

$E_T = 2'2 \cdot 10^6 \, kg/cm^2$

$c = \sqrt{\frac{E_F}{\rho \left[1 + \frac{E_F}{E_T} \frac{Ø}{e}\right]}} = \sqrt{\frac{2'156 \cdot 10^9}{1000 \left[1 + \frac{22000}{2'2 \cdot 10^6} \cdot \frac{0'8}{0'006}\right]}} = 961'25 \, m/s$

$\frac{2L}{c} = \frac{2 \cdot 525}{961'25} = 1'09 s \Rightarrow t > \frac{2L}{c}$ → Ixte motela

$\Delta h = k \frac{L v}{g \, t_{ixte}} = 2 \frac{525 \cdot \frac{1}{\frac{\pi 0'8^2}{4}}}{9'8 \cdot 3'5} = \boxed{60'9 \, m \, ur = \Delta h}$

23.12)

$W_{eder} = 300\ kW$

$\eta_T = 0'85$

$\eta_h = 0'9$

$r_1 = 200\ cm$

$r_2 = 100\ cm$

$\alpha_1 = 15^\circ$

$\beta_1 = 60^\circ$

$h_2 = 0'9$

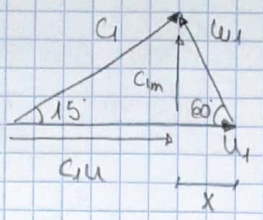
$b_2 = 200\ mm$

$N = 100\ rpm$

$Q = 1'5\ m^3/s$

a) Abiadura hirukiak

Samera hirukia



$u_1 = \omega r_1 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi 100}{60} \cdot 2 = 20'944\ m/s$

$\boxed{u_1 = 20'944\ m/s}$

$$\begin{cases} u_1 = c_{1u} + x \rightarrow c_{1u} + x = 20'944 \\ tg\,\alpha_1 = \frac{c_{1m}}{c_{1u}} \rightarrow tg\alpha\, c_{1u} - c_{1m} = 0 \\ tg\,\beta_1 = \frac{c_{1m}}{x} \rightarrow c_{1m} - tg\beta\, x = 0 \end{cases}$$

$c_{1u} = 18'138\ m/s$

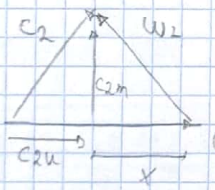
$c_{1m} = 4'86\ m/s$

$x = 2'806\ m/s$

$\sin\beta_1 = \frac{c_{1m}}{w_1} \Rightarrow w_1 = \frac{c_{1m}}{\sin\beta_1} = \frac{4'86}{\sin 60} = \boxed{56'118\ m/s = w_1}$

$\sin\alpha_1 = \frac{c_{1m}}{c_1} \Rightarrow c_1 = \frac{c_{1m}}{\sin\alpha_1} = \frac{4'86}{\sin 15} = \boxed{187'776\ m/s = c_1}$

Irteera:



$u_2 = \omega r_2 = \frac{2\pi N}{60} \cdot r_2 = \frac{2\pi 100}{60} \cdot 1 = \boxed{10'472\ m/s = u_2}$

$Q = c_{2m}\,\pi\, h_2\, b_2\, D_2$

$1'5 = c_{2m}\,\pi\, 0'9\, 0'2\, (2 \cdot 1)$

$c_{2m} = 1'1263\ m/s$

b) ataleon lortutako datuekin: $H_E = 26'77\ m\ u_2$

$H_e = \frac{c_u u_1 - c_{2u} u_2}{g} \Rightarrow 26'77 = \frac{18'138 \cdot 20'944 - c_{2u} \cdot 10'472}{9'8}$

$c_{2u} = 11'22\ m/s$

$c_2 = \sqrt{c_{2m}^2 + c_{2u}^2} = \sqrt{1'1263^2 + 11'22^2} = \boxed{11'3\ m/s = c_2}$

$tg\,\alpha_2 = \frac{c_{2m}}{c_{2u}} = \frac{1'1263}{11'22} \Rightarrow \boxed{\alpha_2 = 6'74^\circ}$

$tg\,\beta_2 = \frac{c_{2m}}{u_2 - c_{2u}} = \frac{1'32}{10'47 - 11'3} \Rightarrow \boxed{\beta_2 = -57'83^\circ}$

$\sin\beta_2 = \frac{c_{2m}}{w_2} \Rightarrow w_2 = \frac{c_{2m}}{\sin\beta_2} = \frac{1'1263}{\sin 57'83} = \boxed{1'56\ m/s = w_2}$

? b) Abiadura espezifikoa eta (e turbina mota)

$n_s = \frac{N\sqrt{Pe}}{Hm^{5/4}}$

Zergatik Wmek

$W_e = W_{mek} \cdot \eta_T \Rightarrow W_{mek} = \frac{W_e}{\eta_T} = \frac{300}{0'85} = 352'94 \, kW$

$W_{mek} = W_H \cdot \eta_H \Rightarrow W_H = \frac{W_{mek}}{\eta_H} = \frac{352'94}{0'9} = 392'157 \, kW$

Zergatik erabili behar dugu Hm (orten?)

$W_{Teo} = \rho g H_E \varphi \Rightarrow 392'157 \cdot 10^3 = 1000 \cdot 9'8 \cdot H_E \cdot 1'5$

$H_E = 26'77 \, mUt$

$Hm = He \, \eta_H = 26'77 \cdot 0'9 = 24 \, mUt$

$n_s = \frac{N\sqrt{Pe}}{Hm^{5/4}} = \frac{100\sqrt{\frac{300 \cdot 10^3}{736}}}{24^{5/4}} = \boxed{38 \, rpm = n_s}$ PELTON TURBINA

c) $N = 200 \, rpm$ — karga potentzia, ~~eta~~ karga altuera eta emaria

$\varnothing = 500 \, cm$

Homologoak:

$\lambda = \frac{D_2}{D_1} = \frac{500}{400} = \frac{5}{4} = 1'25$

$\frac{N_2}{N_1} = \left(\frac{H_2}{H_1}\right)^{1/2} \frac{1}{\lambda}$

$\frac{200}{100} = \left(\frac{H_2}{24}\right)^{1/2} \frac{1}{1'25} \Rightarrow \boxed{H_2 = 150 m}$

$\frac{P_2}{P_1} = \left(\frac{H_2}{H_1}\right)^{3/2} \lambda^2$

$\frac{P_2}{300} = \left(\frac{150}{24}\right)^{3/2} 1'25^2 \Rightarrow \boxed{P_2 = 7324'22 \, kW}$

$\frac{\varphi_2}{\varphi_1} = \left(\frac{H_2}{H_1}\right)^{1/2} \lambda^2$

$\frac{\varphi_2}{1'5} = \left(\frac{150}{24}\right)^{1/2} 1'25^2 \Rightarrow \boxed{\varphi_2 = 5'86 \, m^3/s}$

23.13)

24 talde

$P = 240 \, MW$

$N = 94 \, rpm$

$H = 4'5 \, m$

$\varphi = 285 \, m^3/s$

$n_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{94\sqrt{\frac{240 \cdot 10^6}{24 \cdot 736}}}{4'5^{5/4}} = \boxed{1671'75 \, rpm = n_s}$

$P = \rho g H \varphi = 1000 \cdot 9'8 \cdot 4'5 \cdot 285 = 12'5685 \cdot 10^6 \, W$

$\eta = \frac{P_T}{P} = \frac{\frac{240 \cdot 10^6}{24}}{12'5685 \cdot 10^6} = 0'7956 \Rightarrow \boxed{\eta = \% 79'56}$

23.14)

$N = 375$ rpm

$\beta_1 = 90°$

$\alpha_1 = 9°$

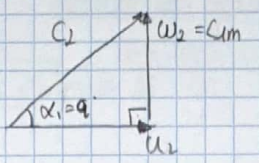
$c_{1m} = c_{2m} = 1'9$ m/s

$D_2 = 0'5\, D_1$

$b_1 = 100$ mm

$c_{2u} = 0$ m/s

a) Eulerren ekuera



$$\operatorname{tg}\alpha_1 = \frac{w_2}{u_2} \Rightarrow u_2 = \frac{w_2}{\operatorname{tg}\alpha_1} = \frac{1'9}{\operatorname{tg} 9}$$

$$\boxed{u_2 = 11'996 \text{ m/s}}$$

$$\sin\alpha_1 = \frac{w_2}{c_2} \Rightarrow c_2 = \frac{w_2}{\sin\alpha_1} = \frac{1'9}{\sin 9}$$

$$\boxed{c_2 = 12'145 \text{ m/s}}$$

$$\boxed{w_2 = 1'9 \text{ m/s}}$$

$$He = \frac{c_{1u}u_1 - c_{2u}u_2}{g} = \frac{11'996 \cdot 11'996}{9'8} = \boxed{14'68 \text{ m} \; u_2 = He}$$

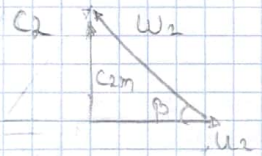
b) β_2?

$$u_1 = \omega \cdot r_1 \Rightarrow 11'996 = \frac{2\pi\, 375}{60} \cdot r_1$$

$$r_1 = 0'305 \text{ m}$$

$$D_1 = 0'611 \text{ m}$$

$$D_2 = 0'5 \cdot D_1 = 0'5 \cdot 0'611 = 0'305 \text{ m}$$



$$u_2 = \omega \cdot r_2 = \frac{2\pi N}{60} r_2 = \frac{2\pi \cdot 375}{60} \cdot \frac{0'305}{2} = 5'998 \text{ m/s}$$

$$\operatorname{tg}\beta_2 = \frac{c_{2m}}{u_2} = \frac{1'9}{5'998} \Rightarrow \boxed{\beta_2 = 17'576°}$$

c) Sarrera eta irteera diametroak

$$\boxed{D_1 = 0'611 \text{ m}}$$

$$\boxed{D_2 = 0'305 \text{ m}}$$

d) Emaria

$$\varphi = c_{1m}\, \pi\, k_1\, b_1\, D_1 = 1'9\, \pi\, 0'1 \cdot 0'611 = 0'364 \text{ m}^3/\text{s}$$

$$\boxed{\varphi = 364'7 \text{ l/s}}$$

23.15)

$\varphi = 33 \text{ m}^3/\text{s}$

$N = 150$ rpm

$\eta_m = 1.70$

$D_1 = 300$ cm

$D_2 = 240$ cm

$b_1 = 300$ mm $= b_2$

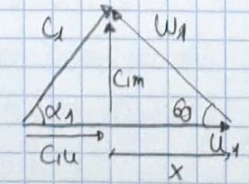
$k_1 = 0'95$

$k_2 = 0'92$

$\beta_1 = 60°$

$\alpha_2 = 90°$

a) Abiadura hirukiak



$$u_1 = \omega \cdot r_1 = \frac{2\pi N}{60} \cdot r_1 = \frac{2\pi 150}{60} \cdot \frac{3}{2} = \boxed{23'562 \text{ m/s} = u_1}$$

$$\varphi = c_{1m}\, \pi\, k_1\, b_1\, D_1$$

$$33 = c_{1m}\, \pi\, 0'95\, 0'3 \cdot 3 \Rightarrow c_{1m} = 12'28 \text{ m/s}$$

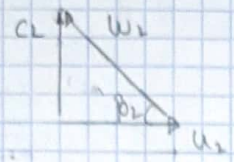
$$\sin\beta_2 = \frac{c_{1m}}{w_1} \Rightarrow w_1 = \frac{c_{1m}}{\sin\beta_2} = \frac{12'28}{\sin 60} = \boxed{14'18 \text{ m/s} = w_2}$$

$$\operatorname{tg}\beta_2 = \frac{c_{2m}}{x} \Rightarrow x = \frac{c_{2m}}{\operatorname{tg}\beta_2} = \frac{12'28}{\operatorname{tg}60} = 7'09 \text{ m/s}$$

$$\operatorname{tg}\alpha_1 = \frac{c_{1m}}{u_2 - x} = \frac{12'28}{23'562 - 7'09} \Rightarrow \boxed{\alpha_1 = 36'70^\circ}$$

$$\operatorname{sin}\alpha_1 = \frac{c_{1m}}{c_1} \Rightarrow c_1 = \frac{c_{1m}}{\operatorname{sin}\alpha_1} = \frac{12'28}{\operatorname{sin}36'7} = \boxed{20'5458 \text{ m/s} = c_1}$$

Triangulo:



$$u_2 = \omega \cdot r_2 = \frac{2\pi N}{60} r_2 = \frac{2\pi 150}{60} \cdot \frac{2'4}{2} = \boxed{18'85 \text{ m/s} = u_2}$$

$$\varphi = c_{2m}\, \pi\, k_2\, b_2\, D_2$$

$$33 = c_{2m}\, \pi\, 0'92 \cdot 0'3 \cdot 2'4 \Rightarrow c_{2m} = 15'857 \text{ m/s}$$

$$\boxed{c_2 = 15'857 \text{ m/s}}$$

$$w_2 = \sqrt{c_2^2 + u_2^2} = \sqrt{15'857^2 + 18'85^2} = \boxed{24'63 \text{ m/s} = w_2}$$

$$\operatorname{tg}\beta_2 = \frac{c_2}{u_2} = \frac{15'857}{18'85} \Rightarrow \boxed{\beta_2 = 40'07^\circ}$$

b) Potencia erabilgarria

$$He = \frac{c_1 u u_1 - c_2 u u_2}{g} = \frac{(23'562 - 7'09) \cdot 23'562}{9'8} = 39'6 \text{ m}$$

$$Hm = He\, \eta_H = 39'6 \cdot 0'7 = 27'722 \text{ m}$$

$$P_H = \delta g\, Hm\, \varphi = 1000 \cdot 9'8 \cdot 27'722 \cdot 33 = 8955416'398 \text{ W}$$

$$\boxed{P_H = 8'955 \text{ MW}}$$

c)

$$n_s = \frac{N\sqrt{P_e}}{Hm^{5/4}} = \frac{150\sqrt{\frac{8'96 \cdot 10^6}{736}}}{27'722^{5/4}} = 260'26 \text{ rpm}$$ Francis turbina lotharra

23.18)

N = 100 rpm

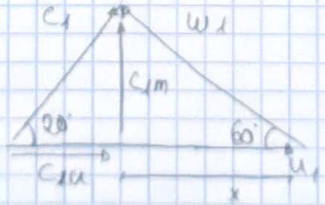
φ = 0'28 m³/s

r_1 = 0'5 m

r_2 = 0'25 m

α_1 = 120°

β_1 = 60°



$$u_1 = \omega r_1 = \frac{2\pi N}{60} r_1 = \frac{2\pi 100}{60} 0'5$$

$$u_1 = 5'236 \text{ m/s}$$

$$\begin{cases} u_1 = c_1 u + x \rightarrow c_1 u + x = 5'236 \\ \operatorname{tg}60 = \frac{c_{1m}}{x} \rightarrow x \operatorname{tg}60 - c_{1m} = 0 \\ \operatorname{tg}20 = \frac{c_{1m}}{c_{1u}} \rightarrow c_{1u} \operatorname{tg}20 - c_{1m} = 0 \end{cases}$$

$$c_1 u = 4'326 \text{ m/s}$$

$$c_{1m} = 1'575 \text{ m/s}$$

$$x = 0'91 \text{ m/s}$$

$$c_1 = \sqrt{4'326^2 + 1'575^2} = \boxed{4'604 \text{ m/s} = c_1}$$

23.19)

$N = 375$ rpm
$H_N = 60$ m
$Pot_{mek} = 600$ kW
$u = 0'45\sqrt{2gH}$
$c_1 = 0'97\sqrt{2gH}$
$\eta_T = 0'8$
$c_1 = 1'5$ m/s

Ardatzeko potentzia mekanikoa dela esaten badigute Pot elektriko bezala hartzen dugu.

a) Emaria?

$Pot = \delta g H Q \eta_T$

$600 \cdot 10^3 = 1000 \cdot 9'8 \cdot 60 \cdot Q \cdot \eta_T$

$\boxed{Q = 0'2126 \, m^3/s}$

b) Emoldetzearen diametroa?

$u = 0'45\sqrt{2gH} = 0'45\sqrt{2 \cdot 9'8 \cdot 60} = 15'4317$ m/s

$u = \omega \cdot r = \frac{2\pi N}{60} \cdot r \Rightarrow r = \frac{u \cdot 60}{2\pi N} = \frac{15'4317 \cdot 60}{2\pi \, 375} = 0'393$ m

$d = 2r = 2 \cdot 0'393 = \boxed{0'786 \, m = d}$

c) Zonotadaren diametroa?

$c_1 = 0'97\sqrt{2gH} = 0'97\sqrt{2 \cdot 9'8 \cdot 60} = 33'26$ m/s

$Q = c_1 \cdot A \Rightarrow A = \frac{Q}{c_1} = \frac{0'21}{33'26} = 6'39 \cdot 10^{-3} \, m^2$

$A = \frac{\pi d^2}{4} \Rightarrow 6'39 \cdot 10^{-3} = \frac{\pi d^2}{4}$

$\boxed{d = 0'09 m}$

d) Manometroaren irakurketa injektorearen sarreran

$\frac{p_{in}}{\gamma} + z_{in} + \frac{v_{in}^2}{2g} = \frac{p_{atm}}{\gamma} + z_{atm} + \frac{v_{atm}^2}{2g}$

$\frac{p_{in}}{\gamma} = \frac{33'26^2}{2g} - \frac{1'5^2}{2g} = 56'32$ m/t

$\boxed{p_{in} = 5'52 \, 10^5 \, Pa}$

23.20)

$P = 5'4$ MW
$n_s = 25$ rpm
$L = 790$ m
$H = 350$ m
$h_a = 0'05H$
$K_v = 0'98$
$u/c = 0'46$
$\eta_T = 0'85$
$\eta_g = 0'96$

a) Bihurgailuaren abiadura

$n_s = \frac{N\sqrt{P}}{H^{5/4}} \Rightarrow 25 = \frac{N\sqrt{\frac{5'4 \cdot 10^6}{736}}}{(350 \cdot 0'95)^{5/4}}$

$\boxed{N = 414'4 \text{ rpm}}$

b) Zorrotadaren diametroa

$$P = \rho g H_N \eta$$

$$V_T = \sqrt{2gH_N} = \sqrt{2g(350 \cdot 0'95)} = 80'728 \, m/s$$

$$V_r = V_T C_v = 80'728 \cdot 0'98 = 79'11 \, m/s$$

$$P = \rho g H_N \eta \varphi \Rightarrow 5'4 \cdot 10^6 = 1000 \cdot 9'8 \cdot (350 \cdot 0'95) \varphi \cdot 0'85$$

$$\varphi = 1'95 \, m^3/s$$

$$\varphi = V_r \cdot A \Rightarrow 1'95 = 79'11 \cdot \frac{\pi d^2}{4}$$

$$\boxed{d = 0'1714 m}$$

c) Ernadetearen diametroa?

$$u/C = 0'46 \rightarrow u = 0'46 \cdot 79'11 = 36'39 \, m/s$$

$$C = V_r$$

$$u = \omega \cdot r = \frac{2\pi N}{60} \frac{D}{2} \Rightarrow 36'39 = \frac{2\pi 414'4}{60} \frac{D}{2}$$

$$\boxed{D = 1'677 m}$$

d) Hodiaren diametroa?

$$h_g = f \frac{L}{D} \frac{V^2}{2g} \Rightarrow 350 \cdot 0'05 = \frac{8 \cdot 0'006 \cdot 790 \cdot (1'95)^2}{9'8 \cdot \pi^2 \cdot D^5}$$

$$\boxed{D = 0'61 m}$$

25. GAIA: Ponpaketa - instalazioak

25.1) Manometroaren irakurketa?

3 balbula itxita

$H_D = 3\,m$

$L_{asp} = 10m$ aspiratzio

$L_{inp} = 190m$

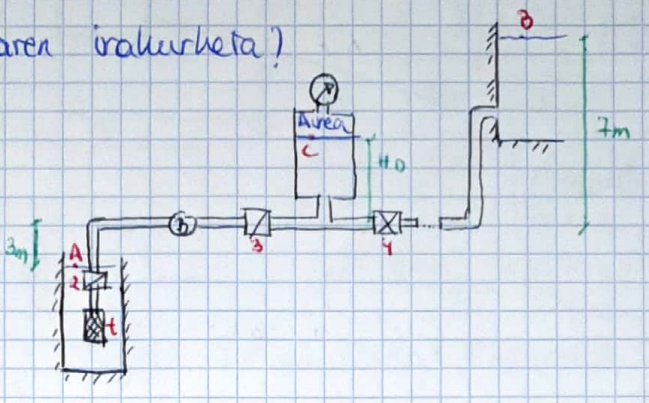
$k_t = 30$

$k_2 = k_3 = 1'5$

$k_4 = 0'1$

$f = 0'02$

$D = 0'2m$



a) $H_B = H_C$ (ura geldiak dagoenez, ez dago h_R)

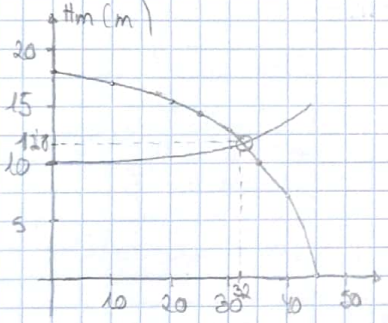
$$\frac{p_B}{\gamma}^{atm} + z_B + \frac{v_B^2}{2g}^{0} = \frac{p_C}{\gamma} + z_C + \frac{v_C^2}{2g}^{0}$$

$$\frac{p_C}{\gamma} = z_B - z_C = 7 - 3 = 4\,m\,H_2O$$

$$\boxed{p_C = 0'4\,kg/cm^2}$$

b) Ponparen funtzionamendu puntua?

Taula: kurba karakterizatzeko



Instalazioaren ekuazioa:

$$H_A + H_m = H_B + h_{R_j} + h_{R_x}$$

$$\frac{p_A}{\gamma}^{0} + z_A^{0} + \frac{v_A^2}{2g}^{0} + H_m = \frac{p_B}{\gamma}^{0} + z_B + \frac{v_B^2}{2g}^{0} + \frac{8fL}{g\pi^2 D^5}Q^2 + \frac{8\sum k}{g\pi^2 D^4}Q^2$$

$$H_m = (3+7) + \frac{8\cdot 0'02\,(10+190)}{9'8\,\pi^2\,0'2^5}Q^2 + \frac{8(30+1'5+1'5+0'1)}{9'8\,\pi^2\,0'2^4}Q^2$$

$$H_m = 10 + 2744'977\,Q^2$$

$Q = 20\,l/s \Rightarrow H_m = 11'11\,m$

$Q = 30\,l/s \Rightarrow H_m = 12'468\,m$

$Q = 35\,l/s \Rightarrow H_m = 13'42\,m$

$\boxed{Q = 32\,l/s \Rightarrow H_m = 12'81\,m}$

25.2)

$N = 250\,rpm$

$Q = 16\,l/s$

$\eta = 0'81$

a) Ponpak zurgatzen duen potentzia [2P]?

Grafikotik lortu ondoren egingo da, baina ez da eter ikusten.

25.3)

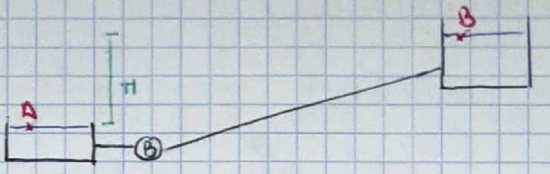
L = 600m

D = 500mm

ε = 0'5

H = 8m

T = 20C



Emaria?

$H_A + H_m = H_B + h_R$

f? Gurtie turbolento betetako hartuko dugu

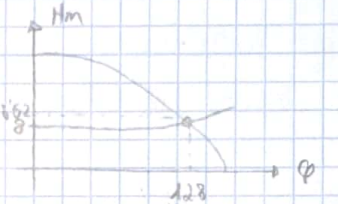
$\frac{\varepsilon}{D} = \frac{0'5}{500} = 0'001 \Rightarrow f = 0'02$

$H_A + H_m = H_B + h_R$

$\frac{p_A}{\gamma} + z_A + \frac{v_A^2}{2g} + H_m = \frac{p_B}{\gamma} + z_B + \frac{v_B^2}{2g} + \frac{8 f L Q^2}{g \pi^2 D^5}$

$H_m = 8 + \frac{8 \cdot 0'02 \cdot 600 \cdot Q^2}{9'8 \, \pi^2 \, 0'5^5}$

$H_m = 8 + 31'761 Q^2$



$Q = 100 \, l/s \Rightarrow H_m = 8'3176 m$

$Q = 116 \, l/s \Rightarrow H_m = 8'427 m$

$Q = 120 \, l/s \Rightarrow H_m = 8'457 m$

$Q = 130 \, l/s \Rightarrow H_m = 8'536 m$

$\Rightarrow$ **$Q = 128 \, l/s \Rightarrow H_m = 8'52 m$**

25.4)

N = 1750rpm

D = 15cm

L = 450m

f = 0'025

Karga altuera eta emaria?

$H_m = 10 + \frac{8 f L Q^2}{g \pi^2 D^5} = 10 + \frac{8 \cdot 0'025 \, 450 \, Q^2}{9'8 \, \pi^2 \, 0'15^5} = 10 + 12253'5 Q^2$

$Q = 0'026 \, m^3/s \Rightarrow H_m = 18'28 m$

Karga estatikoa 10m

Galera sekundarioak inesprietza

25.5)

$Q = 35\ l/s = 0'035\ m^3/s$

$L_1 = 120\ m$

$L_2 = 480\ m$

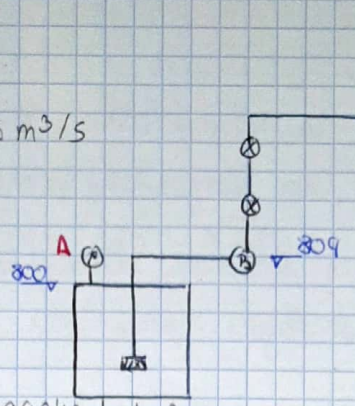
$\phi = 200\ mm$

Burdindutako hodia

$T = 15C \quad \rho(15C) = 999'12\ kg/m^3$

$P_A(abs) = 1'2\ kg/cm^2$

$P_B(man) = 3'5\ kg/cm^2$



a) $P_{abs} = P_{atm} + P_{man}$

B puntuko presioa lortzeko aneroi laurdiko 17-5 ormaldeko TAULA:

H	P/P_0
500	0'9421
832	X
1000	0'8870

$X = 0'9055$

$\frac{P_{832}}{P_0} \Rightarrow P_{832} = 0'9055 \cdot P_0$

$P_{832} = 0'9055 \cdot 1'013 \cdot 10^5$

$\boxed{P_{832} = 91728'52\ Pa}$

b) $H_A + H_m = H_B + h_2$

f? $\quad \nu(15C) = 1'142 \cdot 10^{-6}\ m^2/s$

$Q = A \cdot v \Rightarrow v = \frac{Q}{A} = \frac{0'035\ m^3/s}{\frac{\pi\ 0'2^2}{4}} = 1'114\ m/s$

$Re = \frac{v D}{\nu} = \frac{1'114 \cdot 0'2}{1'142 \cdot 10^{-6}} = 1'951\ 10^5$

$\frac{\varepsilon}{D} = \frac{0'25}{200} = 0'00125$

$\Rightarrow f = 0'022$

$H_A + H_m = H_B + h_2$

$\frac{P_A}{\gamma} + \cancel{z_A} + \frac{v_A^2}{2g} + H_m = \frac{P_B}{\gamma} + z_B + \frac{v_B^2}{2g} + \frac{8 f L Q^2}{g \pi^2 D^5}$

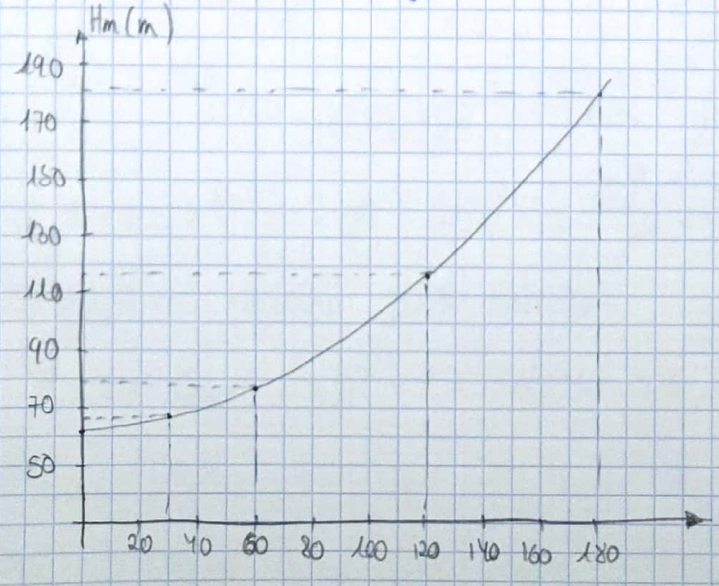
$\frac{117679'8}{999'12 \cdot 9'8} + H_m = \left(\frac{343232'75 + 91728'52}{999'12 \cdot 9'8}\right) + 32 + \frac{8 \cdot 0'022 \cdot (120 + 480 + 10 + 2 + 12 + (3 \cdot 5))}{9'8\ \pi^2\ 0'02^5} Q^2$

$\boxed{H_m = 64'4 + 36336\ Q^2}$

Taula:

Q	0	30	60	120	180	[l/s]
Hm	64'4	67'67	77'44	116'72	182'12	[m]

c) Kurbaren adierazpen grafikoa eskalan



d) Ponpa egokiena aukeratu

Et dira grafikoak ondo ilustes

e) Ponpak emandako Q, Hm eta kurgatutako potentzia?

$\boxed{Q = 35\ l/s} \Rightarrow Hm = 64'4 + 36336 \cdot 0'035^2 = \boxed{68'85 m = Hm}$

f) NPSH? Kabitazio arriskua dago?

$$NPSH_{erab} = \frac{p_A - p_s}{\gamma} - z_2 - h_{A\to 2}$$

$p_s (15^\circ C) = 0'0176\ kg/cm^2 \Rightarrow 1725'9704\ Pa$

$$NPSH_{erab} = \frac{117679'8 - 1725'9704}{999'12 \cdot 9'8} - 9 - \frac{8 \cdot 0'022 \cdot (120+10+5) \cdot 0'035^2}{9'8 \cdot \pi^2 \cdot 0'25}$$

$NPSH_{erab} = 1'9\ mCz$

Kabitazioa gertatuko den ala ez jakiteko grafikoan begiratu, baina ez da ilustes.

Et x 25.6)

$L_1 = L_2 = L_3 = 300m$

$D_1 = 20cm$

$D_2 = 30cm$

$D_3 = 45cm$

$\varepsilon_1 = \varepsilon_2 = 0'08cm$

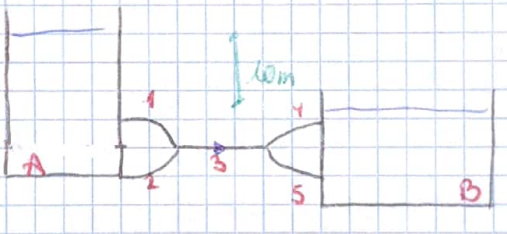
$\varepsilon_3 = 0'036cm$

$L_4 = 600m$

$D_4 = D_5 = 30cm$

$\varepsilon_4 = \varepsilon_5 = 0'003cm$

$L_5 = 720m$



$H_A = H_B + h_e$

f?

1) $\frac{\varepsilon_1}{D_1} = \frac{0'8}{200} = 0'004 \Rightarrow f_1 = 0'028$

2) $\frac{\varepsilon_2}{D_2} = \frac{0'8}{300} = 0'0026 \Rightarrow f_2 = 0'025$

3) $\frac{\varepsilon_3}{D_3} = \frac{0'36}{450} = 0'0008 \Rightarrow f_3 = 0'019$

4) $\frac{\varepsilon_4}{D_4} = \frac{0'03}{300} = 0'0001 \Rightarrow f_4 = 0'012$

5) $\frac{\varepsilon_5}{D_5} = \frac{0'03}{300} = 0'0001 \Rightarrow f_5 = 0'012$

25.7)

$H = H(\varphi) \rightarrow H = 65'2 - 150'6\varphi^2$

$\eta = \eta(\varphi) \rightarrow \eta = 7'13\varphi - 17'64\varphi^2$

a) Ponpareo diseinu puntua finkatu eta eteluin optimoaren % 98 gora lan egiteko altuera eta emari tarteak finkatu

ηoptimoa kalkulatu behar dugun emari maximoa: (deribatua)

$$\frac{d\eta}{d\varphi} = \frac{d(7'13\varphi - 17'64\varphi^2)}{d\varphi} = 7'13 - 35'28\varphi = 0$$

$$\varphi = 0'2021 \, m^3/s$$

ηoptimoa $= 7'13\varphi - 17'64\varphi^2 = 7'13 \cdot 0'2021 - 17'64 \cdot 0'2021^2 = 0'72$

$\boxed{\eta_{opt} = \% 72}$

$\eta = \eta_{opt} \cdot 0'98 = 0'706 \Rightarrow \eta = 7'13\varphi - 17'64\varphi^2$

$0'706 = 7'13\varphi - 17'64\varphi^2$ $\begin{cases} \varphi_1 = 0'231 m^3/s \\ \varphi_2 = 0'1734 m/s \end{cases}$

$\begin{cases} \varphi_1 = 0'231 m^3/s \Rightarrow H_1 = 65'2 - 150'6 \cdot 0'231^2 = 57'16m \\ \varphi_2 = 0'173 m^3/s \Rightarrow H_2 = 65'2 - 150'6 \cdot 0'1734^2 = 60'672m \end{cases}$

$\varphi = 220$ l/s

$H = 50m$

$\phi = 477mm$

$L = 3800m$

b) $f = 0'014$, Instalazioaren kurba karakteristikoa

$H_A + H_m = H_B + h_e$

$$\cancel{\frac{p_A}{\delta}} + \cancel{z_A} + \cancel{\frac{v_A^2}{2g}}^{0} + H_m = \frac{p_B}{\delta} + z_B + \frac{v_B^2}{2g} + \frac{8fL\varphi^2}{g\pi^2 D^5}$$

$$H_m = 50 + \frac{2 \cdot 0'014 \cdot 3800}{9'8\,\pi^2\, 0'477^5}\varphi^2$$

$\boxed{H_m = 50 + 178'19\varphi^2}$

c) Funtzionamendu puntua

$\varphi = 220$ l/s -ko balioak rango barruan ematen digu. Beraz ez du beharrezkoa funtzionamendu puntu balioa izan

$50 + 178'19\varphi^2 = 65'2 - 150'6\varphi^2$

$\boxed{\varphi = 0'215 m^3/s}$

$H = 65'2 - 150'6\varphi^2 = 65'2 - 150'6 \cdot 0'215^2 = \boxed{58'24m = H}$

d) Ponpareo eteluna puntu horretan

$\eta = 7'13\varphi - 17'64\varphi^2 = 7'13 \cdot 0'215 - 17'64\, 0'215^2 = 0'7175$

$\boxed{\eta = \% 71'75}$

25.8)

$\rho_r = 1'1 \cdot 10^3$ kg/m³

$\varphi = 100$ m³/h

$H_A = 900$ m

$H_B = 974$ m

$L_{asp} = 30$ m

$k_{bal} = 2'5$

$k_{uk} = 0'5 \times 4$

$L_{inp} = 1250$ m

$k_{bal-ita} = 1'5$

$k_{esk} = 0'05$

$k_T = 1'5$

$k_{kan-pal} = 0'1$

$\varepsilon = 0'01$ cm

$\phi = 200$ mm

a) kurba karakteristikoa eta grafikoa eskalan

? $\mu(20^\circ C) = 10'25 \cdot 10^{-5} \cdot 9'8 = 1'0045 \cdot 10^{-3}$ N/m²

$$Re = \frac{\rho_r v D}{\mu} = \frac{\rho_r \frac{4\varphi}{\pi D^2} D}{\mu} = \frac{4 \rho_r \varphi}{\pi \mu D} = \frac{4 \cdot 1'1 \cdot 10^3 \frac{100}{3600}}{\pi \cdot 1'0045 \cdot 10^{-3} \, 0'2}$$

$$\begin{cases} Re = 1'9365 \cdot 10^5 \\ \frac{\varepsilon}{D} = \frac{0'1}{200} = 0'0005 \end{cases} \Rightarrow f = 0'019$$

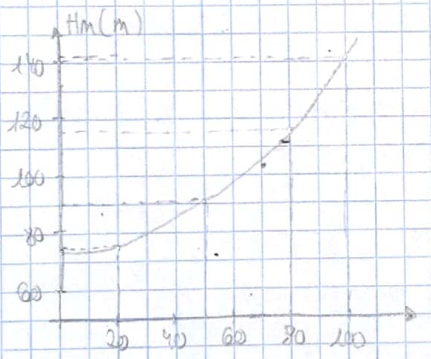
$$H_A + H_m = H_B + h_{R_s} + h_{R_k}$$

$$H_A + H_m = H_B + \frac{8 f L \varphi^2}{g \pi^2 D^5} + \frac{8 \Sigma k \varphi^2}{g \pi^2 D^4}$$

$$900 + H_m = 974 + \frac{8 \, 0'019 \cdot (30 + 1250) \cdot (\varphi^2)}{9'8 \, \pi^2 \, 0'2^5} + \frac{8 (2'5 + 2 + 1'5 + 0'05 + 1'5 + 0'1) \varphi^2}{9'8 \, \pi^2 \, 0'2^4}$$

$$\boxed{H_m = 74 + 6681'51 \, \varphi^2}$$

φ	0	20	50	80	100	[l/s]
H_m	74	74'67	90'7	116'76	140'8	[m]



b) Ponpa egokiena aukeratu

$H_m = 74 + 6681'51 \left(\frac{100}{3600}\right)^2 = 79'15$ m

INP 05/250 aukeratzen nuke errendimendu hobeagoa delako

? c) Hm, φ, eteklina eta potentzia?

d) $h = 901\,m$ — kabitatzeko amitzea aztaldu.

$NPSH_{erab}$ eta $NPSH_{esk}$?

$NPSH_{esk} = 4'5\,m$ grafikotik kurbatako datua

$p_s = 0'0239\ kg/cm^2$

$NPSH_{erab}$. kurbako 17-5 orrieta liburuko taula

$T(20^\circ C)$

$p_s = 2343'78935\,Pa$

h	p/p₀
500	0'9421
901	x
1000	0'8870

$x = 0'8979$

$$\frac{p_1}{p_0} = 0'8979 \Rightarrow p_1 = 0'8979 \cdot p_0$$

$$p_1 = 0'8979 \cdot 1'013 \cdot 10^5$$

$$p_1 = 90958'26274\,Pa$$

$$NPSH_{erab} = \frac{p_1 - p_s}{\gamma} - z_2 - h_{r\,1-2}$$

→ c ataleko emaitzetan

$$NPSH_{erab} = \frac{90958'26274 - 2343'78935}{11103 \cdot 9'8} - 1 - \frac{8\,0'019\,30\left(\frac{105}{3600}\right)^2}{9'8 \cdot \pi^2\, 0'2^5} - \frac{8\,(0'5+0'5)\left(\frac{105}{3600}\right)^2}{9'8\,\pi^2\,0'2^2}$$

$NPSH_{erab} = 6'963$

$NPSH_{erab} > 1'3\,NPSH_{esk} \Rightarrow 6'963 > 1'5 \cdot 4'5$

$6'963 > 6'75 \rightarrow$ Beraz ez dago kabitazioik emateko amitzerik. Gainera $NPSH_{erab}$ 6'963 izanda eta $NPSH_{esk}$ 4'5 izanda, horrek esan nahi du $NPSH_{sg}$. dagoela, eta kabitazioa emateko 0 izan ahi da

e) Δp arrete kolpea eragiten?

$k = 5'5$ Ora dela horrako degu k datua ematen digutelako.

$e = 18\,mm$

$$c = \frac{9900}{\sqrt{48'3 + k\frac{D}{e}}} = \frac{9900}{\sqrt{48'3 + 5'5\frac{200}{18}}} = 947'33\,m/s$$

$$t = c + k\,\frac{Lv}{gHm}$$

41 Taulan:

L	k
1000	1'5
1250	K
1500	1'25

$K = 1'375$

$$\frac{H}{L} = \frac{74}{1250} = 0'0592 \Rightarrow 5'92 \quad c = 1$$

$$V = \frac{Q}{A} = \frac{105/3600}{\frac{\pi\,0'2^2}{4}} = 0'9284\,m/s$$

$$t = c + k\,\frac{Lv}{gHm} = 1 + 1'375\,\frac{1250 \cdot 0'9284}{9'8 \cdot 80} = 3'0353\,s$$

↳ c ataleko kurbatako emaitza

$\frac{2L}{c} = \frac{2 \cdot 1250}{947'33} = 2'64\,s \Rightarrow t > \frac{2L}{c} \Rightarrow 3'0353 > 2'64$

Ixie motela

$\Delta h = k \frac{L}{g} \frac{V}{tute} = 2 \frac{1250 \cdot 0'9284}{9'8 \cdot 3'0353} = 78'027\,m\,Fz$

$\Delta p = \rho g \Delta h = 1100 \cdot 9'8 \cdot 78'027 = 841135'9668\,Pa$

$\boxed{\Delta p = 8'3\,atm}$

25. lo/

$h_m = 48 + 1'226 \cdot 10^{-5} Q^2$

kurba karakteristikoa:

$h = 59'74 - 3'48 \cdot 10^{-4} Q^2$

$NPSH_{esk} = 0'48 + 4'075 \cdot 10^{-5} Q^2$

$h_{asp} = 6$

$h_z = 5 \cdot 10^{-5} Q^2$

T(17'5ºC)

$h_{ps} = 0'21\,mUz$

$P_{atm} = 760\,mm\,Hg$

a) Ponparen funtzionamendu puntua

$h_m = h$

$48 + 1'226 \cdot 10^{-5} Q^2 = 59'74 - 3'48\,10^{-4} Q^2$

$Q = 180'52\,m^3/h$

$h_m = 48 + 1'226 \cdot 10^{-5} \left(\frac{180'52}{3600\,s}\right)^2$

$h_m = 48\,m$

$\boxed{Q = 180'52\,m^3/h}$

$\boxed{h_m = 48\,m}$

b) kabitazio anitzeko?

$NPSH_{esk} = 0'48 + 4'075 \cdot 10^{-5} \cdot 180^2 = 1'808\,mUz$

$h_z = 5 \cdot 10^{-5} \cdot 180^2 = 1'629\,mUz$

$\rho(17'5) = 998'675\,kg/m^3$

$p_{atm} = 760\,mm\,Hg = 101325'024\,Pa$

$NPSH_{erab} = \frac{p_{atm} - p_s}{\gamma} - z_{asp} - h_z = \frac{p_{atm}}{\gamma} - h_{ps} - z_{asp} - h_z$

$NPSH_{erab} = \frac{101325'024}{998'675 \cdot 9'8} - 0'21 - 6 - 1'629 = 2'51$

$NPSH_{erab} = 2'51\,mUz$

$NPSH_{erab} > 1'3\,NPSH_{esk} \Rightarrow 2'51 > 1'3 \cdot 1'808$

$2'51 > 2'35 \rightarrow$ Berak ET da kabitazioik emango.

c) $NPSH_{erab}$ $Q = 100\,m^3/h$ bada?

$NPSH_{erab} = \frac{101325'024}{998'675 \cdot 9'8} - 0'21 - 6 - 5 \cdot 10^{-5} \cdot 100^2 = 3'64\,mUz$

$\boxed{NPSH_{erab} = 3'64\,mUz}$

? **d) Emari maximoa ?**

$NPSH_{erab} = 2'35 = \frac{101325'024}{998'675 \cdot 9'8} - 0'21 - 6 - 5 \cdot 10^{-5} \varphi^2$

$\boxed{\varphi = 189'36 \ m^3/h}$

e) Funtzionamendu puntuan dagoen emariarekin aspirazio altuera maximoa

$NPSH_{erab} = 1'3 \ NPSH_{esk} = 1'3 \cdot 1'808 = 2'35$

$NPSH_{erab} = \frac{p_{atm}}{\gamma} - h_{ps} - z - h_R = \frac{101325'024}{998'675 \cdot 9'8} - 0'21 - z - 5 \cdot 10^{-5} \cdot 180'52^2$

$\boxed{z = 6'13 m}$

25.11)

$L = 1 \ km$

$z = 12$

$\varphi = 32 \ l/s$

$\varnothing = 15 \ cm$

$f = 0'02$

$k = 0'3$

$k_{sen} = 0'5$

$R_n = 10m$ ← 1km betetzeko 100 jarri behar dira

$k_2 = 1$

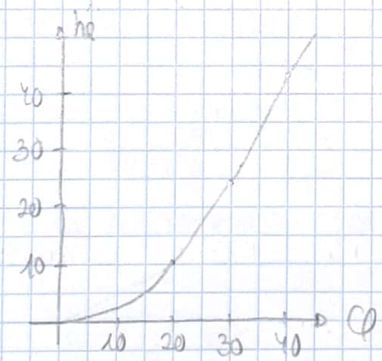
a) $h_R - \varphi$ kurba lortu

$h_R = \frac{8 f L \varphi^2}{g \pi^2 D^5} + \frac{8 \sum k \varphi^2}{g \pi^2 D^4}$

$h_R = \frac{8 \cdot 0'02 \cdot 1000 \cdot \varphi^2}{9'8 \pi^2 0'15^5} + \frac{8 (0'3 \cdot 100 + 0'5 + 1) \varphi^2}{9'8 \cdot \pi^2 \ 0'15^4}$

$h_R = 26930'48 \ \varphi^2$

φ	0	20	30	40	[l/s]
h_R	0	10'77	24'24	43'08	[m]



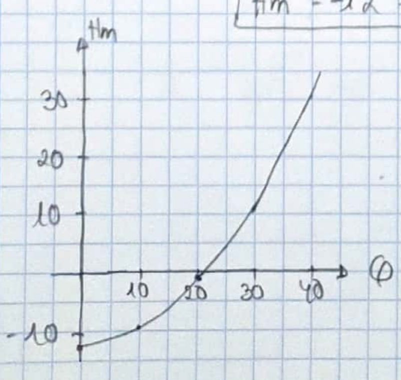
b) Ezin da, ~~dauden hodiak motzak direlako~~. ~~Gainera~~ $h_R = 27'57$ mlt dira eta dugun altuera 12m, beraz galerak dugun altuera baina gehiago dira.

c) Ponpa instalatu eta kurba karakteristikoa

$H_A + H_m = H_B + h_R$

$\frac{p_A}{\gamma} + z_A + \frac{v_A^2}{2g} + H_m = \frac{p_B}{\gamma} + z_B + \frac{v_B^2}{2g} + h_R$

$\boxed{H_m = -12 + 26930'48 \ \varphi^2}$



3) Beste soluzio bat?

Diametroa handitzea

$$H_A = H_B + h_R$$

$$12 = \frac{8 \cdot 0'02 \cdot 1000 \cdot 0'032^2}{9'8 \cdot \pi^2 D^5} + \frac{8\,(100 \cdot 0'3 + 1 + 0'5)\, 0'032^2}{9'8\, \pi^2 D^4}$$

$$12 = 1'6939247683 \cdot 10^{-3}/D^5 + 2'66793151 \cdot 10^{-3}/D^4$$

D tren balioak lortu

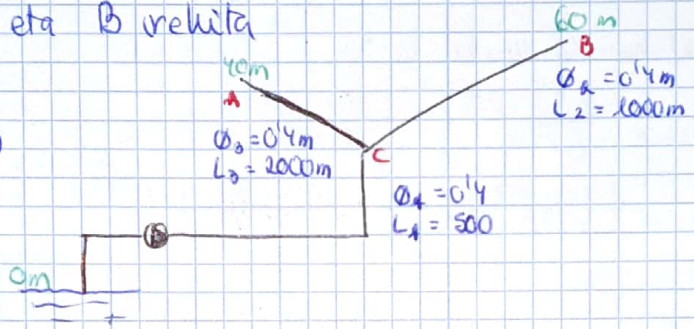
25.12)

Grafikoki Q, Pot eta η?

a) A itxita eta B irekita

$\varepsilon = 0'0259\,cm$

$p_A = p_B = atm$



Fluxua turbulentoa dela suposatuz

$$\frac{\varepsilon}{D} = \frac{0'0259 \cdot 10}{400} = 0'0006475 \Rightarrow f = 0'018$$

$$H_0 + H_m = H_B + h_R$$

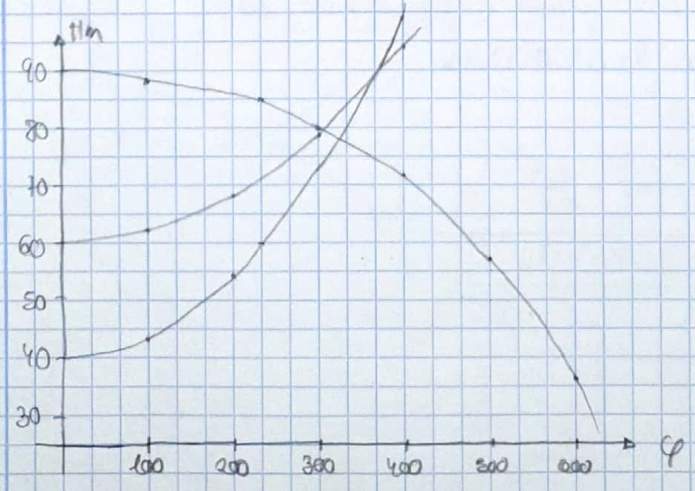
$$\frac{p_0}{\gamma}{}^{atm} + z_0 + \frac{V_0^2}{2g}{}^{0} + H_m = \frac{p_B}{\gamma}{}^{atm} + z_B + \frac{V_B^2}{2g}{}^{0} + \frac{8 f L Q^2}{g \pi^2 D^5}$$

$$H_m = 60 + \frac{8 \cdot 0'018 \cdot (1000+500)\, Q^2}{9'8\, \pi^2\, 0'4^5}$$

$$H_m = 60 + 218'086\, Q^2$$

$Q = 300\,l/s \Rightarrow H_m = 79'62\,m$ ↑

$Q = 400\,l/s \Rightarrow H_m = 94'86$ ↓



$$W_B = \frac{\gamma g H Q}{\eta} =$$

b) A balbula tabalik eta B ctaita

$$Hm = 40 + \frac{8 \cdot 0'018 \cdot (500+2000)\, Q^2}{9'8 \cdot \pi^2 \cdot 0'4^2}$$

$$Hm = 40 + 363'477\, Q^2$$

c) Bi balbulak irekita (Grafikoan kota)

Zegulik 40?

$$Hm = 40 + \frac{8 \cdot 0'018\,(500+1000+2000)\, Q^2}{9'8 \cdot \pi^2 \cdot 0'4^5}$$

$$Hm = 40 + 5088'6\, Q^2$$

25.13)

$S_r = 1 = 1000\ kg/cm^2$

$p_B = 0'6\ atm \rightarrow 60795\ Pa$

$L = 2000m$

$L_{as} = 12m$

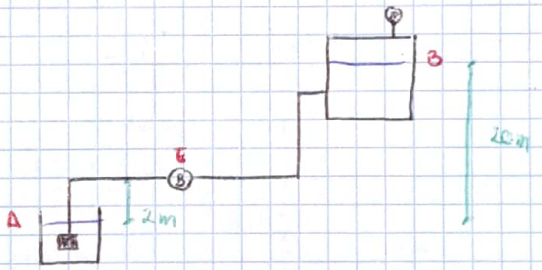
$z_B - z_A = 20m$

$z = 2m$

$f = 0'013$

$\phi = 0'2m$

$h_{e_{sch}} = h_e \cdot 0'1$



a) Funtzionamendu puntua?

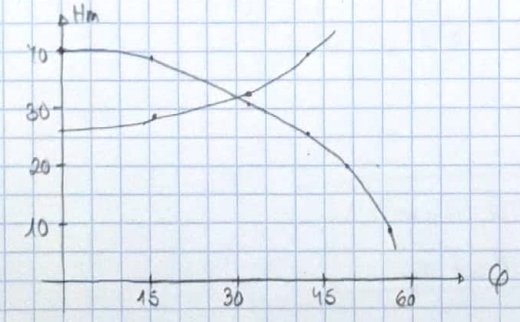
$$H_A + Hm = H_B + h_e + h_e \cdot 0'1$$

$$\frac{p_A}{\gamma} + z_A + \frac{v_A^2}{2g} + Hm = \frac{p_B}{\gamma} + z_B + \frac{v_B^2}{2g} + \frac{8 f L Q^2}{g \pi^2 D^5} + \frac{8 f L Q^2}{g \pi^2 D^5} \cdot 0'1$$

($p_A = 0\ atm$, $z_A = 0$, $v_A = 0$)

$$Hm = \frac{60795}{1000 \cdot 9'8} + 20 + \frac{8 \cdot 0'013 \cdot 2000\, Q^2}{9'8\, \pi^2 0'2^5} + \frac{8 \cdot 0'013 \cdot 2000\, Q^2}{9'8\, \pi^2\, 0'2^5} \cdot 0'1$$

$$Hm = 26'203 + 7392'31\, Q^2$$



$Q \simeq 30\ l/s$

$Hm = 32'85m$

$\eta =$

b) Kurgatutako potentzia?

$$W = \frac{\delta g H Q}{\eta} = \frac{1000 \cdot 9'8 \cdot 32'8 \cdot 0'03}{} =$$

d) Kabitazio anitzkua?

- $NPSH_{eskk} = 2m$ Uz

$p_s(20) = 0'0239\ kg/cm^2 \rightarrow 2343'78935\ Pa$

$\delta(20) = 998'23\ kg/m^3$

$p_A = 1atm = 101325\ Pa$

- $NPSH_{erab} = \frac{p_A - p_s}{\gamma} - z_E - h_{A\to E} =$

$= \frac{101325 - 2343'78935}{998'23 \cdot 9'8} - 2 - \frac{8 \cdot 0'013 \cdot 12 \cdot 0'03^2}{9'8 \cdot \pi^2 \cdot 0'2^5}\ (1+0'1)$

$NPSH_{erab} = 8'07$

$NPSH_{erab} > 1'3\ NPSH_{eskk} \Rightarrow 8'07 > 1'3 \cdot 2$

$8'07 > 2'6 \rightarrow$ Beraz, E2 da kabitazioko emaitza

25.16)

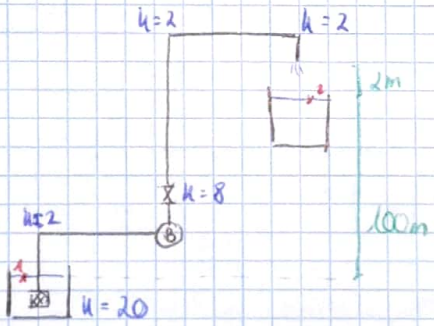
$L = 80cm$

$k_1 = 8$

$\phi = 12cm$

$\varepsilon = 0'12mm$

$Hm = 250 - 2'5 \cdot 10^5 Q^2$



Turbulentoiral kartzia:

$\frac{\varepsilon}{\phi} = \frac{0'12}{120} = 0'001$

$f = 0'02$

a) Funtzionamendu puntua?

$$H_1 + Hm = H_2 + h_{e_{1\to 2}}$$

$$\frac{p_1}{\delta} + z_1 + \frac{v_1^2}{2g} + Hm = \frac{p_2}{\delta} + z_2 + \frac{v_2^2}{2g} + \frac{8 f L Q^2}{g \pi^2 D^5} + \frac{8 \Sigma k Q^2}{g \pi^2 D^4}$$

$$Hm = 100 + \frac{8 \cdot 0'02 \cdot 800\ Q^2}{9'8\ \pi^2\ 0'12^5} + \frac{8 \cdot (20+2+8+2+2)\ Q^2}{9'8\ \pi^2\ 0'12^4}$$

$$Hm = 100 + 66745'44\ Q^2$$

$$\begin{cases} Hm = 250 - 2'5 \cdot 10^5\ Q^2 \\ Hm = 100 + 66745'44\ Q^2 \end{cases} \Rightarrow \boxed{\begin{array}{l} Q = 0'02176\ m^3/s \\ Hm = 131'61\ m \end{array}}$$

b) Kurgatutako potentzia?

$\eta = \%75$

$$W = \frac{\rho g H Q}{\eta} = \frac{1000 \cdot 9'8 \cdot 131'61 \cdot 0'02176}{0'75} = \boxed{37420'76\ W = Pot}$$

c) Emaria ordua baldin bada:

i) Altuera manometrikoa

$$Hm' = 250 - 2'5 \cdot 10^5 \cdot \left(\frac{0'0217}{2}\right)^2 = \boxed{220'57m = Hm'}$$

ii) Karga galera koefizientea?

$$\nu(15) = 1'142 \cdot 10^{-6}\ m^2/s$$

$$Q = 0'0108\ m^3/s$$

$$V = \frac{Q}{A} = \frac{0'0108}{\frac{\pi^2\, 0'12^2}{4}} = 0'304\ m/s$$

$$\begin{cases} Re = \frac{VD}{\nu} = \frac{0'304 \cdot 0'12}{1'142 \cdot 10^{-6}} = 3'19^4 \\ \frac{\varepsilon}{D} = \frac{0'12}{120} = 0'001 \end{cases} \Rightarrow f = 0'027$$

$$220'57 = 100 + \frac{8 \cdot 0'026 \cdot 800 \cdot 0'0108^2}{9'8\ \pi^2\ 0'12^5} + \frac{k \cdot (20 + 2 + k + 2 + 2)\ 0'0108^2}{9'8\ \pi^2\ 0'12^4}$$

$$\boxed{k = 2385'5}$$

iii) Potentzia $\eta = \%70$ bada?

$$Pot' = \frac{\rho g H Q}{\eta} = \frac{1000 \cdot 9'8 \cdot 220'57 \cdot 0'0108}{0'7} = \boxed{33350'2\ W = Pot'}$$

25. 17)