UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACCALAUREUS INGENERIAE *CIVIL ENGINEERING*
SUBJECT	:	**Hydraulic Engineering 3A**
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WEIGHT	:	50 : 50
TOTAL MARKS	:	100

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MODERATOR	:	DR S. NYENDE-BYAKIKA
NUMBER OF PAGES	:	3 PAGES AND 1 ANNEXURE

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INSTRUCTIONS	:	QUESTION PAPERS MUST BE HANDED IN
REQUIREMENTS	:	2 ANSWER BOOKLETS

INSTRUCTIONS TO STUDENTS

- PLEASE ANSWER ALL QUESTIONS
- PROVIDE SHORT AND PRECISE ANSWERS FOR THE THEORETICAL PART
- SHOW ALL THE STEPS FOR CALCULATIONS CLEARLY

QUESTION 1 [28 Marks]

1.1. Discuss how Bernoulli's Equation was developed and its limitations. Show its derivation and state the three basic assumptions. (7)

- Bernoulli's equation was derived from Euler's equation;
- Euler stated that there are 3 forms of energy:
  - Potential energy
  - Pressure energy
  - Kinetic energy
- The three energies can be exchanged: potential →pressure → Kinetic

$$E = E_{potential} + E_{pressure} + E_{kinetic} = mgz + P\frac{m}{\rho} + \frac{1}{2}mv^2$$

3

$$W = E = mgz + P\frac{m}{\rho} + \frac{1}{2}mv^2$$

$$\frac{E}{mg} = H = z + \frac{p}{\rho g} + \frac{v^2}{2g}$$

$$H = z + \frac{p}{\gamma} + \frac{v^2}{2g} = cons\tan t$$

mgz = potential/elevation energy

P m/ρ = Pressure energy

(½)mv^2 = kinetic energy

2

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

- The limitation of Bernoulli's Equation is that it was derived based on assumptions: 2
  - **Fluid is incompressible** (**ρ = constant)**
  - **No friction** – energy between the different forms is converted without losses
  - **No external work** - No energy added or withdrawn as the fluid flows through the control volume (steady flow).

1.2. Define secondary losses and their typical nature. Also discuss the various types of secondary losses and the possible causes for each briefly. Also discuss the concept & advantages of converting secondary losses to an equivalent length of a pipe. (8)

- Secondary (minor) losses include all the **pipeline energy losses which are not due to wall friction**. It is very small compared to friction losses and sometimes can be neglected.
- The nature of the secondary losses is such that it is a **constant fraction of the kinetic energy**. Each type of loss can be **quantified using a loss coefficient (K)**, which leads to a straightforward mathematical formulation. (1)

$$h_s = K\left(\frac{V^2}{2g}\right)$$

  - **find an appropriate K-value for each fitting type.**

(3)

- **Different types of secondary losses:**
  - inlets and outlets – due to change from small pipe to reservoir
  - Sudden (or gradual) contraction
  - Sudden (or gradual) expansion

    (contraction and expansion: losses due to changes in flow area (flow geometry), which causes speed change)
  - Losses in bends, elbows and T's – due to directional changes (change in momentum)
  - fitting losses - cause a change in the flow pattern, such as valves, meters, sieves, etc.

- concept & advantages of converting the secondary losses to an equivalent length of a pipe. (3)

- It is a length of pipe which causes the same head loss as the minor head loss factors (e.g. valve or fitting). Frictional losses are assumed to be equal to secondary losses. The pipe has the same length & same properties.
- There are some **computational advantages** to convert the secondary losses to an equivalent length of straight pipe, with the **same hydraulic properties**. Head loss is due to friction only, and hence makes calculation quicker, simpler/easier and efficient since secondary losses are accounted within the pipe's equivalent length.

1.3. Discuss the operating mechanisms of centrifugal pumps. Also list the components of submersible centrifugal pumps and their function. (9)

- **Centrigugal pump operates by the action of centrifugal force -** is the apparent **force** that draws a rotating body away from the center of rotation. It is caused by the inertia of the body. (2)
- The centrifugal pump creates an increase in pressure by **transferring mechanical energy** from the motor to the fluid through the rotating impeller.
- The pump casing provides a pressure boundary for the pump and contains channels to properly direct the suction and discharge flow. The fluid flows from the inlet to the impeller centre and out along its blades/eyes. As the water enters the **flow paths between the impeller vanes**, the **water is accelerated** tremendously, thereby **gaining a lot of kinetic energy due to the action of centrifugal force**. The centrifugal force hereby increases the fluid velocity and consequently also the **kinetic energy is transformed to pressure**. (2)
- The **volute casing** collects the fluid from the impeller and leads into the outlet flange. The volute casing converts the **dynamic pressure** rise in the impeller to **static pressure**. As the **water leaves the impeller and flows towards the outlet**, the water slows down again. The **kinetic energy lost** is then largely **recovered as pressure energy** - the well-known **Bernoulli principle**.
- the **main components** of a centrifugal pump and mention the purpose (5)
  - (i) **Impeller** – rotating part of centrifugal pump, consists of a series of backward curved vanes (blades). It is driven by shaft , which is connected to the shaft of an electric motor. Imparts kinetic energy (velocity) by rotating the liquid
  - (ii) **Casing** - an air-tight passage surrounding the impeller, which is a **stationary part**. Casing collects fluid (velocity) from the impeller and converts into a static pressure.
  - (iii) **Suction Pipe –** pipe which conveys water from reservoir to impeller
  - (iv) **Delivery Pipe –** pipe that delivers water from impeller to reservoir or distribution system
  - (v) **Shaft** – the bar by which the power is transmitted from the **motor** to impeller. It can be driven by electric motor or oil engine
  - (vi) **Driving Motor** – responsible for rotating the shaft. It can be mounted directly on the pump, above it or adjacent to it

1.4. Discuss the difference between arranging pipes in series and in parallel in terms of objectives and operation. Also discuss the concept and advantage of converting pipes in series to an equivalent pipe length. (6)

- **Pipes in Series:**
  - **Objective → to increase Hand keep Q constant**
  - **In this configuration, all pumps must operate simultaneously.** (2)
- **Pipes in Parallel:**
  - **Objective → to increase Q and keep H constant**
    - Discharge from the parallel pumps will be collected to a single point for the same head.
  - **In this configuration, any number of pump can be operated simultaneously.** (2)

- Any number of pumps can be brought to operation by automatic switching according to the level in the suction reservoirs.
- In series pumps, the system will not operate if one pump is out of operation.

- **Concept and advantage of converting pipes in series to an equivalent pump :** (2)
  - It means that the hydraulic engineer converts the entire pipe, with all its different sections in series, to a single pipe section with uniform properties.
  - The equivalent pipe will have the exact same hydraulic properties as the real pipe with its different sections in series. Hence, makes calculation quicker, simpler/easier and efficient

QUESTION 2 [15 Marks]

2.1 Derive Darcy Weisbach Formula using the Mechanical Principles. (5)

Pressure drop Δp is expressed as the **pressure head due to friction h_f**

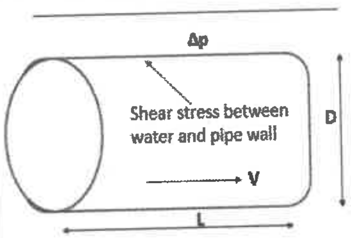


Fig. 3.1 Variables within a section of a pipe

Force moving the plug of water forward = wetted area* av. pressure differential

$$F=\left(\frac{\pi D^2}{4}\right)\Delta p$$

Resisting Force due to effective shear stress Δ τ_o

$$F=\tau_o(\pi DL)$$

At const. velocity, the two forces are in balance:

$$F=\Delta p\left(\frac{\pi D^2}{4}\right)=\tau_o(\pi DL)$$

$$\Rightarrow \Delta p=\frac{4\tau_o L}{D}$$

For turbulent flow condition: $\tau_0 \propto V^2$

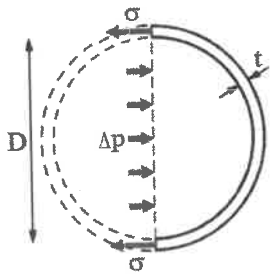
$$\tau_o=k_1V^2$$

Substituting the above equations in the form of pressure drop in length terms:

$$h_f=\frac{\Delta p}{\rho g}=\left(\frac{8k_1}{\rho}\right)\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

$$h_f=\frac{fLV^2}{2gD}$$ **Darcy-Weisbach Eqn**

2.2 Derive wave celerity and transient pressure equations for an elastic pipe carrying a compressible fluid. (8)



From the diagram, an increase in pressure **ΔP** induces a hoop **stress σ**. If **D** is the **internal diameter of the pipe** and **t is the wall thickness.**

Equating forces per unit length:

$$2\sigma t = \Delta P.D$$ **0.5**

Stress = Young's modulus * strain

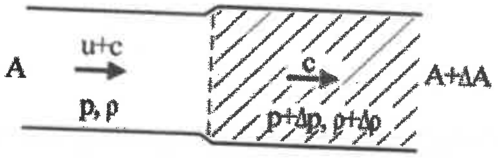
$$\sigma = E*\frac{\pi.\Delta D}{\pi.D}=E\frac{\Delta D}{D}$$

$$\Rightarrow \frac{\Delta D}{D}=\frac{D}{2Et}\Delta P$$ **0.5**

This is the fractional change in diameter

Fractional change in area:

- From the geometry: $\Delta A \approx \frac{dA}{dD}\Delta D = \frac{2\pi D}{4}\Delta D \Rightarrow \frac{\Delta A}{A} = 2\frac{\Delta D}{D} = \frac{D}{Et}\Delta P$ **1.0**



The pressure change across the shock is the same as that of rigid pipes, still given by:

$\Delta P = \rho c u_o$ **0.5**

- **Continuity principle:** $\rho(c+u_o)A = (\rho+\Delta\rho)c(A+\Delta A)$ **1.0**

Divide by ρcA

$$1+\frac{u_o}{c} = \left(1+\frac{\Delta\rho}{\rho}\right)\left(1+\frac{\Delta A}{A}\right) = 1+\frac{\Delta\rho}{\rho}+\frac{\Delta A}{A}+2^{\text{nd}}d-order\ term$$

$$\Rightarrow \frac{u}{c} = \frac{\Delta\rho}{\rho}+\frac{\Delta A}{A}$$ **1.0**

- **From momentum:** $\frac{u}{c} = \frac{\Delta P}{\rho c^2}$ **0.5**
- **From compressibility:** $\frac{\Delta\rho}{\rho} = \frac{\Delta P}{K}$ **0.5**
- **From elasticity:** $\frac{\Delta A}{A} = \frac{D}{Et}\Delta P$ **0.5** $\Rightarrow \frac{1}{\rho c^2} = \frac{1}{K}+\frac{D}{Et}$ **1.0**

- **Wave celerity for non-rigid pipes after substitution:**

$$c = \sqrt{\frac{1}{\rho\left[\frac{1}{K}+\frac{D}{Et}\right]}}$$ **1.0**

$$c = \sqrt{\frac{K'}{\rho}}$$

$$\frac{1}{K'} = \frac{1}{K}+\frac{D}{Et}$$

QUESTION 3 [18 Marks]

A reservoir is connected to a steel pipeline at the upstream end as shown in **Fig. 1**. At the end of the pipe there is a valve. Under standard operating conditions, petrol (density = 740 kg m^{-3}, bulk modulus = 1.3 GPa) flows from the reservoir to the pipe at a steady flow rate of 300 L/s and is discharged through the control valve into a collection reservoir. The pipeline is built with an elastic steel pipe (modulus of elasticity = 210 GPa) of 55 cm diameter, 5 mm thickness and 4.5 km length. The pipe has cylindrical surge tank with a diameter of 110 cm.

Calculate the:

a) area and maximum elevation of that surge tank? (5)

b) wave celerity, transient pressure and final pressure of the surge wave if the valve is closed in 20 s. (9)

c) time required for the pressure wave to travel from the valve to the reservoir (3)

Assume the initial pressure of 140 KN/m^2

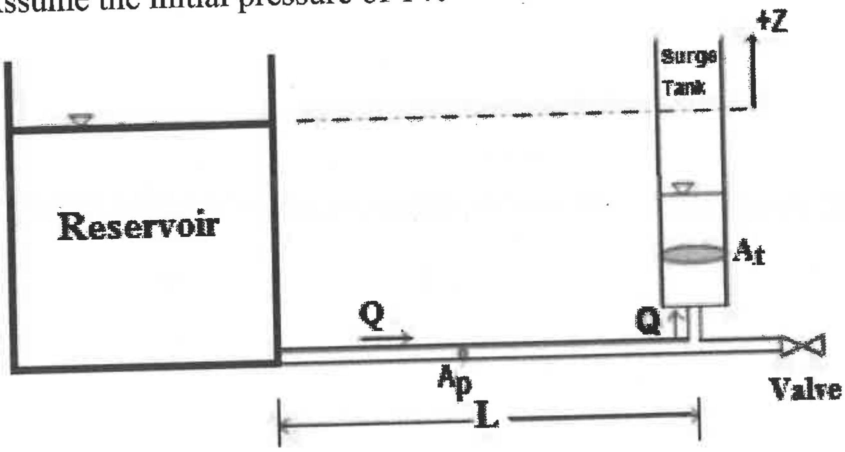


Fig. 1 Question 3

Solution

Solution

a) **Area and maximum elevation of the surge tank** (5)

Area of the pipe:

$$A = \frac{\pi D^2}{4} = \frac{\pi (0.6)^2}{4} = 0.283\ m^2 \quad \checkmark\ [1]$$

$$V = \frac{Q}{A} = \frac{0.30}{0.283} = 1.061\ m/s \quad \checkmark\ [1]$$

Area and height of the surge tank:

$$a = \pi r^2 = \pi (0.75)^2 = 1.22\ m^2 \quad \checkmark\ [1]$$

$$H = V\sqrt{\frac{AL}{ag}} = 1.061\sqrt{\frac{(0.283)(3500)}{(1.22)(9.81)}} = 9.62\ m \quad \checkmark\checkmark\ [2]$$

b) **Wave Celerity (c) and transient pressure** (10)

Wave celerity assuming:

– **Elastic Pipe:**

$$c_{, elastic} = \sqrt{\frac{1}{\rho_w\left[\frac{1}{K_w} + \frac{c_1 D}{ES}\right]}} = \sqrt{\frac{1}{1000\left[\frac{1}{2.2\times10^{9}} + \frac{0.90\times0.6}{0.005\times2.6\times10^{9}}\right]}} = 153.47\ m/s \quad \checkmark\checkmark\ [2]$$

Check if the valve closure is rapid or gradual - determined based on the travel time:

Travel time:

$$t_c = \frac{2L}{c} = \frac{2(3500)}{153.47} = 45.6\ sec > 20\ s \rightarrow \text{the closure is considered as gradual} \quad \checkmark\ [1]$$

Transient pressure:

Elastic pipe: $\Delta h = \frac{\Delta p}{\rho g} = \frac{L}{g}\left(\frac{u_o}{\Delta t}\right) = \frac{3500}{9.81}\left(\frac{1.061}{20}\right) = 18.93\ m \quad \checkmark\checkmark\ [2]$

$$\Delta P = \rho c V = 1000(153.47)(1.061) = 162852\ N/m^2 = 162.9\ KN/m^2 \quad \checkmark\ [1]$$

Change in pressure: $\Delta P = \Delta h \ast \rho g = 18.93(9810) = 185692\ N/m^2 = 185.7\ KN/m^2$

$$\Delta H = \frac{\Delta P}{\gamma} = \frac{162.852}{9.81} = 16.6\ m \quad \checkmark\checkmark\ [2]$$

$$N = \frac{\rho L u_o}{P_o t_c} = \frac{1000(3500)(1.061)}{(1500)(20)} = 123.78 \quad \checkmark\ [1]$$

$$\Delta P = P_o\left[\frac{N}{2} + \sqrt{\frac{N^2}{4} + N}\right] = 1500\left[\frac{123.78}{2} + \sqrt{\frac{123.78^2}{4} + 123.78}\right] = 23076\ KN/m^2 \quad \checkmark\ [1]$$

c) **Time required for the surge wave:** (2)

$$t_c = \frac{2L}{c} = \frac{2(3500)}{153.47} = 45.6\ sec \quad \checkmark\checkmark\ [2]$$

L	4500 m	ρ_p	740		D	1.1	m (Surgae tank)
K	1.3E+09	D	0.55	m (Pipe)			
E	2.1E+11	t	20	sec	Po	1E+05 pa	
T	0.005 mm	η	0.3				
Q	0.3 m^3/s						

(a) Area and maximum elevation of surge tank

Area of pipe(A) = 0.238 m^2 [1] $A = \pi r^2$

V = **1.263** m^3 [1] = U_o

Area surge tank) (a) **0.950** m^2 [1]

Elevation of surge tank

$$H = V\sqrt{\frac{AL}{ag}}$$ **13.523 m** [2]

$$\Delta h = c\left(\frac{u_o}{g}\right)$$

(b) Wave celerity and transient pressure

Assume Elastic pipe:

C_1	**0.91**	**0.9**		
C_e	**1041**	**1044**	m/s	[3]
Δt	**8.64**	**8.62**	s	< t [2]
	(Instantaneous closure)			
Δh	**134.1**	**134.3**	m	[2]
ΔP	**973212**	**975264**	Pa	[2]

N 1.50182 $N = \frac{\rho L U o}{P.t}$

ΔP 306343 Pa [1]

© t **4.32 s** [2]

QUESTION 4 [20 Marks]

A pipe network is given bellow (**Fig. 2**). All pipes are 1 km long and 600 mm in diameter, with with Hazen Williams Coefficient of 140.

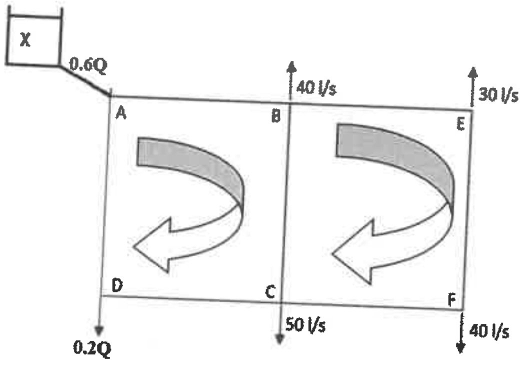
a) Determine the value of Q and state the basic hydraulic criteria for the analysis (4)

b) Determine the correct flows in each pipes (using Hardy-cross method) after the first iteration [Hint: Assume **Q_o for pipe AB = 130 L/s**] (10)

c) Determine the pressure heads at each node if the pressure head at reservoir X is 70 m. (4)

d) Set the matrix for the network (4)

Ignore all minor losses. Show all your assumptions.



Pipe	Elevation (m)
A	28
B	26
C	30
D	32
E	25
F	30

Fig. 2. Two loop pipe network (Question 4)

(a) Continuity Eqn: 0.6Q = 40+30+40+50+0.2Q →Q = 160/0.4 = 400 L/s

Q_D = 0.2*400 = 80 L/s; 0.6Q = 240 L/s (3)

Basic hydraulic criteria:

- Continuity principle applies at each node
- Energy Conservation principle applies within the loops

(b) Flow rates at each pipe: Hardy Cross Method

Initial Trial: Q_{AB}=110 L/S = 0.110 m³/s

Loop 1:

Pipe	Q	D	C	R_{HW} [1]	h_f [1]	h_f/Q_o	Qc [1]	hf [0.5]	h_f/Q_o
AB	0.12	0.600	120	18.2	0.36	3.01	**0.122**	0.27	0.75
BC	0.02	0.600	120	18.2	0.01	0.66	**0.022**	0.01	0.68
CD	-0.04	0.600	120	18.2	-0.05	1.18	**-0.038**	-0.03	0.55
AD	-0.12	0.600	120	18.2	-0.36	3.01	**-0.118**	-0.25	0.70
			Sum		**-0.034**	**7.8**		**0.002**	**2.7**

$\Delta Q = \Sigma h_f / 2 * \Sigma(h_f/Q$ **-0.002** m³/s Not ok

Loop 2

Pipe	Q	D	C	R_{HW} [1]	h_f [1]	h_f/Q_o	Qc [1]	hf [0.5]	h_f/Q_o
BE	0.06	0.600	120	18.2	0.10	1.67	**0.062**	0.07	0.70
EF	0.03	0.600	120	18.2	0.03	0.93	**0.032**	0.02	0.68
CF	-0.01	0.600	120	18.2	0.00	0.36	**-0.008**	0.00	0.31
BC	-0.018	0.600	120	18.2	-0.01	0.60	**-0.016**	0.00	0.42
			Sum		**0.114**	**3.6**		**0.084**	**2.1**

$\Delta Q = \Sigma h_f / 2 * \Sigma(h_f/Q$ **0.016** m³/s **Not ok** [1]

Trial 2

(c) Pressure Heads (4)

To find the pressure heads at B, C, and D, apply the energy equation:

			P (Pa)
Hx	70	m	
HA	42	m	**137092.8**
HB	43.7	m	**173618.2**
HC	39.7	m	**95181.56**
HD	38.1	m	**59909.55**
HE	44.7	m	**192419.5**
HF	39.6	m	**94300.25**

H = P/γ + z

Pipe	Z (m)
A	28
B	26
C	30
D	32
E	25
F	30

Pipe	h_f
AB	0.27
BC	0.01
CD	-0.03
BE	0.07
DA	-0.118
EF	0.02
FC	-0.008

Note: P/γ = H & V²/2g = the same in all pipes since their diameters are equal.

(d) Set the matrix for the network

$$
\begin{bmatrix}
A_1+A_4+A_o & -A_1 & 0 & -A_4 & 0 & 0 \\
-A_1 & A_1+A_2+A_5 & -A_2 & 0 & -A_5 & 0 \\
0 & -A_2 & A_2+A_3+A_7 & -A_3 & 0 & -A_7 \\
-A_4 & 0 & -A_3 & A_3+A_4 & 0 & 0 \\
0 & -A_5 & 0 & 0 & A_5+A_6 & -A_6 \\
0 & 0 & -A_7 & 0 & -A_6 & A_6+A_7
\end{bmatrix}
\begin{bmatrix} H_A \\ H_B \\ H_C \\ H_D \\ H_E \\ H_E \end{bmatrix}
=
\begin{bmatrix} Q_A+A_0H_O \\ -Q_B \\ -Q_C \\ -Q_D \\ -Q_E \\ -Q_F \end{bmatrix}
$$

$$
\begin{bmatrix}
A_1+A_4+A_o & -A_1 & 0 & -A_4 & 0 & 0 \\
-A_1 & A_1+A_2+A_5 & -A_2 & 0 & -A_5 & 0 \\
0 & -A_2 & A_2+A_3+A_7 & -A_3 & 0 & -A_7 \\
-A_4 & 0 & -A_3 & A_3+A_4 & 0 & 0 \\
0 & -A_5 & 0 & 0 & A_5+A_6 & -A_6 \\
0 & 0 & -A_7 & 0 & -A_6 & A_6+A_7
\end{bmatrix}
\begin{bmatrix} H_A \\ H_B \\ H_C \\ H_D \\ H_E \\ H_E \end{bmatrix}
=
\begin{bmatrix} 240+70A_0 \\ -40 \\ -50 \\ -80 \\ -30 \\ -80 \end{bmatrix}
$$

QUESTION 5 [25 Marks]

Water is flowing from a lower reservoir to an upper reservoir as shown in Figure 3. The reservoir is open to the atmosphere at 12 KPa gauge pressure. A centrifugal pump running at 2500 rpm was designed to satisfy the following system shown in the table. The pump is connected to suction and delivery pipes as shown in the figure. Assume motor power as 700 KW, motor efficiency = 82%, friction factor = 0.018 and secondary loss factor = 6.8. The pump performance curve is given in Figure 4.

Q (m^3/hr)	3	6	9	12
H_L (m)	10	20	40	65

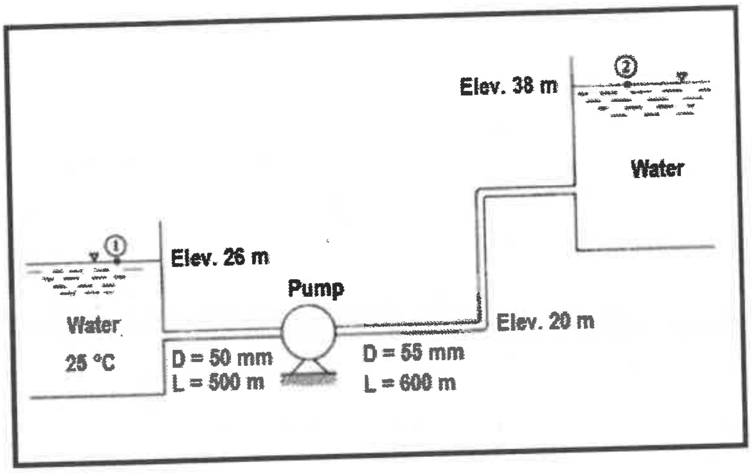
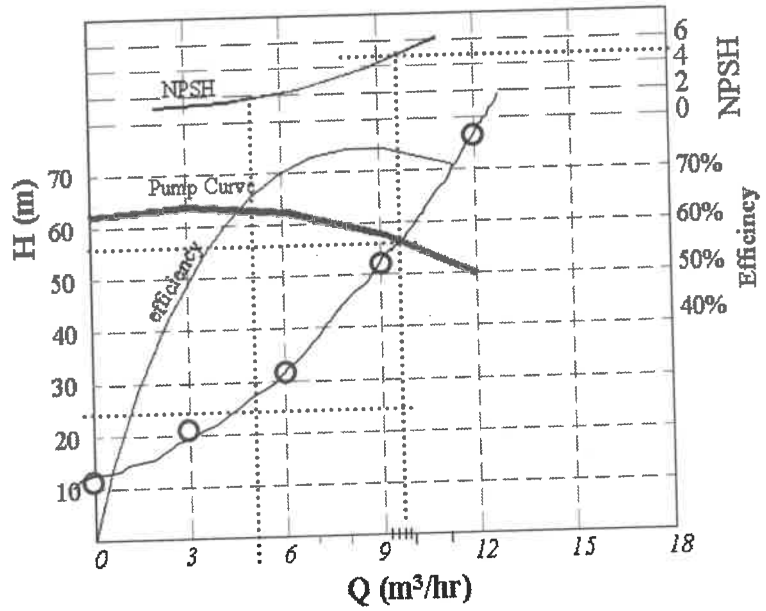


Figure 3. Pump connecting 2 reservoirs **(Question 3)**

The pump is connected to suction and delivery pipes as shown in the figure. Assume motor power as 700 KW, motor efficiency = 82%, friction factor = 0.018 and secondary loss factor = 6.8.

Answer the following questions:

a) Calculate the static and total dynamic heads (3)
b) Check whether the pump is suitable or not (5)
c) Calculate the water power and applied power (3).
d) Calculate Q & H at duty point if the pumps are coupled in parallel (5)
e) Calculate the safety margin and safety factor required to avoid cavitation. (2)
f) If it is required to adjust the flow by regulating the pump speed, estimate the speed to reduce the flow to one-half. (2)



Q (m^3/hr)	12	9		6	3
H_L (m)	65	40		20	10
H_{system}	77		52	32	22

Figure 4. Pump characteristics curve **(Q5)**

Solution

					Suctior	Disch						
h_s	6	m					f	0.018		P_{gauge}	12000 Pa	
h_d	18	m		D	0.05	0.055	P_m	700	KW	P_{atm}	1E+05	
K	6.8	m		L	500	600	N	2500	rpm			
T	25 °C			ρ	997.1		η_m	0.82				

(a) H_{stat} 12 m (Case 1) [1]
[2] Q 9.6 m^3/hr 0.0027 m^3/s
H 56 m

	Suction	Discharge	
[1] h_f	16.92	12.61	m
[1] h_m	0.639	0.437	m
[2] H_t	**42.67**		m

(b) P_{abs} **113300** Pa
P_v **3.2** Pa

	Suction	Discharge		
V	1.358	1.122		
Pa	11.583	m		[1]
Pv	0.2351	m		[1]
V^2/sg	0.09	0.06		
$NPSA_A$	-12.22	m		[2]
[1] $NPSA_R$	4.8	m (Cavitation)		

©
P_w	1113.1	W	[1]
Pa	574	KW	[1]
η_p	0.002	(-)	
η_O	0.0016	(-)	
Ns	399.286	(-)	

Centrifugal pump

(e) [1]
F.S	1.393	(-)	[2]
M	39.294		
σ	0.11248	%	

b_3 = 63

57 = b1 $(0.22)^2$+b2 (0.22)+48   -10 = b1 $(0.3^2 - 0.22^2)$+b2(0.30-0.22)

40 = b1 $(0.30)^2$+b2 (0.30)+48   4.86E-06 0.00083

b1 = -3497143 -171.43 b2   **b1 = -74.4-1.786b2**   b2

b_2 = 11100 [1]   **b1 = -240.4-1.923b2**

36 = (-240-1.923b2)*(0.22^2)+0.08b2+67

↔ b_1 = -5400000   -6 -21.857 -0.0011 b2   0.003 b2

15.8571 0.001 b2

H_p =-5400000 Q^2 + 11100 Q+63 [1] Pump curve

H_p= -18.4 $(Q/3)^3$-31.4 (Q/3)+58   [1] 3 pumps in parallel

= 2.31Q^2 17.78Q+58   Q = 0.25

H_p = -1003986 m [1]

b1	-5400000	-16200000
b2	11100	33300
b3	63	189

Hs = a^1 Q2+a2 $a_2 = H_{stat}$ = 12

56 = a_1 $(0.0025)^2$ + 12 [1] a_1 7040000

H = [2]

46 = 20.8(Q^2)+ (-53.33) Q (1.1*0.88)+58(1.1*0.8)

46= 20.8 Q^2 -51.63Q+56.14   4bc #VALUE!

b2 0

Q = #VALUE! m^3/s   #VALUE! [1]

$$Q_b = \frac{-b_2 - \sqrt{b_2^2 - 4.b_1.(b_3 - H)}}{2.b_1}$$

[2]

[2]

Table 6.2 Examples of secondary loss coefficients for different valves

Valve	Secondary loss coefficient K [no unit]
Globe valve, fully open	10
Angle valve, fully open	2
Gate valve, fully open	0.15
Gate valve, 1/4 closed	0.26
Gate valve, 1/2 closed	2.1
Gate valve, 3/4 closed	17
Ball valve, fully open	0.05
Ball valve, 1/3 closed	5.5
Ball valve, 2/3 closed	200
Sudden enlargement (D_1/D_2 = 2)	0.56
Sudden contraction (D_2/D_1 = 2)	0.37

Table. Density, viscosity and vapour pressure as function of temp.

T (°C)	ρ (kg/m3)	μ (kg/m.s)	V.P (Kpa)
5	1000.0	1. 521E -3	0.9
10	999.7	1.307E -3	1.2
15	999.1	1.138E -3	1.7
20	998.2	1.002E -3	2.3
25	997.1	0.891E -3	3.2
30	995.7	0.798E -3	4.3
35	994.0	0.719E -3	5.6

FORMUAL SHEET

$$P_w = \gamma Q H_t \qquad \frac{Q_1}{Q_2} = \left(\frac{D_1}{D_2}.\frac{N_1}{N_2}\right) \qquad \frac{H_1}{H_2} = \left(\frac{D_1}{D_2}.\frac{N_1}{N_2}\right)^2 \qquad \frac{P_1}{P_2} = \left(\frac{D_1}{D_2}.\frac{N_1}{N_2}\right)^3$$

$$R_e = \frac{\rho V D}{\mu} \qquad \frac{NPSHR_1}{NPSHR_2} = \left(\frac{N_1}{N_2}\right)^2 \qquad P = A\left[\frac{1-(1+i)^{-n}}{i}\right] \qquad c = \sqrt{\frac{K}{\rho}}$$

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right) \qquad \frac{1}{\sqrt{f}} = 2\log\left(\frac{3.7D}{\varepsilon}\right)$$

$$N_S = 51.64N\frac{Q^{0.5}}{H^{0.75}}$$

$$H_t = h_d + h_{f_d} + \sum h_{m_d} + \frac{v_d^2}{2g} \pm \left[h_s - h_{f_s} - \sum h_{m_s} - \frac{v_s^2}{2g} + \frac{v_s^2}{2g}\right]$$

$$b_1.Q^2 + b_2.Q + b_3 = H$$

$$H = n(b_1.Q^2 + b_2.Q + b_3)$$

$$(NPSH)_A = \pm h_S - h_{fS} - \sum h_{mS} + \frac{P_{atm}}{\gamma_{air}} - \frac{P_{Vapor}}{\gamma_{vapor}} \qquad Dh = \frac{4A}{P}$$

$$Q = AV \qquad a_1.Q^2 + a_2. = H$$

$$H_t = h_d + h_{f_d} + \sum h_{m_d} + \frac{v_d^2}{2g} \pm \left[h_s - h_{f_s} - \sum h_{m_s}\right] \qquad b_1.\left(\frac{Q}{n}\right)^2 + b_2.\left(\frac{Q}{n}\right) + b_3 = H \qquad Q = \sqrt{\frac{H - a_2}{a_1}}$$

$$z_1 + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} + H_P = z_2 + \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + H_L \qquad \eta_P = \frac{P_o}{P_a} = \frac{\gamma Q H}{P_a} \qquad y_v = 14\frac{D}{R_e\sqrt{f}}$$

$$y_t = 184\frac{D}{R_e\sqrt{f}}$$

$$Q = AV \qquad V = \frac{Ku}{n}R^{2/3}S_o^{1/2} \qquad h_f = f\frac{L}{D}\frac{V^2}{2g}$$

$$h_s = K\frac{V^2}{2g} \qquad Q = \sqrt{\frac{h_f}{L}\frac{\pi^2 g}{8f}D^5} \qquad \Delta Q = \frac{\sum hf}{\sum h_f/Q_o} \qquad A = \frac{1}{KQ_o} \qquad C_e = \sqrt{\frac{1}{\rho\left[\frac{1}{K} + \frac{C_1 D}{TE}\right]}}$$

$$\frac{1}{\sqrt{f}} = -2\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right) \qquad f = \frac{0.25}{\left[\log\left(\frac{\varepsilon/D}{3.7} + \frac{5.74}{\mathrm{Re}^{0.9}}\right)\right]^2} \qquad Q_1 = 0.5Q_o + 0.5A(H_{begin} - H_{end})$$

$$H = V\sqrt{\frac{AL}{ag}} \qquad N = \frac{\rho L u_o}{P_o t_c} \qquad \Delta P = P_o\left[\frac{N}{2} + \sqrt{\frac{N^2}{4} + N}\right]$$