1

Q/ at a location investigation yielded the following data for the instillation of hydroelectric power plant; head available is 200 m, power available is 40 KW, speed chosen is 500 rpm. A model study was proposed in the laboratory. Head available was 20 m . it was proposed to construct a 1/6 scale model. Determine the speed and the power to test the model. Also, determine the flow rate required in terms of prototype flow rate ?

Solution:

Scale 1/6 means $\frac{D_m}{D_P} = \frac{1}{6}$

$$\frac{N_m\, D_m}{H_m^{1/2}} = \frac{N_P\, D_P}{H_P^{1/2}} \Rightarrow N_m = N_P \frac{D_P}{D_m} \left(\frac{H_m}{H_P}\right)^{\frac{1}{2}}$$

(Head Coefficient)

$$N_m = 500 \times 6 \times \left(\frac{20}{200}\right)^{\frac{1}{2}} = 948.7\ rpm$$ Ans. 1

$$\frac{P_m}{N_m^3\, D_m^5} = \frac{P_P}{N_P^3\, D_P^5}$$ (Power Coefficient)

$$P_m = P_P \left(\frac{N_m}{N_P}\right)^3 \left(\frac{D_m}{D_P}\right)^5$$

$$P_m = 40000 \left(\frac{948.7}{500}\right)^3 \left(\frac{1}{6}\right)^5 = 35.13\ KW$$ Ans. 2

$$\frac{Q_m}{N_m\, D_m^3} = \frac{Q_P}{N_P\, D_P^3}$$ (flow Coef.)

$$Q_m = Q_P \left(\frac{N_m}{N_P}\right)\left(\frac{D_m}{D_P}\right)^3$$

$$Q_m = Q_P \frac{948.7}{500} \left(\frac{1}{6}\right)$$

$$\boxed{Q_m = 0.00877 Q_P}$$ Ans. 3

69.A

2

Q/a turbine is to operate under head of 25 m at speed of 300 rpm. The discharge is 9 m^3/s if the overall efficiency is 90%. Determine the performance of the turbine under head of 20 m & the discharge.

Solution:

Since there is one turbine, scale ratio is unity. So, $D_1=D_2$

$N_1= 300$ rpm , $H_1=25$ m , $H_2=20$ m , $Q_1=9$ m^3/s , $\eta_o = 90\%$

$$\eta_o = \frac{Power\ at\ the\ shaft}{Water\ power}$$

$$P_1 = \eta_o\ \rho\ Q_1\ g\ H_1$$

power at the shaft (performance)

$$P_1 = 0.9 \times 1000 \times 9 \times 0.81 \times 25 = 1986.52\ KW$$

$$\frac{N_1\ \cancel{D_1}}{H_1^{1/2}} = \frac{N_2\ \cancel{D_2}}{H_2^{1/2}}$$

Model (Head Co.)

prototype

$$N_2 = N_1 \sqrt{\frac{H_2}{H_1}}$$

$$N_2 = 300 \sqrt{\frac{20}{25}} = 268.3\ rpm$$

Ans.

$$\frac{Q_1}{N_1\ D_1^3} = \frac{Q_2}{N_2\ D_2^3}$$

(Flow Co.)

$$Q_2 = Q_1\ \frac{N_2}{N_1}$$

$$Q_2 = 9\ \frac{268.3}{300} = 8.05\ m^3/s$$

Ans.

$$\frac{P_1}{N_1^3\ D_1^5} = \frac{P_2}{N_2^3\ D_2^5}$$

(Power Co.)

$$P_2 = P_1\ (\frac{N_2}{N_1})^3$$

$$P_2 = 1986.52(\frac{268.3}{300})^3 = 1421\ KW$$

Ans.

69.B

• Bernoulli's Equation:

Bernoulli's equation states as follow, " *In an ideal fluid, when the flow is steady and continuous, the summation of pressure, kinetic and potential energies remains constant along the stream line*". Mathematically,

$$\frac{P}{\gamma} + \frac{V^2}{2g} + z = constant$$

$$Or,\ \ P + \frac{1}{2}\rho V^2 + \gamma z = constant$$

Meanwhile, for a flowing fluid between any two points, Bernoulli's equation can be applied as,

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f$$

Assumptions;

① Ideal and incompressible liquid, ② Steady and continuous flow, ③ One dimensional flow, ④ The velocity is uniform over the section and equal to the mean velocity and ⑤ The forces acting on the liquid are the gravity and pressure forces.

Example # 2

A liquid of specific gravity of (1.15) is draining from a bottom of a large open tank through (80 mm) diameter pipe. The drain pipe ends at a point of (10 m) below the free surface of liquid. Calculate the velocity of flow. Take, $P_{atm} = 101325$ Pa

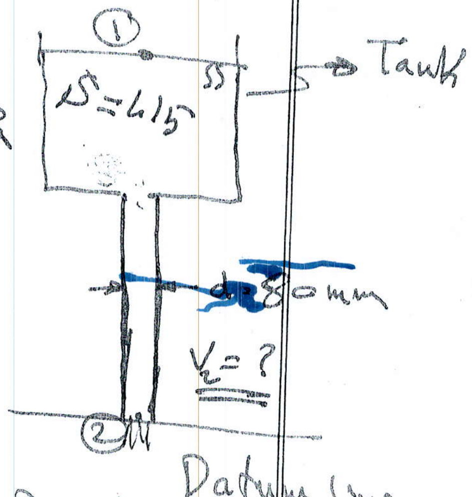
Bernollie's Equ ② & ①

$$\cancel{\frac{P_1^{\,0}}{\gamma}} + \cancel{\frac{V_1^2}{2g}}^{\,0} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \cancel{z_2}^{\,0}$$

$$+10 = \frac{101325}{1.15 * 9810} + \frac{V_2^2}{2(9.81)}$$

$$10 = 8.98 + \frac{V_2^2}{2(9.81)}$$

$$\boxed{V_2 = 4.47\ m/s}\ \ \underline{Ans.}$$



$P_2 = P_{atm} = 101325$ K.Pa

* في حالة أعطى في السؤال قيمة
الضغط أعوض الاعتيادي

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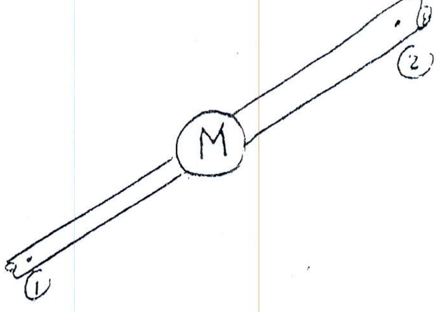
Power Considerations In Fluid Flow

In Bernollies equation If we multiply the total head by the Specific weight of the liquid we will get the power



$$\text{Power} = \gamma \cdot Q \cdot h_p \qquad \text{watt (W)}$$

$$= \frac{\gamma \cdot Q \cdot h_p}{745} = \text{horsepower}$$

- For the figure above (M) represent any machine installed in the pipe system shown. Bernollie's equation between (1) + (2) with existing of (M) may be written as follow.-

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 + M = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

* If (M) is denoting for a <u>turbine</u>, this mean that (M) is negative because the turbine extracted the power from the Power of liquid, if (M) denoting for a <u>pump</u>, then (M) will be positive. because pump gives the fluid an energy.-

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 + h_p = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 \qquad \text{(for Pump)}$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 - h_T = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 \qquad \text{(for Turbine)}$$

* So if we want to evaluate the power extracted by the turbine or added by the pump,

$$\boxed{\text{Power}_{\text{Turbine}} = \gamma \cdot Q \cdot h_T}$$

$$\boxed{\text{Power}_{\text{pump}} = \gamma \cdot Q \cdot h_p}$$

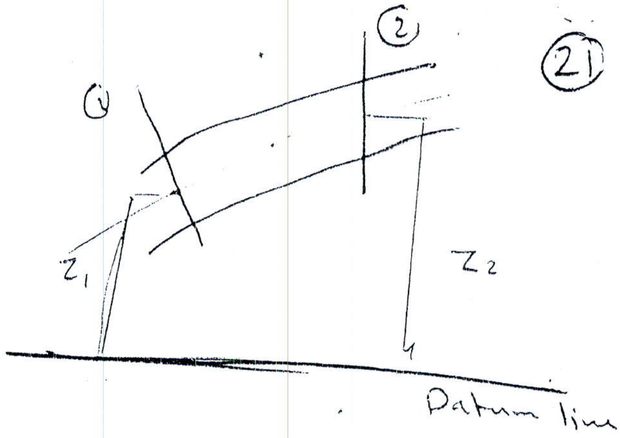
we can get the power of the jet of any liquid as follow

$$\boxed{\text{Power})_{\text{jet}} = \gamma \cdot Q \left(\frac{V^2}{2g}\right)_{\text{jet}}}$$

W: angular Velo
$w = \frac{2\pi}{60} N \ (\frac{1}{s})$
N: speed of T
r.p.m

$$\eta_{pump} = \frac{\text{output Power}}{\text{Input Power}} = \frac{\gamma \cdot Q \cdot h_p}{T \cdot W} \quad , \quad \eta_{Turbine} = \frac{T \cdot W}{\gamma \cdot Q \cdot h_T} \quad , \quad V = \frac{2\pi r}{60} N$$

Friction Consideration in Fluid flow



Bernollie's equation Commonly written as:

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

or $H_1 = H_2$

The above equation may be written In Case of No friction through the System.

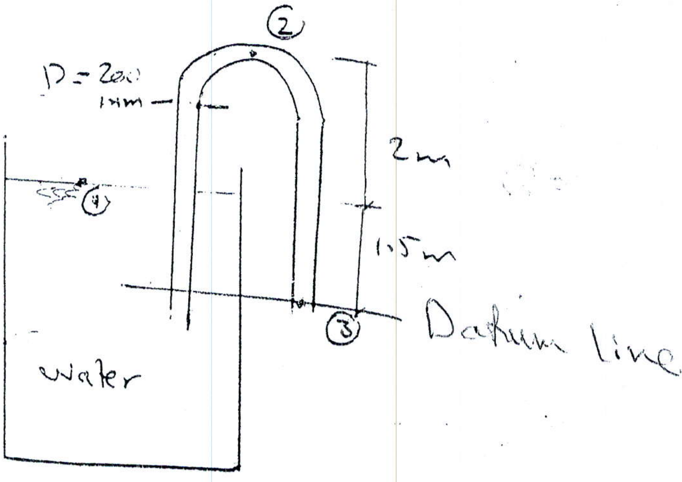
If friction taken into account, then the total head between ① & ② will not equal to each other ~~but~~ but the equation will be written

$$H_1 = H_2 + h_L$$

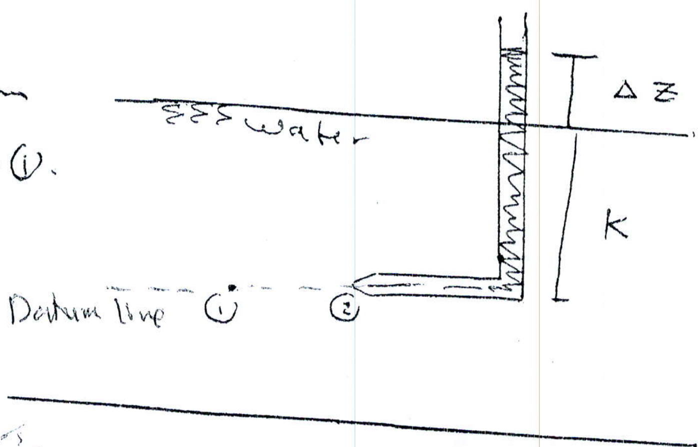
where **h_L =** the losses due to friction (allways written in the right hand Side)

* Power lost due to friction canbe found as :

$$\boxed{Power)_{lost} = \gamma \cdot Q \cdot h_L}$$

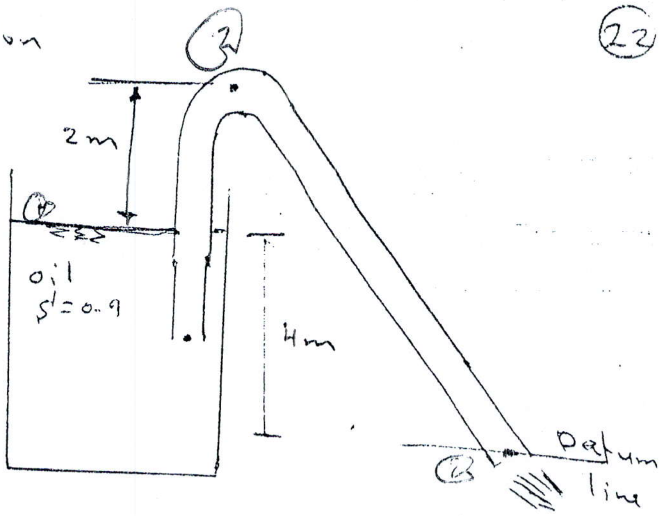


Ex 6 For the figure Shown the discharge is 150 Litre/sec. Find the losses between ① & ③ in terms of $\frac{V^2}{2g}$. also find the pressure at point ② if two-third of losses occures ~~at~~ from Points ① & ②.

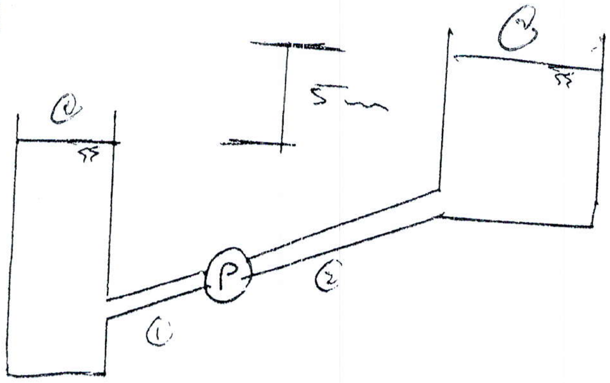


Ex 7 If $\Delta Z = 20cm$ & $K = 60cm$ determine the velocity of point ①. neglecting all losses.

Ex 18 For the Siphon shown, evaluate the velocity of water at the outlet, neglecting friction losses, also find the pressure at the upper point of siphon.

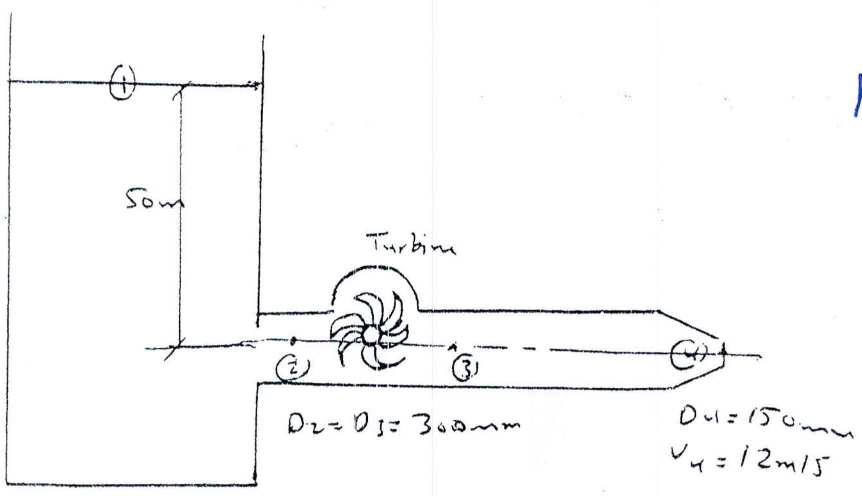


Ex 19

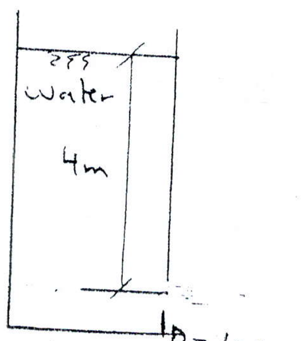


Evaluate the discharge when the pump gives a head of (24m). Assume the losses in the first line is ($h_{L1} = 5\frac{V_1^2}{2g}$) the diameter of first line is (150mm). The losses in the second line ($h_{L2} = 12\frac{V_2^2}{2g}$ and its diameter is 100mm). take $\alpha = 1$ for two pipes. what will be the horse power of the Pump.

Ex 20 Evaluate the power of the Turbine in the figure shown, neglecting all losses.



Ex 21 evaluate the discharge through the jet & its power.



Ex.8/Sol. Bernollie's Equ. ① & ②, let datum line at ②

$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}} + Z_1 = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + \cancel{Z_2} + \cancel{h_L}^{0}$$

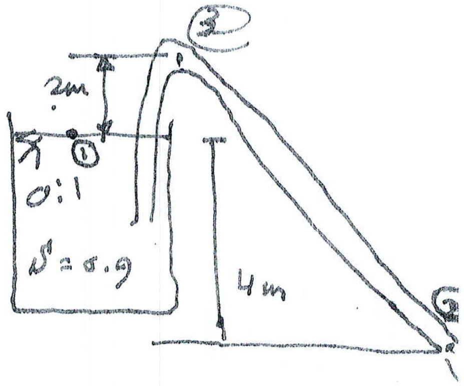
free surface   zero   zero

$$4 = \frac{V_2^2}{2(9.81)} \Rightarrow V_2 = 8.85 \text{ m/s} = V_3$$

Bernollie's equ ① & ③

$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + Z_1 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + Z_3$$

$$4 = \frac{P_2}{\gamma} + \frac{8.85^2}{2*9.81} + 2$$



$$\boxed{P_3 = -19620 \text{ Pa}}$$

Ex.9/Sol.

$h_p = 24$ m

$h_{L_1} = 5\frac{V_1^2}{2g}$

$d_1 = 150$ mm

$h_{L_2} = 12\frac{V_2^2}{2g}$

$d_2 = 100$ mm

Power pump = ?

$$Q = V_1 A_1 = V_2 A_2 \Rightarrow V_1 (75\times10^{-3})^2 \pi = V_2 (50\times10^{-3})^2 \pi$$

$$V_1 = 0.444 V_2 \quad — ①$$

Bernollie's Equ. ① & ②, datum line at ① ⇒

$$h_p + \cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + \cancel{Z_1}^{0} = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + Z_2 + h_{L_1} + h_{L_2}$$

free surface   free surface

$$25 = 5 + 5\frac{V_1^2}{2g} + 12\frac{V_2^2}{2g} \quad — ②, \text{ sub ① in ②} \Rightarrow$$

$$20 = 5\frac{(0.444 V_2)^2}{2(9.81)} + 12\frac{V_2^2}{2(9.81)} \Rightarrow$$

$$V_2 = 5.5 \text{ m/s}$$

$$Q = A_2 \cdot V_2 = \pi(50\times10^{-3})^2 * 5.5 \Rightarrow Q = 0.043 \text{ m}^3/\text{s}$$

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$$\therefore \text{Power}_{pump} = \gamma \cdot h_p \cdot Q = 1 * 24 * 0.043 = 1.036 \text{ W}$$

Power

Sol.

Ex. 20

$Power_{Turbine} = ?$

اكلا لحقيقي

Bernolli's equ. ① & ③, ③ datum line

$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + Z_1 - h_T = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + \cancel{Z_3}^{0} \Rightarrow$$

$$Z_1 - h_T = \frac{V_3^2}{2g} + \frac{P_3}{\gamma} \quad \text{—— ①}$$

$$Q_4 = Q_3 \Rightarrow A_4 V_4 = A_3 V_3 \Rightarrow \cancel{\pi}\left(\frac{150}{2}\times 10^{-3}\right)^2 (12) = \cancel{\pi}\left(\frac{300}{2}\times 10^{-3}\right)^2 V_3$$

$$V_3 = 3 \text{ m/s}$$

Bernolli's equ ③ & ④ $\Rightarrow$

$$\frac{P_3}{\gamma} + \frac{V_3^2}{2g} + \cancel{Z_3}^{0} = \cancel{\frac{P_4}{\gamma}}^{0} + \frac{V_4^2}{2g} + \cancel{Z_4}^{0}$$

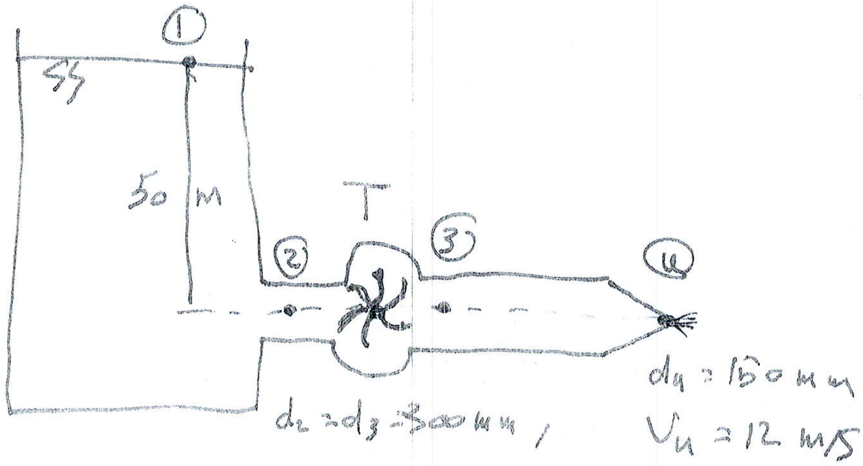
$$\frac{P_3}{\gamma} = \frac{V_4^2}{2g} - \frac{V_3^2}{2g} = \frac{12^2 - 3^2}{2(9.81)} \Rightarrow$$

$\frac{P_3}{\gamma} = 6.87$ m , sub. V_3 & $\frac{P_3}{\gamma}$ in equ. ① $\Rightarrow$

$$50 - h_T = \frac{3^2}{2(9.81)} + 6.87 \Rightarrow h_T = 43.5 \text{ m}$$

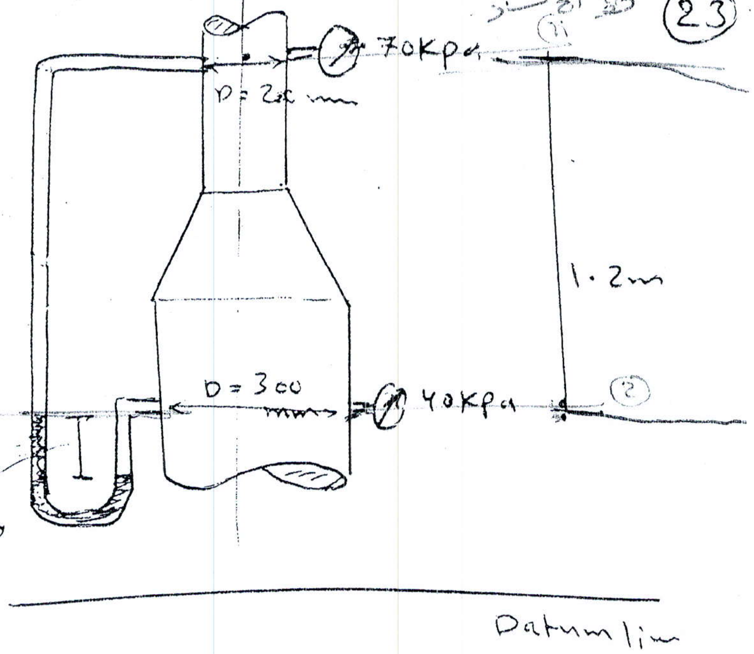
$$\therefore Power_{Turbine} = \gamma \cdot Q \cdot h_T = 9810 * \pi \left(\frac{150}{2}\times 10^{-3}\right)^2 (12)(43.5)$$

$$\therefore \boxed{Power_T = 90492.3 \text{ W}}$$ Ans.

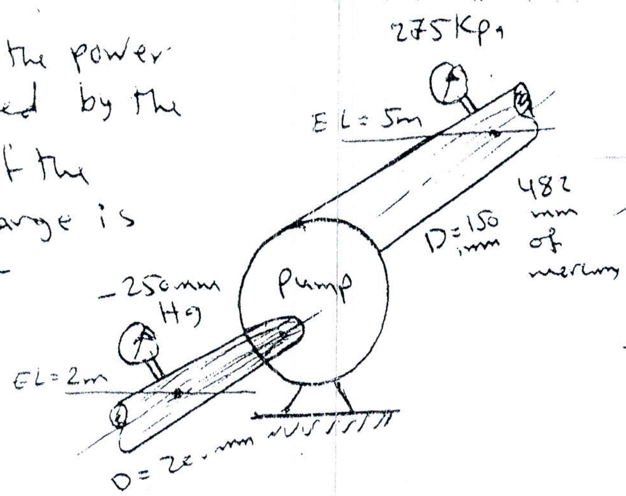


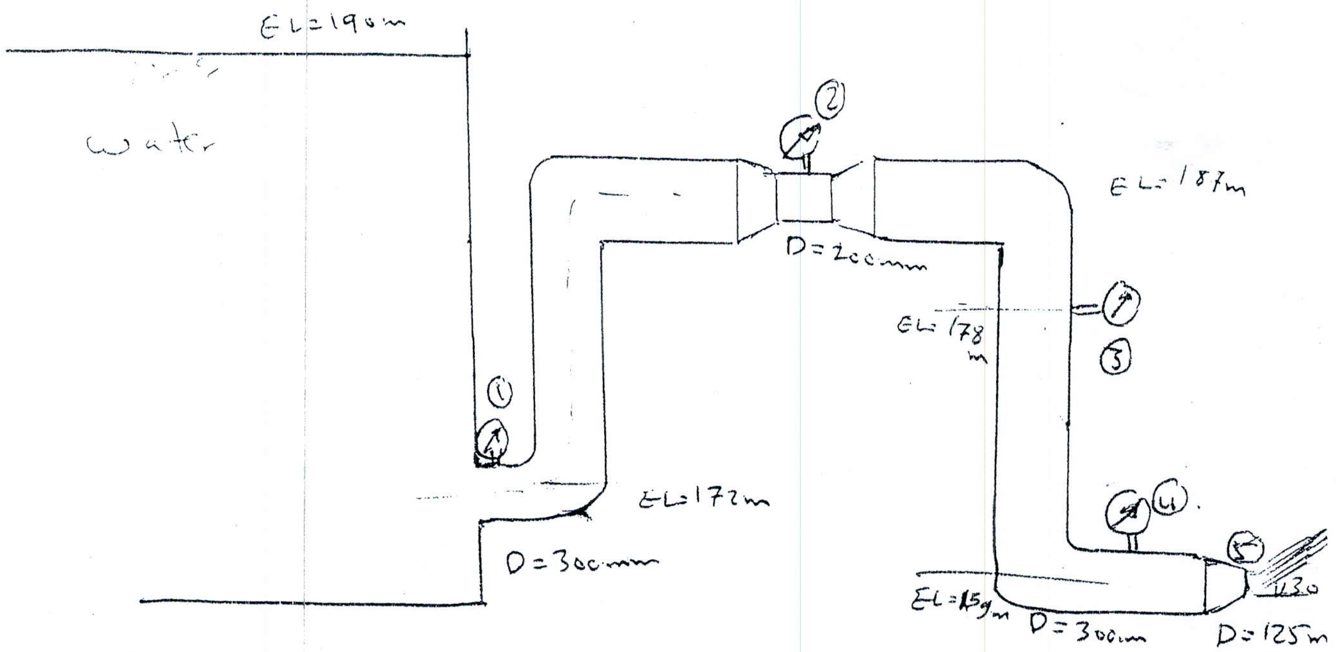
2.

Ex 12 Evaluate the Discharge of Benzene ($S' = 0.82$) through the pipe system shown Using Manometer then gauges.



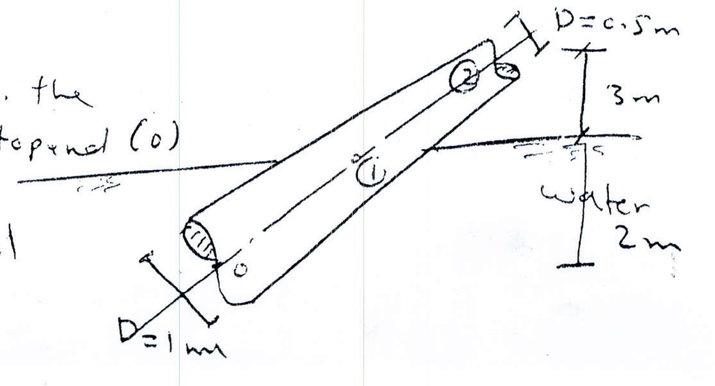
Ex 13
what is the power required by the Pump if the discharge is $0.15 m^3/s$





Ex 14 Evaluate the Discharge through the system shown & the pressure in each shown point, Draw the energy line & Hydraulic gradient line.

Ex 15 A drain pump has a tapered Section pipe. the pipe is full of water, the pressure at the tapered (0) is (25 cm of mercury) vaccum & its known that the loss head by friction between (0 → 2) equal $\frac{1}{10}\frac{V_2^2}{2g}$. Evaluate the discharge.



Ex16) The velocity distribution for a two dimensional incompressible flow is given by:

$$u = \ln x^2 y^2 - 4\ln x t$$
$$v = \frac{2y}{x} + 4\ln x t$$

Does this flow satisfy continuity equation?.

Ex17) given that $u = 2x^2 + 2xy$ & $v = 2yz^2 + 3z^2$
find the missing component of velocity such that the equation of continuity is satisfied.

Ex18) show that for $u = \frac{-x}{x^2+y^2}$ & $v = \frac{-y}{x^2+y^2}$, the flow satisfy continuity equation and find the equation of stream line.

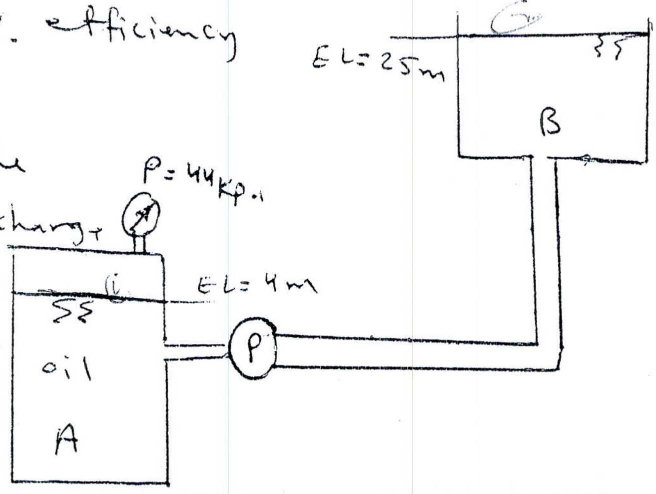
Ex19) A three dimensional flow given as $u = -x$, $v = 2y$ & $w = 5 - z$
find the equation of stream line at (2, 1, 1). Does it satisfy continuity equation.

Ex20) for the velocity component $u = -y/b^2$ & $v = \frac{x}{a^2}$, verify that the flow satisfy continuity equation and the ellipse $\frac{x^2}{a^2} + y^2/b^2 = 1$ is a stream line.

Ex21) show that the velocity vector below satisfy continuity equation

$$q = i\left(\frac{4x}{x^2+y^2}\right) + j\left(\frac{4y}{x^2+y^2}\right)$$, then find its stream line.

Ex22) A pump of 15 Hp. with 80% efficiency discharging crude oil ($S = 0.9$) to the upper tank. If the losses in the system is 1.5 m. Find the discharge



Ex. 10 / Sol.

$Power_{Turbine} = ?$

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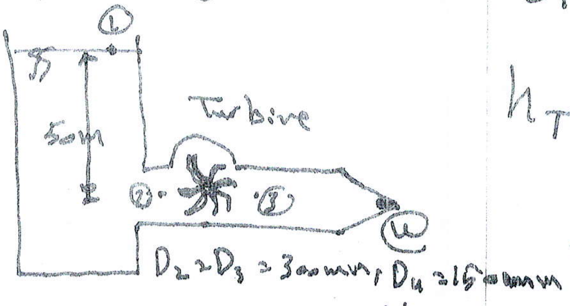
عند اهمال فقدان
طول الانبوب بين ③ – ④



$D_2 = D_3 = 300\,mm$, $D_4 = 150\,mm$
$V_4 = 12\,m/s$

Bernollie's Equ. ① & ④

$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + Z_1 - h_T = \cancel{\frac{P_4}{\gamma}}^{0} + \frac{V_4^2}{2g} + \cancel{Z_4}^{0}$$

$$Z_1 - h_T = \frac{V_4^2}{2g}$$

$$h_T = Z_1 - \frac{V_4^2}{2g}$$

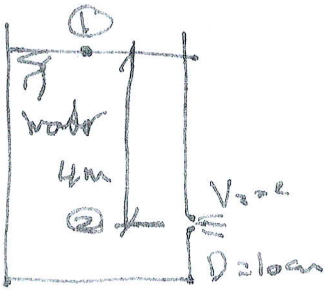
$$= 50 - \frac{12^2}{2(9.81)} \Rightarrow \boxed{h_T = 42.6\ m} \Rightarrow$$

$$Power = \gamma Q h_T = 88620.1\ W$$

Ex. 11 / Sol.

$Q_{jet} = ?$

$Power_{jet} = ?$



Bernollie's Equ ① & ②, datum line ②

$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + Z_1 = \cancel{\frac{P_2}{\gamma}}^{0} + \frac{V_2^2}{2g} + \cancel{Z_2}^{0}$$

$$Z_1 = \frac{V_2^2}{2g}$$

$$V_2 = \sqrt{2g Z_1} = \sqrt{2(9.81)(5)}$$

$$V_2 = 8.85\ m/s \quad \text{(jet Velocity)}$$

$$Q = A_2 \cdot V_2 = \pi(5 \times 10^{-2})(8.85)$$

$$\boxed{Q = 0.07\ m^3/s}$$ Ans.

$$Power\ jet = \gamma \cdot Q \cdot \left(\frac{V^2}{2g}\right)_{jet}$$

$$= 9810 \times 0.07 \left(\frac{8.85^2}{2(9.81)}\right)$$

$$\boxed{Power\ jet = 2741\ W}$$ Ans.

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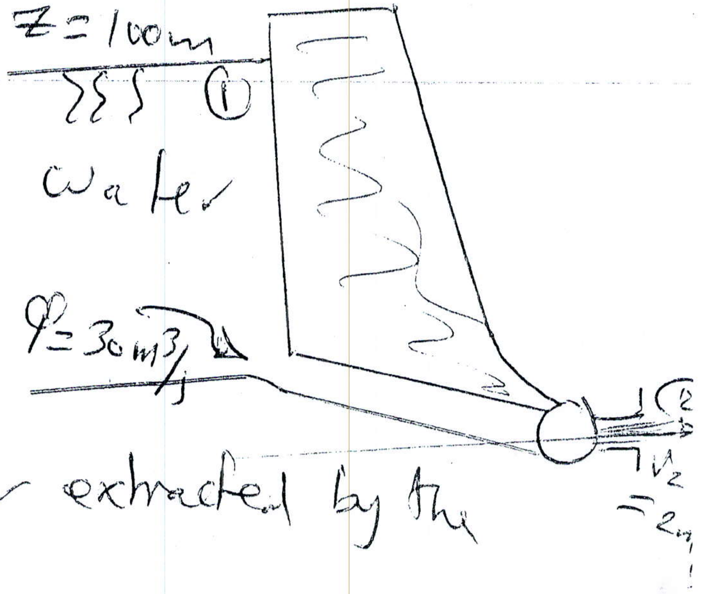
⊗ A hydroelectric power plant, takes $30\,m^3/s$ of water through its turbine & discharge it to the atmospher at $V_2 = 2\,m/s$. The head losses in the turbine & penstock is $h_f = 20\,m$. Find the power extracted by the turbine. (5)



Sol/ Bernollies between ① & ②

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + Z_1 = \cancel{\frac{P_2}{\gamma}} + \frac{V_2^2}{2g} + \cancel{Z_2} + h_f + \underline{h_t}$$

أدي الطرف الأيمن ممكن وضعه ولكن يكون بالسالب

$$100 = \frac{(2)^2}{2 \times 9.81} + 20 + h_t$$

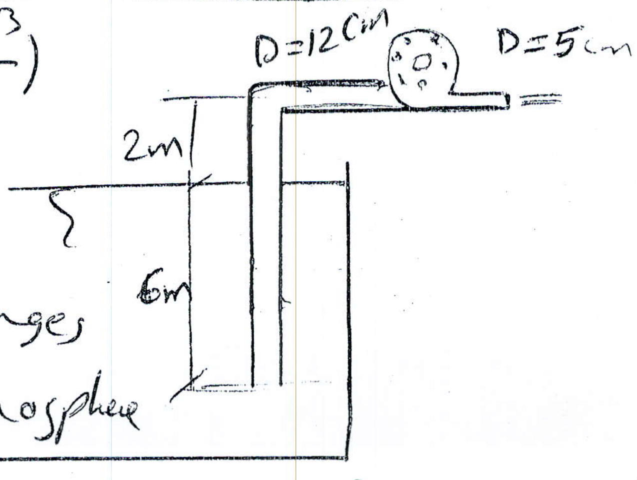
$$h_t = 79.8\,m$$

Power extracted by turbine $= \gamma \cdot Q \cdot h_t$

$$= 9810 \times 30 \times 79.8$$

$$= 23.4\ MW.$$

⊗ The pump shown draws $(220\,\frac{m^3}{h})$ of water from the reservoir, the total friction head loss is 5m. The flow discharges through a nozzle to the atmosphere



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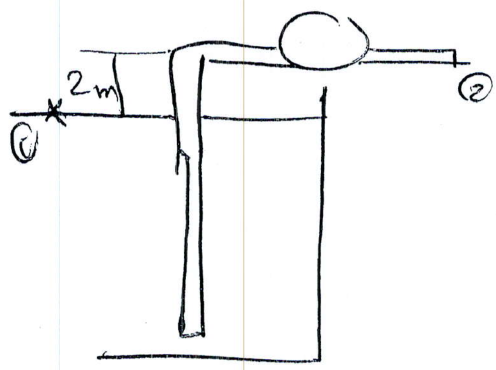
Sol/ Bernollie's between ① & ② gives

$$\rightarrow \frac{P_1}{\gamma}+\frac{V_1^2}{2g}+Z_1+h_p=\frac{P_2}{\gamma}+\frac{V_2^2}{2g}+Z_2+h_f$$

$$V_2 = \frac{220}{3600} \Big/ \left(\frac{\pi \times 0.025^2}{4}\right) = 31.12 \text{ m/s}$$



$P_1=0$, $Z_1=0$, $V_1=0$

$P_2=0$

$$h_p = 0+\frac{31.12^2}{2\times 9.81}+2+5$$

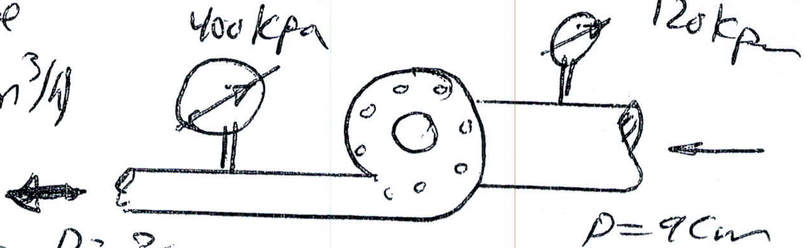
$$h_p = 56.4 \text{ m}$$

$$\therefore P = \rho \cdot g \cdot Q \cdot h_p = 9810 \times \left(\frac{220}{3600}\right)(56.4)$$

$$= 33.7 \text{ KW} = \left(\frac{33.7}{746}\right) \text{ hp}$$

R Repeat the previous example if $h_f = 4$m & the pump delivers (25 KW), Estimate, a) the exit velocity & b) the flowrate Q.

✱ Thepump discharge flowrate of (57 m³/h) what power is (KW) delivered to the water by the pump?



Sol

$$V_1 = \frac{Q}{A_1} = \frac{57/3600}{\pi(0.045^2)} = 2.49 \text{ m/s}$$

$$V_2 = \frac{Q}{A_2} = 22.4 \text{ m/s}$$

8

$$\frac{P_1}{\gamma}+\frac{v_1^2}{g}+z_1+h_p=\frac{P_2}{\gamma}+\frac{v_2^2}{g}+z_2+h_f$$ ⑦

$$h_p+\frac{120000}{9810}+\frac{2.49^2}{2*9.81}+0=\frac{400000}{9810}+\frac{22.4^2}{2(9.81)}$$

$$h_p=53.85\,m$$

$$P=\gamma\cdot Q\cdot h_p=9810\left(\frac{57}{3600}\right)*53.8$$

$$=8350\,W=8.4\,kW$$

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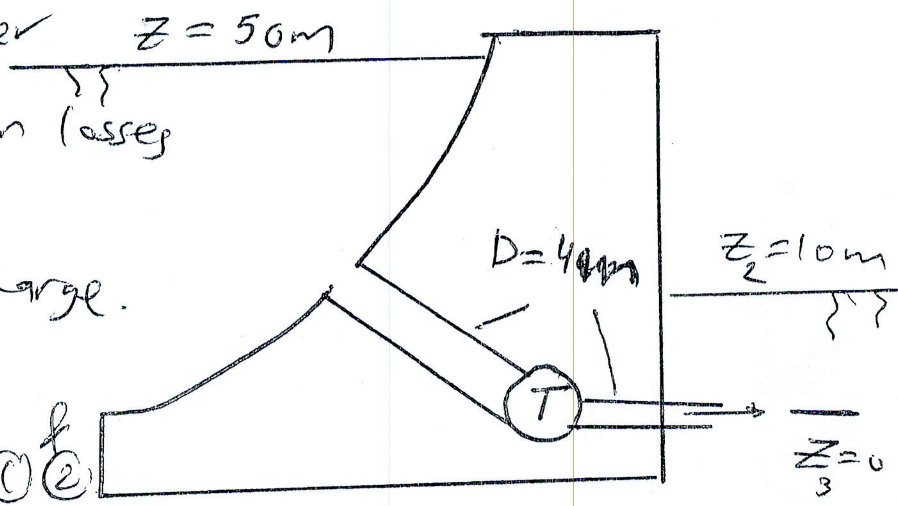
⑧ The large turbine shown extracted power 25 MW. System friction losses are ($h_f=3.5\frac{V^2}{2g}$). estimate the discharge.



Sol:

Bernollie's between ① ②

$$\cancel{\frac{P_1}{\gamma}}+\cancel{\frac{V_1^2}{2g}}+Z_1=\cancel{\frac{P_2}{\gamma}}+\cancel{\frac{V_2^2}{2g}}+Z_2+h_f+h_T$$

$$50=10+3.5\frac{V_2^2}{2g}+\frac{25*10^6}{9810\,Q}$$

$$P=\gamma\cdot Q\cdot h_T$$

$$h_T=\frac{P}{\gamma Q}=\frac{25*10^6}{9810\,Q}$$

$$Q^3-35410\,Q+2.26*10^6=0$$

$$V=\frac{Q}{A}=\frac{Q}{\frac{\pi}{4}D^2}$$

Solve: $Q=76.5\,m^3/s$ $Q=137.9\,m^3/s$

$Q=-214.4\,m^3/s$ (neglected)

for larger $Q=137.9\longrightarrow h_f=21.5\,m$

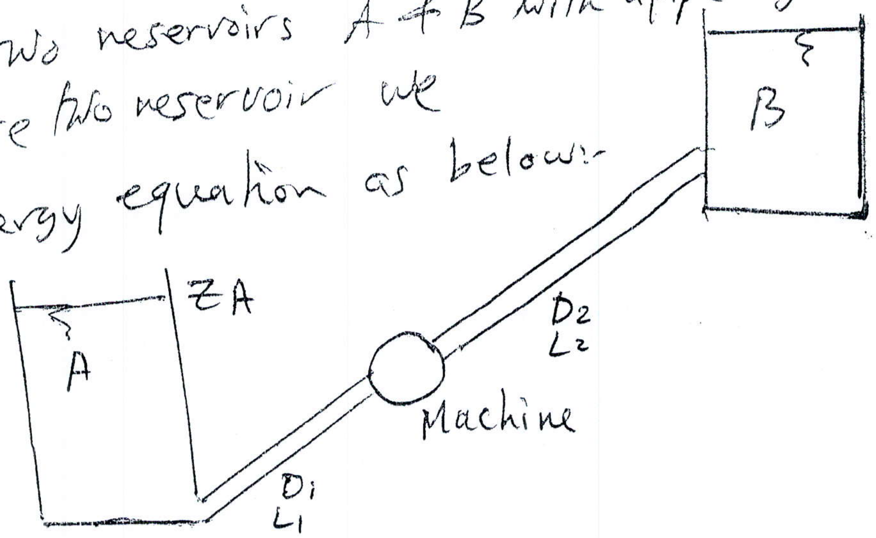
for smaller $Q=76.5\longrightarrow h_f=6.6\,m$

8)

$$\therefore Q_{taken}=76.5\,m^3/s$$

General Energy Equation between two Reservoirs :

If we have two reservoirs A & B with a pipe system connecting these two reservoir we can write energy equation as below:-



Bernollies between A & B

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + Z_A = h_{machine} + \frac{V_B^2}{2g} + Z_B + \text{losses due to frictio}$$

* losses can be denoted as h_f
* $h_{machine} = h_{pump}$ and its used in the L.H.S
* $h_{machine} = h_{Turbine}$ " " " " " R.H.S

Always put h_f in the right hand side (R.H.S).

for the above diagram if the machine is pump the equation will be :-

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + Z_A + h_p = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B + h_{f1} + h_{f2}$$

where h_{f1} = losses through pipe 1
h_{f2} = losses through pipe 2

for Turbine

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B + h_{f1} + h_{f2} + h_T$$

Power of Turbine:

$$P_{Turbine} = \gamma \cdot Q \cdot h_T \quad \left\{ \frac{N}{m^3} * \frac{m^3}{s} * m \right\} = \frac{N.m}{s} = \frac{J}{s} = \text{watt}$$

Note that $746 \text{ watt} = 1$ horse power

$$\eta_{Turbine} = \frac{\text{Output Power}}{\text{Input power}} = \frac{T \cdot \omega}{\gamma \cdot Q \cdot h_T}$$

where $T =$ Torque $\{N \cdot m\}$

$\omega =$ angular velocity $(\frac{1}{s})$

$$\omega = \frac{2 \pi N}{60}$$ where $N =$ speed of Turbine r.p.m

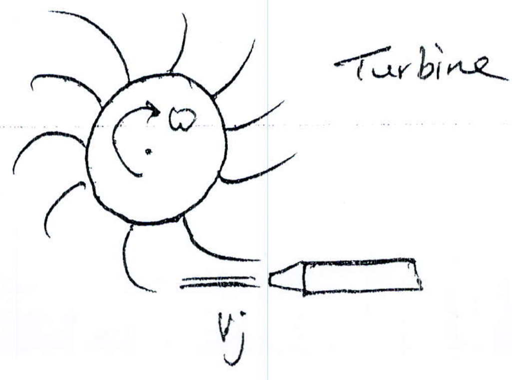
Power of Pump $P_{pump} = \gamma \cdot Q \cdot h_p$

$$\eta_{pump} = \frac{\text{Output power}}{\text{Input power}}$$

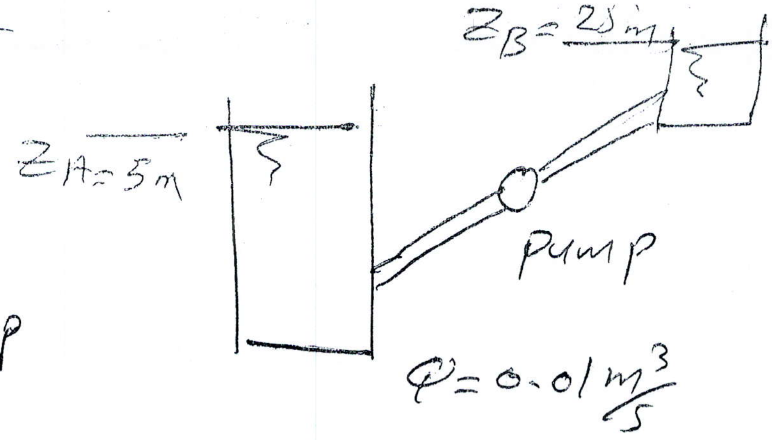
$$\eta_{pump} = \frac{\gamma \cdot Q \cdot h_p}{T \cdot \omega}$$

~~Pamp~~ of jet $P_{jet} = \gamma \cdot Q \cdot \frac{V_j^2}{2g}$

$V_j =$ jet velocity



Ex) Find the power of the pump. (Neglect losses)



Sol) $Power = \gamma \cdot Q \cdot h_p$

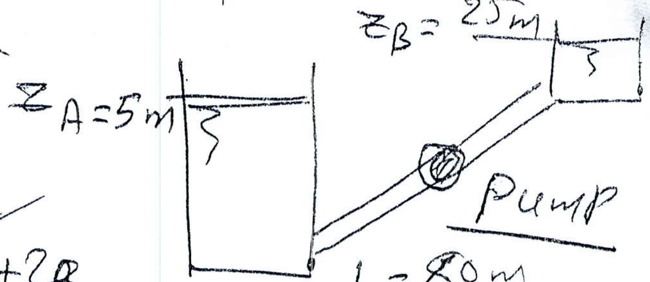
Bernollie's betwen A + B

$$\cancel{\frac{P_A}{\gamma}} + \cancel{\frac{V_A^2}{2g}} + z_A + h_p = \cancel{\frac{P_B}{\gamma}} + \cancel{\frac{V_B^2}{2g}} + z_B$$

$$5 + h_p = 25 \Rightarrow h_p = 20\,m$$

$$Power = 9810 \times 0.01 \times 20 = 1962\,Watt$$
$$P = 2.63\,hp$$

Ex) For the system shown, Find the power of the Pump. (neglect minor losses).



$L = 80\,m$
$D = 0.15\,m$
$f = 0.018$
$Q = 0.05\,m^3/s$

SoL)

$$\cancel{\frac{P_A}{\gamma}} + \cancel{\frac{V_A^2}{2g}} + z_A + h_p = \cancel{\frac{P_B}{\gamma}} + \cancel{\frac{V_B^2}{2g}} + z_B + h_{Losses}$$

$$5 + h_p = 25 + f\frac{L}{D}\frac{V^2}{2g}$$

$$h_p = 20 + 0.018 \times \frac{80}{0.15}\,\frac{0.566^2}{2 \times 9.81}$$

$Q = VA$

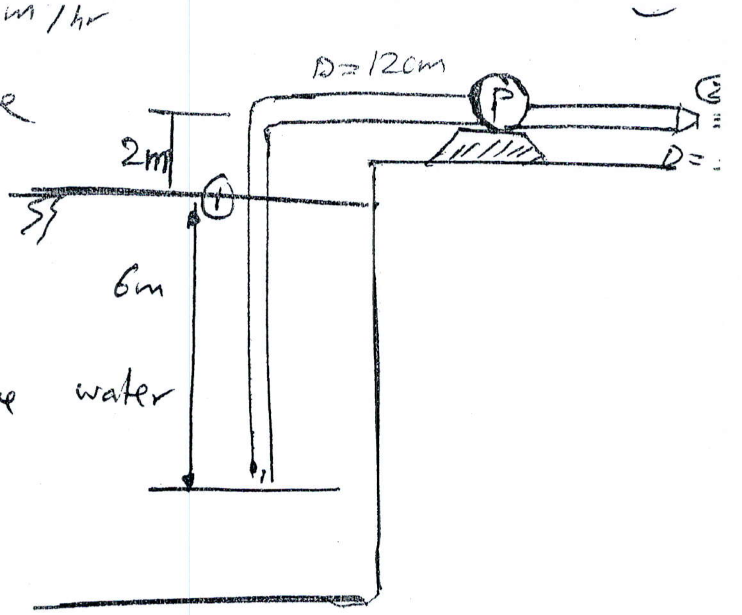
$$V = \frac{0.01}{\left(\frac{\pi\,0.15^2}{4}\right)} = 0.566\,m/s$$

2.83 m/s

$$h_p = 20 + 3.92 = 23.92$$

$$P = \gamma \cdot Q \cdot h_p = 9810 \times 0.05 \times 23.92$$
$$= 11733\,Watt = 15.73\,hp.$$

Ex) the water pump draws 220 m/hr of water from the reservoir, the total friction head loss is (5m). The flow discharges through the nozzle to atmosphere water. Estimate the power of the pump.



SoL)

$$Q = 220 \frac{m^3}{hr} = \frac{220}{3600} = 0.0611\ m^3/s$$

$$V_2 = \frac{Q}{A_2} = \frac{0.0611}{\frac{\pi}{4} 0.05^2} = 31.14\ m/s$$

Bernollies between ① & ② [Datum line at water surface]

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 + h_p = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 + losses$$

$$0 + 0 + 0 + h_p = 0 + \frac{31.14^2}{2 * 9.81} + 2 + 5$$

$$h_p = 56.4\ m$$

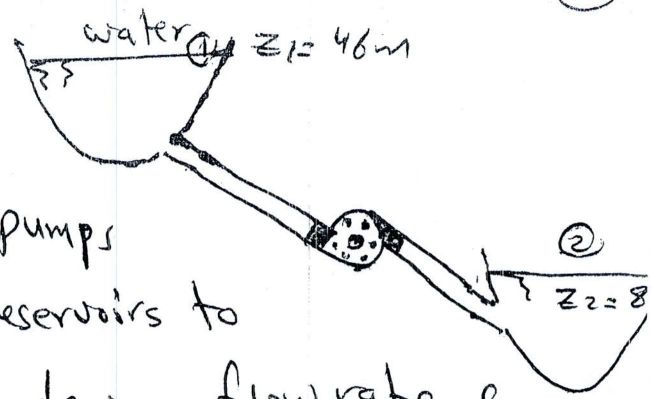
$$Power = \gamma \cdot Q \cdot h_p$$

$$= 9810 * 0.0611 * 56.4$$

$$= 33811\ watt = 33.8\ Kw$$

$$= 45.3\ hp$$

Ex) The pump – turbine system draws water from the upper reservoir in the day time to produce power for a city. At night, it pumps water from lower ~~to~~ upper reservoirs to restore the situation. For a design flow rate of 57 m^3/min in either direction. The friction head loss is [5.2 m]. Estimate the power in (kW) (a) extracted by the turbine + (b) delivered by the pump.



SoL) $Q = \frac{57}{60} = 0.95\ m^3/s$

ⓐ Bernollies between ① + ②

$$\cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + z_2 + h_T + \text{losse}$$

$$46 = 8 + h_T + 5.2$$

$$h_T = 32.8\ m$$

$$P_{\text{extracted by a turbine}} = \gamma . Q . h_T$$

$$= 9810 \times 0.95 \times 32.8$$

$$= 305.679\ kW$$

$$\boxed{P_{\text{Turbine}} = 409.75\ hp}$$

ⓑ Bernollies between ② + ①

$$\cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + z_2 + h_p = \cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 + \text{losses}$$

$$8 + h_p = 46 + 5.2$$

$$h_p = 43.2\ m$$

86

$\therefore$ $P_{\text{delivered by the pump}} = \gamma . Q . h_p = 402.602\ kW$

$= 539.6\ hp$