Kafrelshiekh University
Faculty of Engineering
Department of Mechanical Engineering
Year: ٣ Subject: Hydraulic Machines
Final Exam: ٢ pages
Name: Assoc. Prof. Ayman Bakry

Date: ١٠/٠١/٢٠١٨
Time allowed: ٣ hours
Full Mark: ٩٠
Academic Number:

Please, answer the following questions (assume any missing data):-

١- The following details refer to a water centrifugal pump. The impeller outer diameter is ٣٠ cm in diameter and its inlet diameter is ١٥ cm. The impeller width at outlet is ٢ cm. The blade angle at inlet is ٣٠° and at outlet is ٢٥°. The impeller speed is ١٤٥٠ rpm. The impeller is designed for constant flow velocity through the impeller and for no-whirl at inlet. The input shaft power is ٢٦.٥ kW and the overall efficiency is ٧٦%. Determine: the width of the impeller at inlet and the theoretical head developed by this impeller (١٥ Marks)

$$U_1=\frac{2\pi N r_1}{60}=\frac{2\pi\times1450\times7.5}{60\times100}=11.38\,m/s,\quad U_2=\frac{2\pi N r_2}{60}=\frac{2\pi\times1450\times15}{60\times100}=22.76\,m/s$$

$$Q=2\pi r_1 b_1 C_{r1}=2\pi r_2 b_2 C_{r2}\qquad \because C_{r1}=C_{r2}$$

$$\therefore r_1 b_1=r_2 b_2\qquad 15\times b_2=30\times2\qquad b_1=4\ cm$$

$$\text{for no whirl at inlet}: C_{x1}=0\qquad \therefore \tan30^\circ=\frac{C_{r1}}{U_1}=\frac{1}{\sqrt{3}}=\frac{C_{r1}}{11.38}\qquad \therefore C_{r1}=6.575\ m/s$$

$$\therefore Q=2\pi r_1 b_1 C_{r1}=2\pi\times0.04\times.075\times6.575=0.12394\qquad m^3/s$$

$$\because \eta=\frac{\rho gQH}{P_{in}}=\frac{1000\times9.81\times0.12394\times H}{26.5\times1000}=0.76\qquad \therefore H=16.56\qquad m$$

$$H_{th}=\frac{1}{g}(U_2C_{x2})\qquad ,C_{x2}=U_2-C_{r2}\cot\beta_2=U_2-C_{r1}\cot\beta_2$$

$$\therefore C_{x2}=22.76-6.575\times\cot25^\circ=8.66\qquad m/s,$$

$$H_{th}=\frac{1}{g}(U_2C_{x2})=\frac{1}{9.81}\times22.76\times8.66=20.1\,m$$

٢- A centrifugal pump has the following characteristics at ١٠٠٠ rpm:

Q (m³/h)	٠	٢٣	٤٦	٦٩	٩٢	١١٥
H (m)	١٧	١٦	١٣.٥	١٠.٥	٦.٦	٢
Eff (%)	٠	٤٩.٥	٦١	٦٣.٥	٥٣	١٠

The pump is used to pump water from a low reservoir to a high reservoir through a total length of ٨٠٠ m of pipe ١٥ cm in diameter. The difference between the water levels in the reservoirs is ٨ m. considering only frictional losses where the friction factor is ٠.٠١٦. Find the rate of flow between the reservoirs. Also determine the power input to the pump.
If the pump speed is reduced to ٨٠٠ rpm, deduce all new performance data plus the input power performance and plot them in addition to the power curve. Also, determine the new operating point and the power. Identify the power consumed at zero discharge. (٢٠ Marks)

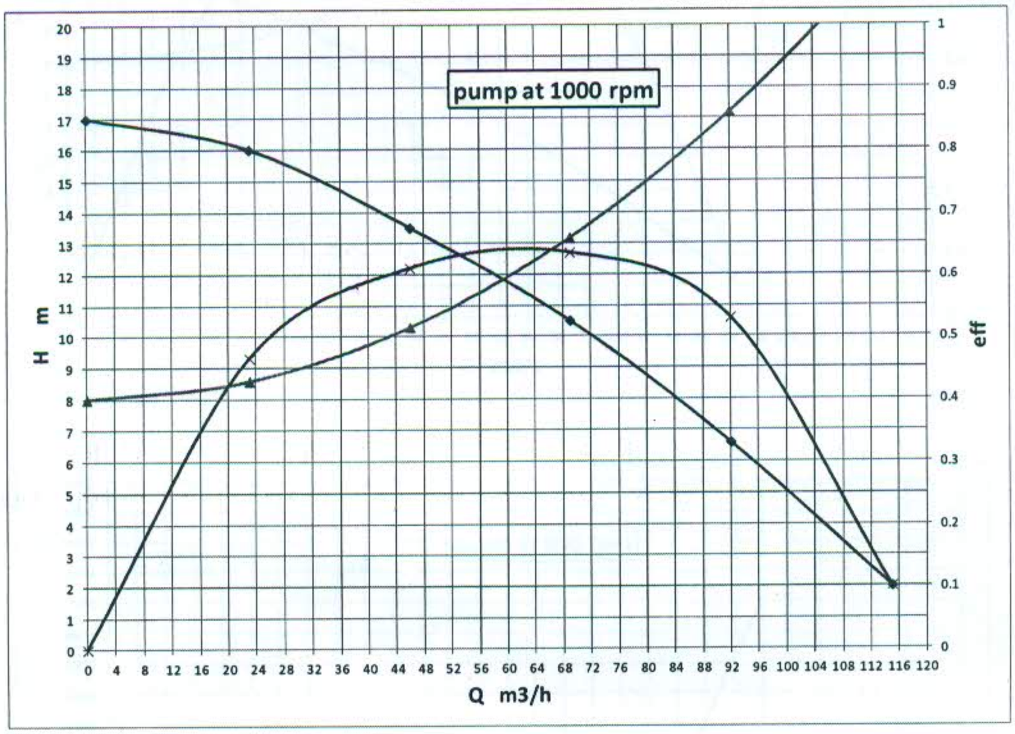
a- The system eq is: $H = ٨ + (٠.٠١٦*٨٠٠/٠.١٥ + ١)(Q^{٢}/ ٢ga^{٢})$

$a = ٣.١٤/٤\ (٠.١٥)^{٢} = ٠.٠١٧٦٧\ m^{٢}$

$H = ٨ + ١٤٠٩٠.٧٧ * Q^{٢}$

From the drawing the operating point is : Q = ٥٨.٥ m٣/h , H = ١١.٧ m, eff = ٠.٦٤

The required power= ٩٨١٠*٥٨.٥ * ١١.٧/(٠.٦٤ * ٣٦٠٠ * ١٠٠٠) = ٢.٩١٤ kW



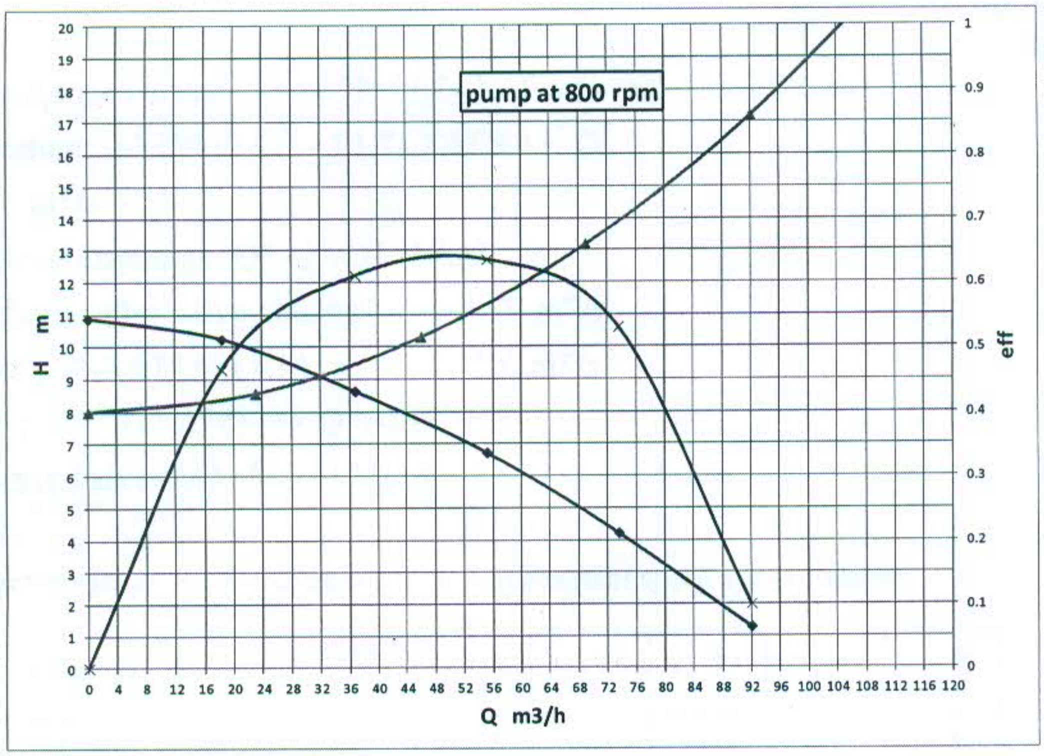
b- from siimilarity laws: $Q_{٨٠٠} = ٠.٨\ Q_{١٠٠٠}$

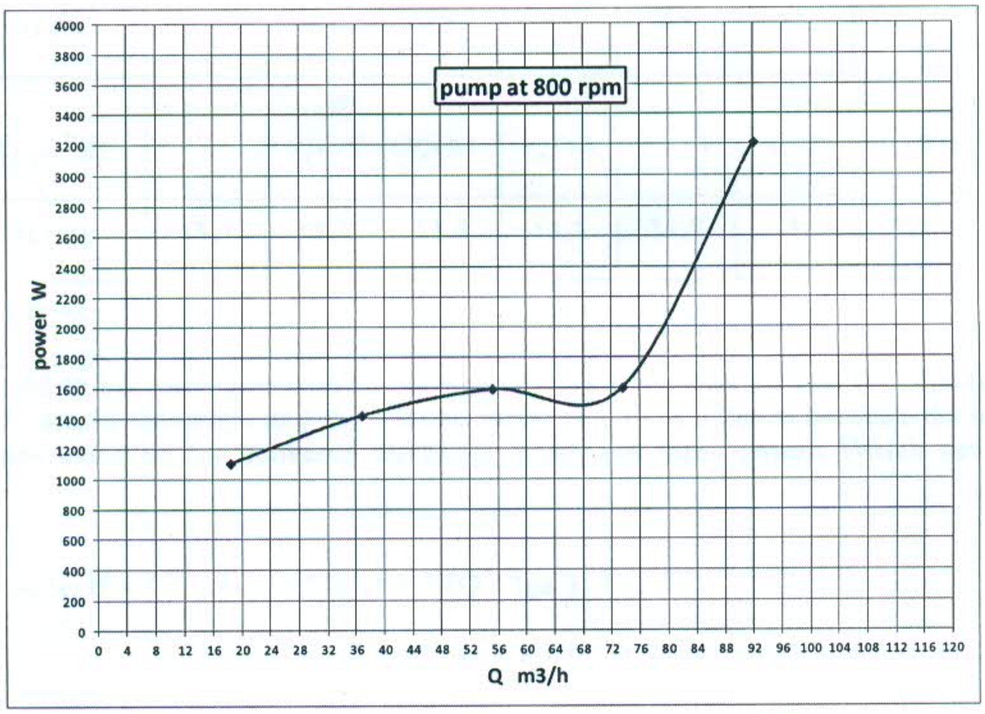
$H_{٨٠٠} = ٠.٦٤\ H_{١٠٠٠}$

$P_{٨٠٠} = ٠.٥١٢\ P_{١٠٠٠}$

The new performance table at ٨٠٠ rpm:

Q (m٣/h)	٠	١٨.٤	٣٦.٨	٥٥.٢	٧٣.٦	٩٢
H (m)	١٠.٨٨	١٠.٢٤	٨.٦٤	٦.٧٢	٤.٢٢٤	١.٢٨
Eff (%)	٠	٤٩.٥	٦١	٦٣.٥	٥٣	١٠
Power (kW)		١.١٠٤	١.٤٢	١.٥٩١	١.٥٩٨	٣.٢٠٨





The required power= ٩٨١٠*٣٢.٥ * ٩.٢/(٠.٥٨ * ٣٦٠٠ * ١٠٠٠) = ١.٠٨ kW

Power at zero discharge by extrapolating the power curve to cut the power axis at ٠ discharge.

Then P at ٠ Q ~ ٠.٧ kW

٣- (a) ٠.٠٥ $m^٣$ /s of water flows from tank A to tank B due to a difference of water level of ٦ m. In order to increase this discharge, a booster pump is used in the line. Calculate the percentage increase in discharge. The performance of the pump is given by H = ٣١.٣ - ١.٨٣ x $١٠^٣$ $Q^٢$.

(b) If a valve, located on the discharge side of the pump, is partially closed to reduce the discharge by ١٠٪, how much power lost in the valve. **(١٠ Marks)**

The system curve : H=-٦+٢٤٠٠ Q^{٢}

The performance curve: H=٣١.٣- ١.٨٣ x ١٠^{٣} Q^{٢}

At intersection: -٦+٢٤٠٠ Q^{٢} = ٣١.٣- ١.٨٣ x ١٠^{٣} Q^{٢}

Q= ٠.٠٩٤ m٣/s

% increase of discharge=Q٢-Q١/Q١=٨٧.٨٪

New discharge after valve closing: ٠.٠٨٤٦ m٣/s

H by system = -٦ +٢٤٠٠ (٠.٠٨٤٦)^{٢} = ١١.١٧٧ m٣/s

H by pump =٣١.٣-١.٨٣*١٠٠٠ Q^{٢} =١٨.٢ m٣/s

Power lost in valve=٩٨١٠*٠.٠٨٤٦*(١٨.٢-١١.١٧٧) = ٥.٨ kW

٤- **The characteristics of two rotodynamic pumps at constant speed are as follows:**

Pump A

Q (m^{٣}/s)	٠	٠.٠٠٦	٠.٠١٢	٠.٠١٨	٠.٠٢٤	٠.٠٣	٠.٠٣٦
H (m)	٢٢.٦	٢١.٩	٢٠.٣	١٧.٧	١٤.٢	٩.٧	٣.٩
Eff (%)	٠	٣٢	٧٤	٨٦	٨٥	٦٦	٢٨

Pump B

Q (m^{٣}/s)	٠	٠.٠٠٦	٠.٠١٢	٠.٠١٨	٠.٠٢٤	٠.٠٣	٠.٠٣٦
H (m)	١٦.٢	١٣.٦	١١.٩	١١.٦	١٠.٧	٩	٦.٤
Eff (%)	٠	١٤	٣٤	٦٠	٨٠	٨٠	٦٠

If they are used to lift water continuously through ٣.٢ m of vertical lift and the pipe to be used is ٢١ m long, ١٠ cm in diameter, and the friction factor is ٠.٠٢. Compare between the operation of the two pumps based on the delivered discharge, head, and input power. Which one would you prefer to use?

(٢٠ Marks)

The system eq is: H = ٣.٢ + (٠.٠٢*٢١/٠.١ + ١)(Q^{٢}/ ٢ga^{٢})

a = ٣.١٤/٤ (٠.١)^{٢}

H = ٣.٢ + ٤٢٩٦.٦ * Q^{٢}

From the drawing the operating point for pump A:

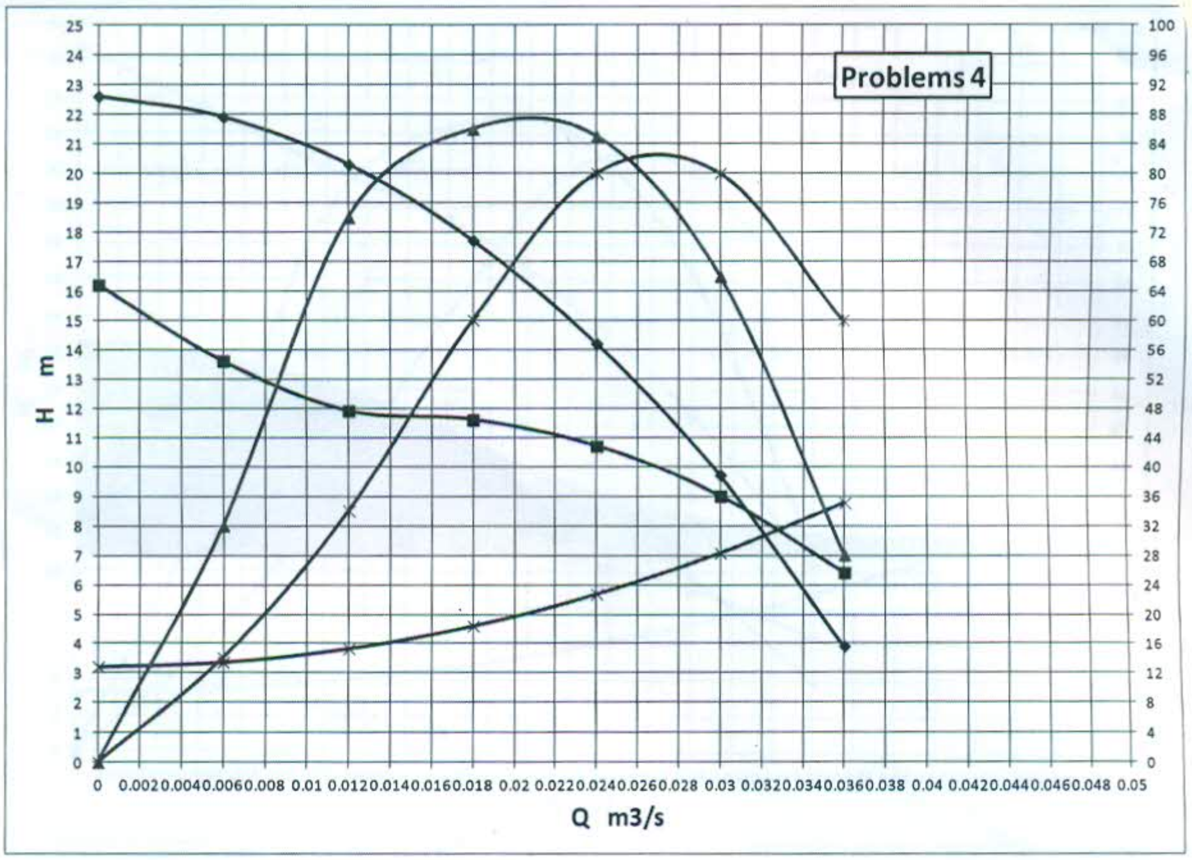
Q = ٠.٠٣٢ m٣/s , H = ٧.٧ m, eff = ٠.٥٥

From the drawing the operating point for pump B:

Q = ٠.٠٣٣ m٣/s , H = ٧.٩ m, eff = ٠.٧٢

The required power= ٩٨١٠*٠.٠٣٢ * ٧.٧/(٠.٥٥ * ١٠٠٠) = ٤.٤ kW

The required power= ٩٨١٠*٠.٠٣٣ * ٧.٩/(٠.٧٢ * ١٠٠٠) = ٣.٥ kW



٥- **If the pumps in problem (٤) are used one time in series and another time in parallel, plot both characteristics curves for the two combinations. Determine the consumed power by the pumps in the two cases.** **(١٥ Marks)**

Series connections:

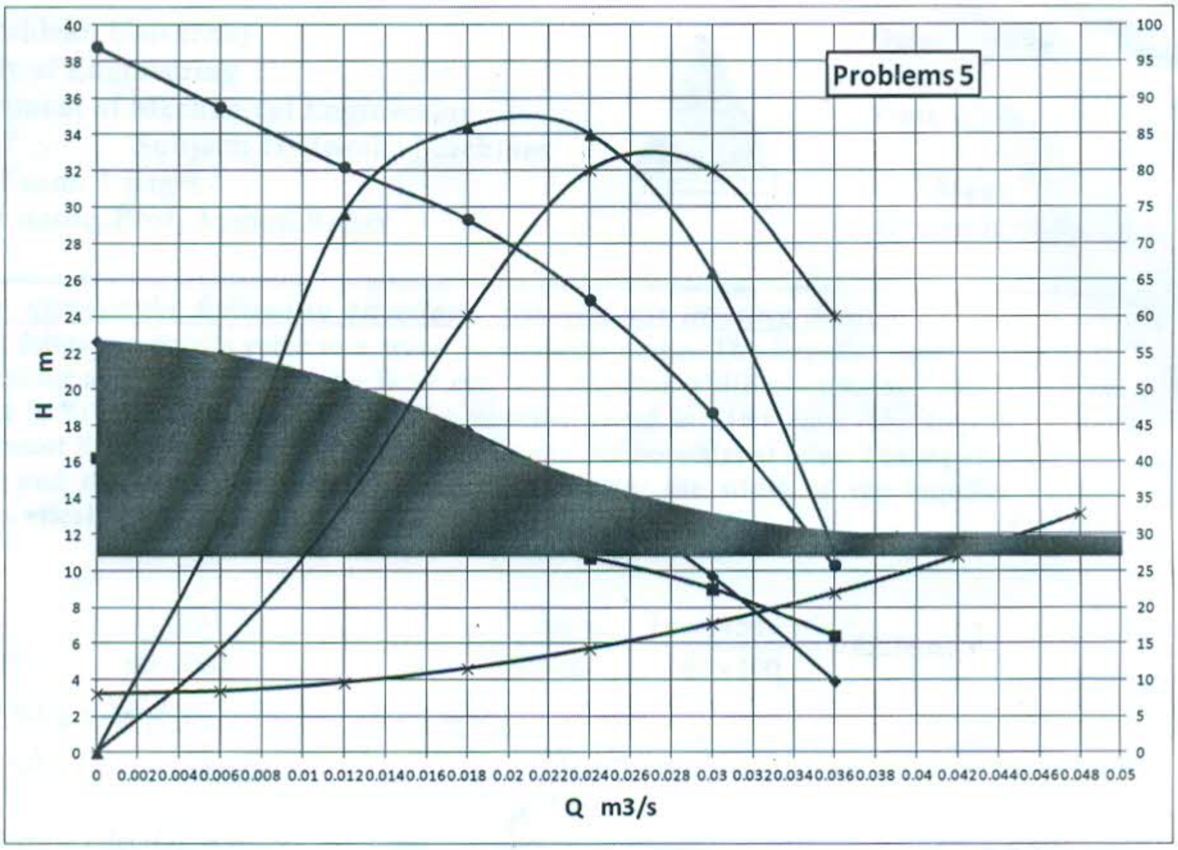
QA = ٠.٠٣٧ m³/s , HA = ٣ m, eff A= ٠.٢٢

QB = ٠.٠٣٧ m³/s , HB = ٦ m, effB = ٠.٥٧

Parallel connections:

QA = ٠.٠٢٧ m³/s , HA = ١٢ m, eff A= ٠.٧٨

QB = ٠.٠١٨ m³/s , HB = ١٢ m, effB = ٠.٦



٦- Do the pumps in problem (٤) operate free of or with cavitation? The suction pipe is ٣ m long with the same pipe. The suction static lift is ٠.٥ m. If the water temperature is ٢٥°C (p_v = ٣.٣ kPa abs and water density = ٩٩٧ kg/m٣) and the atmospheric pressure is ١٠١ kPa. Consider the Thoma cavitation factor as ٠.٢٥. (١٠ Marks)

For pump A:

NPSHr = .٢٥*٧.٧ = ١.٩٢٥ m

NPSHa = ١٠.٣٢ - ٠.٥ - ١.٣٥٤ - ٠.٣٣٧ = ٨.١٢٩ m

The pump A is save of cavitation

For pump B:

NPSHr = .٢٥*٧.٩ = ١.٩٧٥ m

NPSHa = ١٠.٣٢ - ٠.٥ - ١.٤٤ - ٠.٣٣٧ = ٨.٠٤٣ m

The pump B is save of cavitation

أنتهت الأسئلة،،، مع أطيب الأمنيات بالتوفيق،،،

د. أيمـن بكـــري