الفرقة الثالثة

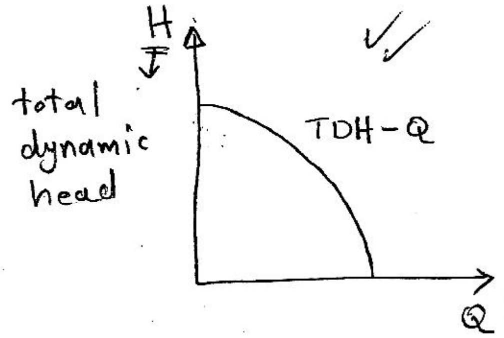
هيدروليكا

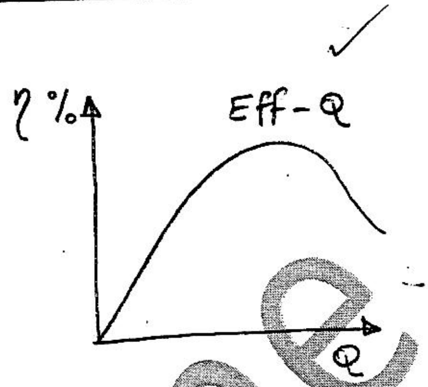
Part (13)

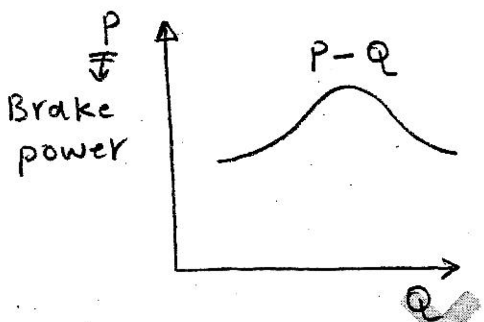
Pump characteristic (performance) curves & system curve :

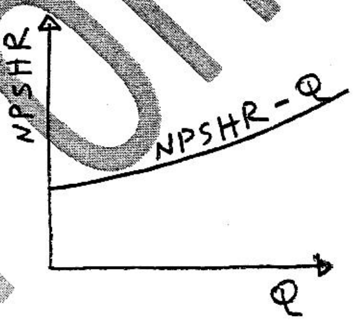
منحنيات آداء المضخه .

1- Typical four Pump characteristic (performance) curves are :



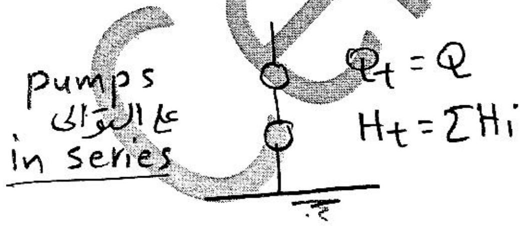


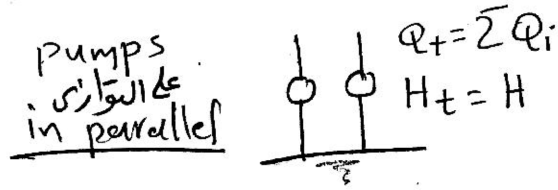


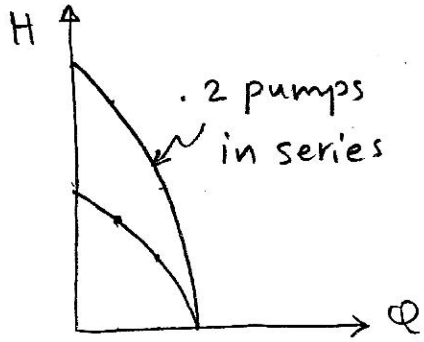


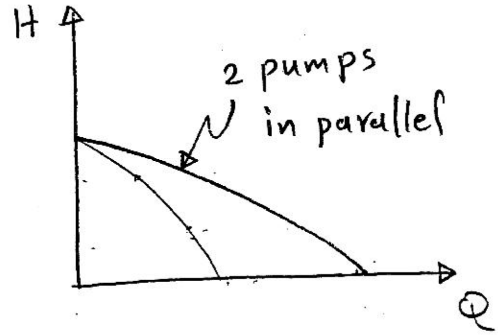
لرسم منحنى الآداء إما أن يُعطى جدول أو يُعطى معادلة نعوض فيها.

إذا أعطى مضختين على التوالى نضرب H للمضخة الواحدة فى 2 ثم نرسم المنحنى ، أما إذا أعطى مضختين على التوازى نضرب Q للمضخة الواحدة فى 2 ثم نرسم المنحنى.





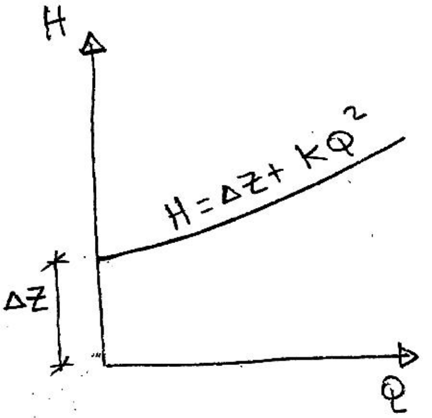


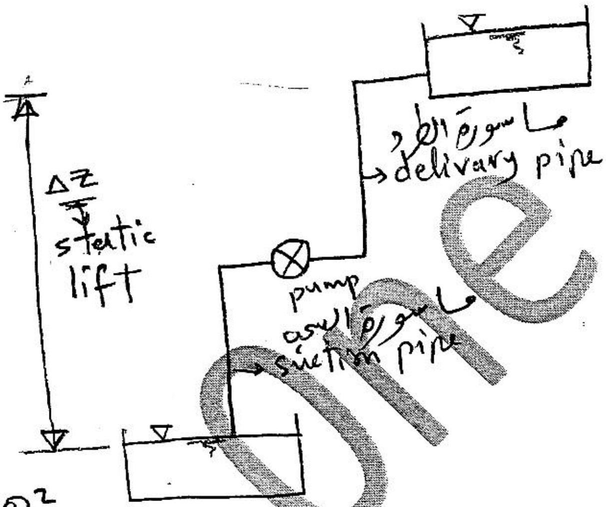


منحنى النظام

2- system curve are :

For Rotodynamic pumps $\qquad H_m = f(Q)$





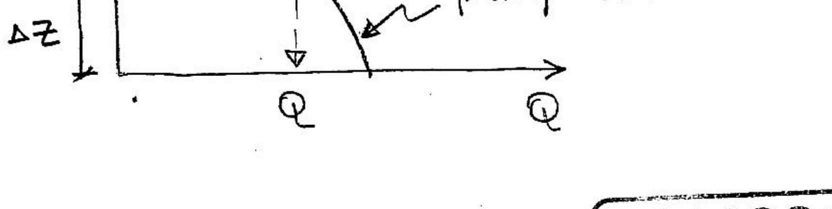
$$h_f = \frac{4 f . L V^2}{2 g d} = \frac{32 f L Q^2}{g \pi^2 d^5} = K . Q^2$$

- **Operating point :** نقطة التشغيل

is a point on the ***pump characteristic*** at which it operates , and at the same time it is also the point on the ***system characteristic*** which the system operates , so that , it deserves the required flow rate operating at best efficiency.

هي نقطه تقاطع منحنى النظام مع منحنى آداء المضخة التي عندها تكون الكفاءه تقريباً قصوى ما يمكن .

تعريف نظري



(June 19,1999):

The head discharge relationship for a certain pump can be represented by the equation :

$$H_m = 36 - 450\,Q$$

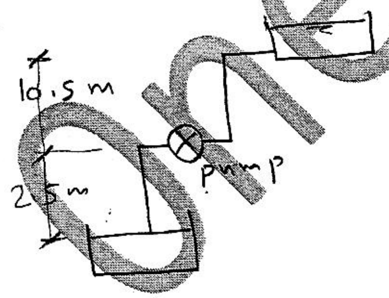
The pump is fixed 2.5 m above the water surface in a river and it discharges the water to a level 10.5 m above the pump , suction and delivery pipes are 15 m and 950 m. respectively and each pipe is 600 mm diameter. The pipes coefficient of friction is 0.005 . Neglect minor losses, Estimate the suitable pump discharge and the power consumed ($\eta_t = 83\%$).

→ characteristic Curve :

نرسم المنحنى باستخدام المعادله المعطاه بفرض قيم ل Q وإيجاد H_m المقابله لها

→ System Curve :

$$H = \Delta Z + K Q^2$$



$\Delta Z = 2.5 + 10.5 = 13$ m

$L = 15 + 950 = 965$ m

$d = 600$ mm

$f = 0.005$

$\eta = 0.83$

$Q = ??$

$P = ??$

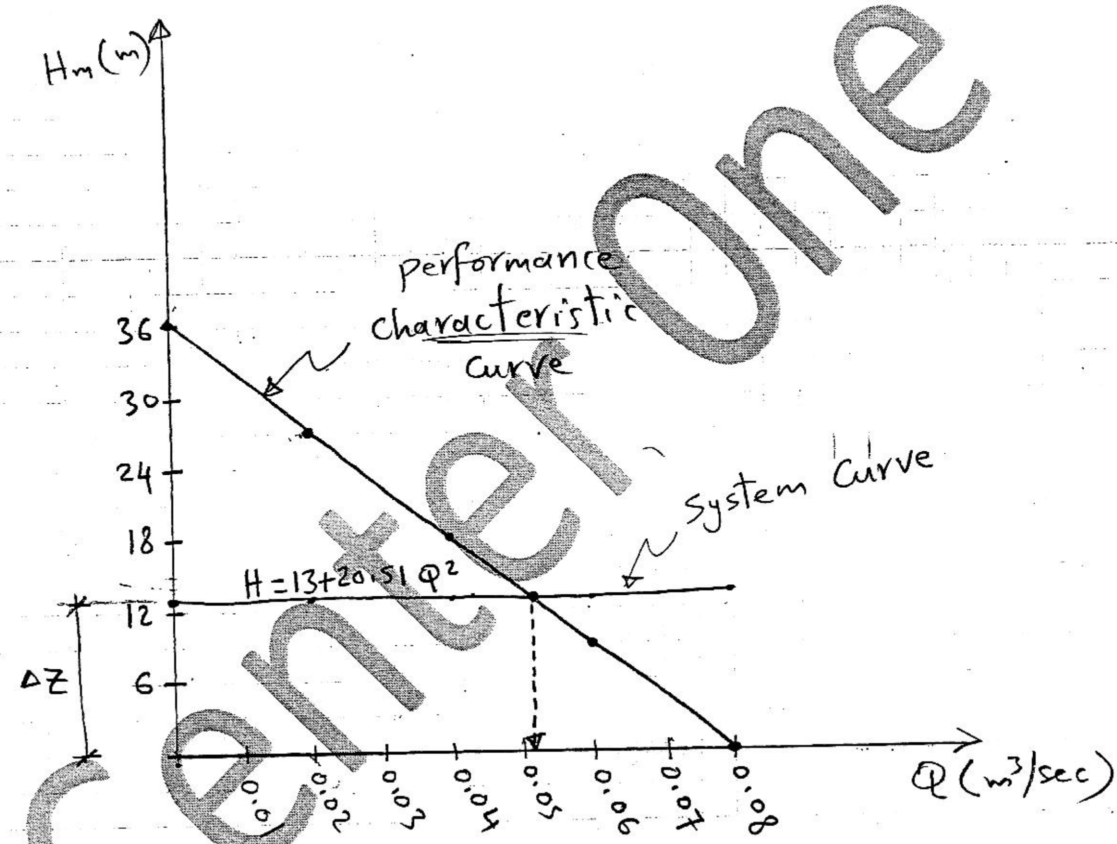
$$h_f = \frac{32 f \cdot L \cdot Q^2}{g\, \pi^2 \cdot d^5} = \frac{32 * 0.005 * 965\, Q^2}{9.81 * \pi^2 * 0.6^5} = 20.51\, Q^2$$

$$\therefore \boxed{H = 13 + 20.51\, Q^2}$$

characteristic Curve : at $Q = 0.0 \Rightarrow H = 36$ m

at $H = 0.0 \Rightarrow Q = 0.08\ m^3/sec$

$Q\ (m^3/sec)$	0	0.02	0.04	0.06	0.08
H_m (m)	36	27	18	9	0



from curve : $Q = \underline{0.052}\ m^3/sec$

$H = 13.05$ m

$$\eta = \frac{\frac{\gamma Q H}{75}}{P}$$

$$0.83 = \frac{\frac{1000 * 0.052 * 13.05}{75}}{P} \Rightarrow P = \underline{10.9}\ h.p$$

(May 27, 2000):

A 60 cm diameter impeller centrifugal pump has the following characteristics at 750 r.p.m :

Q (m^3/sec)	0	0.012	0.018	0.024	0.030	0.036	0.042
H_m (m)	22.6	21.3	19.4	16.2	11.6	6.5	0.6
η (%)	0	74	86	85	70	46	8

a] The pump is used to lift water over a vertical distance of 6.5 m by means of a 10 cm diameter pipe , 65 m long, for which friction coefficient f = 0.005 find the rate of flow and the power input to the pump.

b] If a geometrically similar pump but 50 cm impeller diameter is used running at 900 r.p.m. determine the discharge and the power consumed.

D = 60 Cm

N = 750 r.p.m

$\Delta Z = 6.5$ m

d = 10 Cm

L = 65 m

f = 0.005

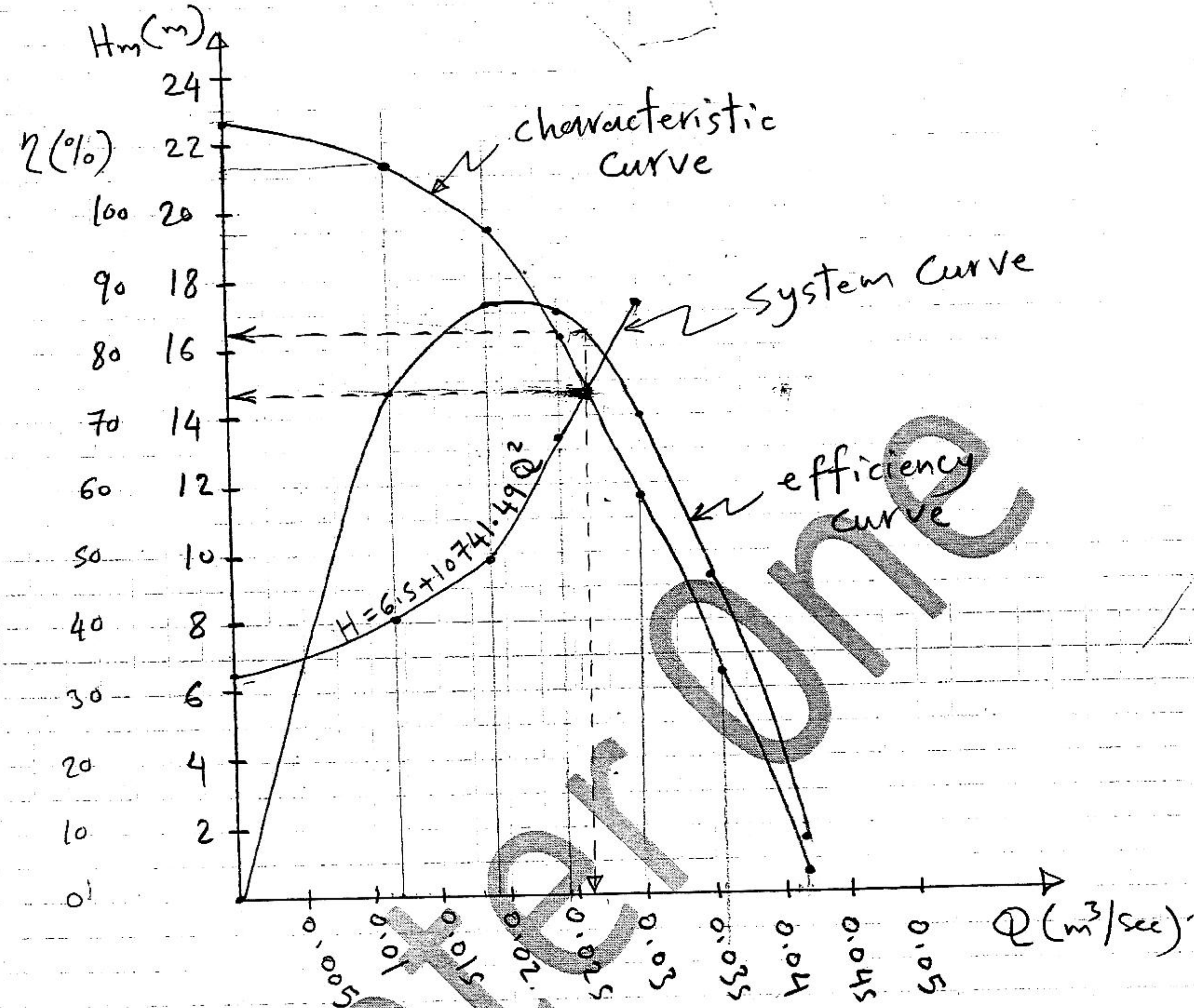
Q = ??

P = ??

→ System Curve : $H = \Delta Z + KQ^2$

$$h_f = \frac{32 f L Q^2}{g \pi^2 d^5} = \frac{32 * 0.005 * 65 Q^2}{9.81 * \pi^2 * 0.1^5} = 10741.49 Q^2$$

$$\therefore \boxed{H = 6.5 + 10741.49 Q^2}$$



From curve: $Q = 0.027\ m^3/sec$

$H_m = 14.6\ m$

$\eta = 82\% = \dfrac{\frac{1000 * 0.027 * 14.6}{75}}{P} \Rightarrow P = 6.4\ h.p$

b]
$\begin{pmatrix} D = 50\ cm \\ N = 900\ r.p.m \\ Q = ?? \\ P = ?? \end{pmatrix}_{model}$

$K_1 = \left(\dfrac{N.D}{\sqrt{H}}\right)_m = \left(\dfrac{N.D}{\sqrt{H}}\right)_p$

$\left(\dfrac{900 * 50}{\sqrt{H}}\right)_m = \left(\dfrac{750 * 60}{\sqrt{14.6}}\right)_p$

$\therefore H_{model} = 14.6\ m$

$K_2 = \left(\dfrac{PN^2}{H^{5/2}}\right)_m = \left(\dfrac{PN^2}{H^{5/2}}\right)_p$

$\left(\dfrac{P * 900^2}{14.6^{5/2}}\right)_m = \left(\dfrac{6.4 * 750^2}{14.6^{5/2}}\right)_p$

$\therefore P_m = \underline{\underline{4.44}}\ h.p$

$K_3 = \left(\dfrac{Q}{D^2\sqrt{H}}\right)_m = \left(\dfrac{Q}{D^2\sqrt{H}}\right)_p$

$\left(\dfrac{Q}{50^2\sqrt{14.6}}\right)_m = \left(\dfrac{0.027}{60^2\sqrt{14.6}}\right)_p$

$\therefore Q_m = \underline{\underline{0.0188}}\ m^3/sec$

(June, 11, 2002):

The characteristic of an axial flow pump running at 1450 r.p.m. is as follows:

Q (m^3/sec)	0	0.069	0.115	0.138	0.18
H (m)	5.6	4.35	3.38	2.42	0

When such two pumps are connected in parallel the flow rate through the system is the same as when they are connected in series. At what speed should a single pump run in order to deliver the same volume ? If the overall efficiency is 85 %, find the power consumed in watts. Assume the system characteristic to be purely resistive and no static lift.

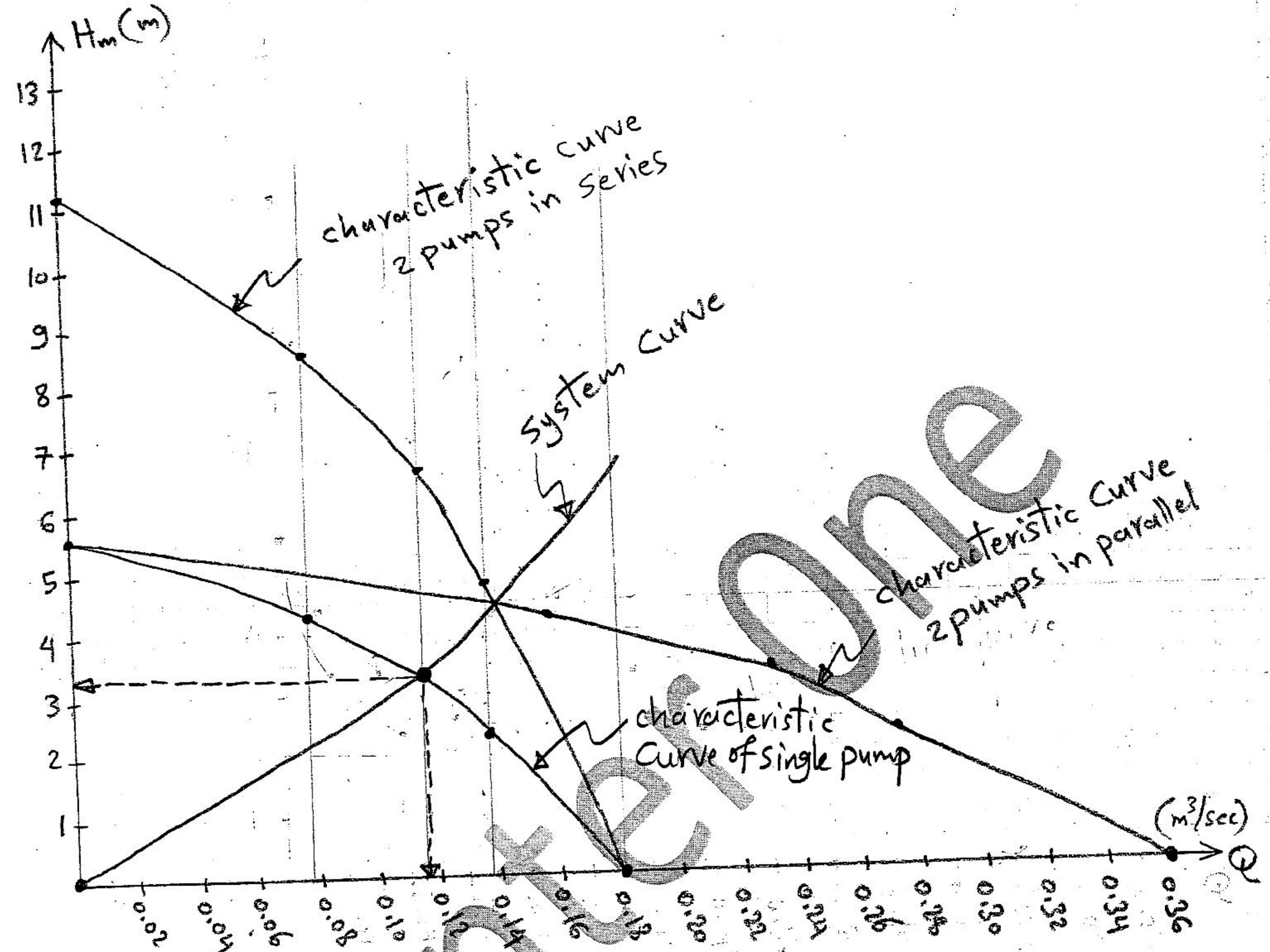
$\Delta Z = 0.0$

$N = 1450$ r.p.m

$$\eta = 0.85 = \frac{\gamma Q H}{P}$$

$$0.85 = \frac{9810 * 0.115 * 3.38}{P}$$

$\therefore P = 4486.06$ watt



From curve : for single pump

$Q = 0.115 \ m^3/sec$

$H_m = 3.38 \ m$

$$\frac{Q_{single}}{Q_{2\,pump}} = \frac{N_{single}}{N}$$

$$\frac{0.115}{0.14} = \frac{1450}{N}$$

$\therefore N_{single\ pump} = \underline{1765.2}$ r.p.m

مطلوب : عدد لفات المضخه الواحده لكى تضخ نفس Q لمضختين تم توصيلهم على التوالى أو التوازى

(May 27, 2003):

A pump has the following characteristics when running at 1450 r.p.m :

Q (m³/sec)	0	0.335	0.545	0.650	0.75	0.8
H (m)	20	15	10	7	3	0

A system is designed where the static lift is 5.0 m and the operating point is $H = 11.1$ m and $Q = 0.5$ m³/sec. Using the pump as above, the system is redesigned, the static lift is being the same but the frictional and other losses increase by 40 %. Find the new pump speed such that the flow rate of 0.5 m³/sec can be obtained.

$N = 1450$ r.p.m

$\Delta Z = 5.0$ m

operating point $H = 11.1$ m

$Q = 0.5$ m³/sec

→ **System Curve:**

$$H = \Delta Z + K Q^2$$

حيث أن نقطة التشغيل تقع على منحنى النظام فإنها تحقق معادلة

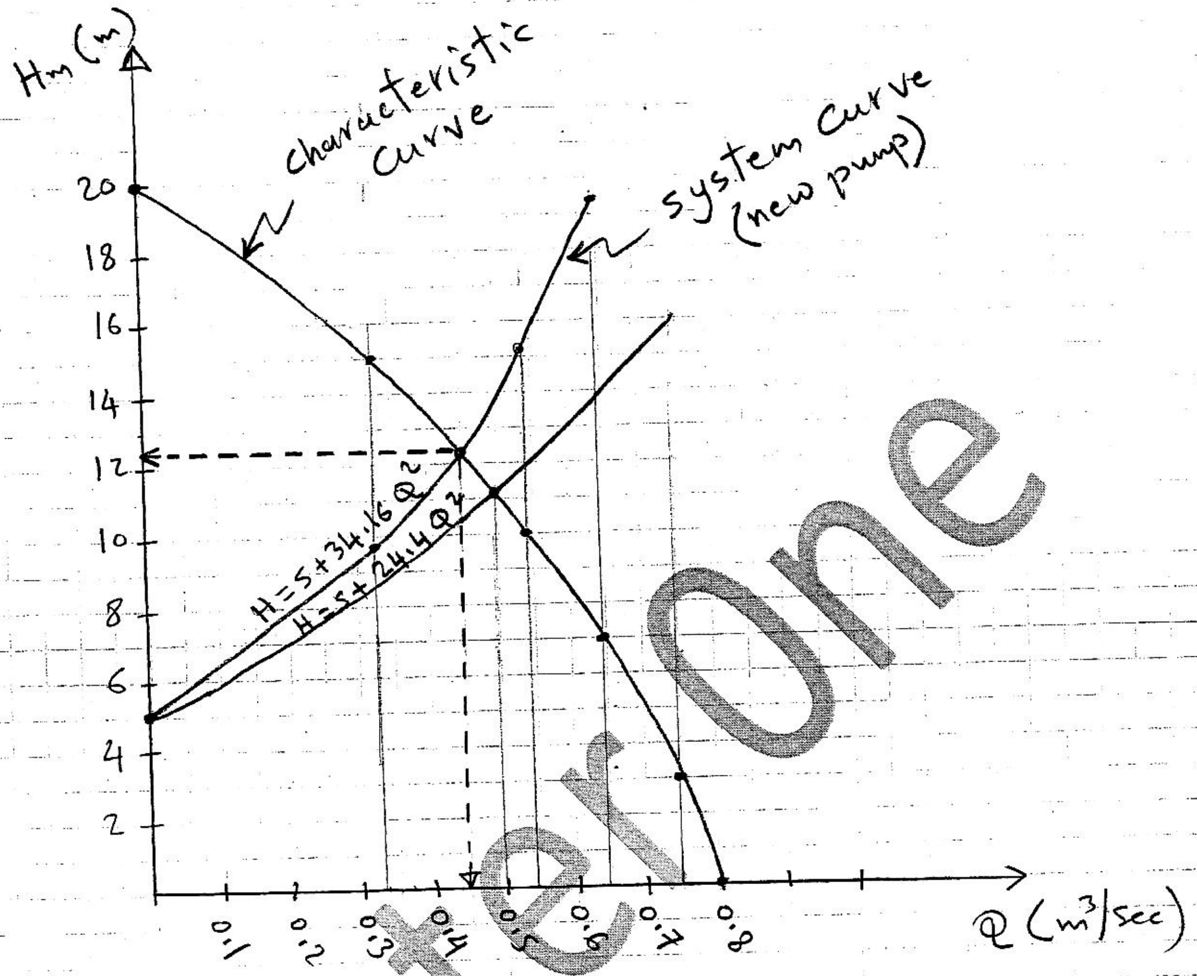
$$11.1 = 5.0 + K * 0.5^2 \Rightarrow K = 24.4$$

For new pump:

∵ frictional and other losses increase by 40 %

$$\therefore K = 1.4 * 24.4 = 34.16$$

$$\therefore \boxed{H = 5.0 + 34.16\, Q^2}$$



For new pump: N = ??

from Curve:

$Q = 0.45\ m^3/sec$

$H_m = 12.4\ m$

مطلوب سرعة المضخه الجديده المناظره لتصرف $Q = 0.5\ m^3/sec$

$$\frac{Q_{new}}{Q} = \frac{N_{new}}{N}$$

$$\frac{0.45}{0.5} = \frac{1450}{N}$$

$\therefore N = 1611.1$ r.p.m

(June 7, 2005):

A pump has the following characteristics when running at 1400 r.p.m :

Q (m^3/sec)	0	0.335	0.545	0.650	0.75	0.8
H (m)	20	15	10	7	3	0

A system curve is given by the following equation $H = 5 + 24.4\,Q^2$ which gives a discharge of 0.5 m^3/sec. Using the pump as above, the system is redesigned, that is the static lift is being the same and the friction losses increase by 30 %. Find the new pump speed such that the flow rate of 0.6 m^3/sec and calculate the power consumed if the pump total efficiency at the new operating point is 78 %.

$N = 1400$ r.p.m

System Curve :

$$H = 5 + 24.4\,Q^2$$

For new pump :

$$\Delta Z = 5.0 \text{ m}$$

$$K = 1.3 * 24.4 = 31.72$$

$$\therefore \boxed{H = 5.0 + 31.72\,Q^2}$$

$P = ??$

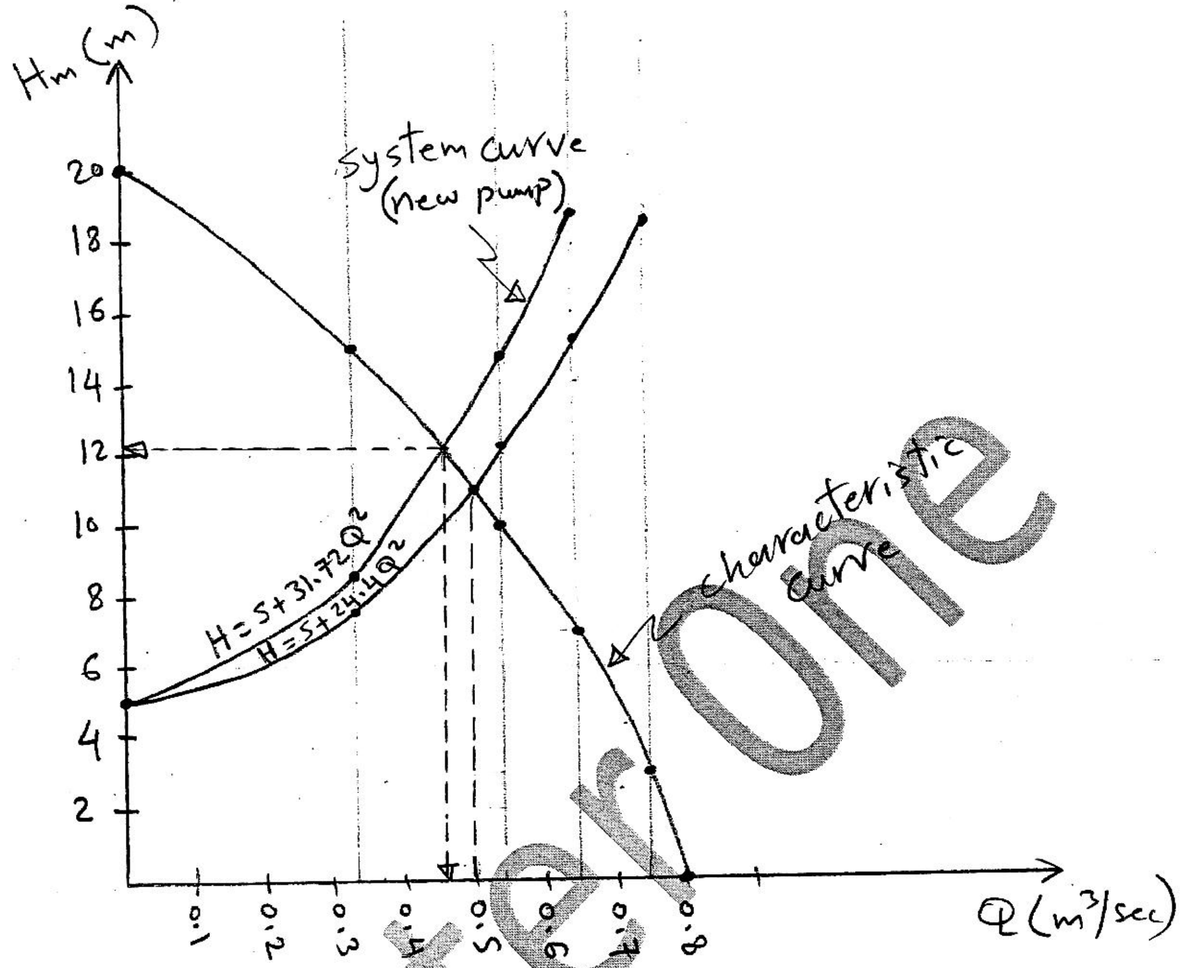
$\eta = 0.78$

new operating point $Q = 0.46$ m^3/sec

$H = 12.2$ m

$$\eta = \frac{\frac{\gamma Q H}{75}}{P}$$

$$0.78 = \frac{\frac{1000 * 0.46 * 12.2}{75}}{P} \Rightarrow P = 95.93 \text{ hp}$$



<u>For new pump:</u> $N = ??$

from curve: $Q = 0.46\ m^3/sec$

$H_m = 12.2\ m$

$$\frac{Q}{Q_{new}} = \frac{N}{N_{new}}$$

$$\frac{0.46}{0.6} = \frac{1400}{N_{new}}$$

$\therefore N_{new} = \underline{\underline{1826.1}}$ r.p.m

El-Mansoura University
Faculty of Engineering
Dept. of Irrigation & Hydraulics
Third Year Civil Engineering

Second Term Exam
Hydraulics (2)
May 30 , 2006
Time Allowed:1.5 hrs

Answer the following questions. Any missing data can be reasonably assumed. Illustrate your answers with neat sketches.

Question (I):

(a) A 1 :10 model of boat is towed in water of kinematic viscosity 10^{-6} m^2 /sec.What should be the speed of the model to simulate a speed of 4.0 m / sec, If the resistance is due to :
(i) internal friction only ; and (ii) waves only?
Calculate the kinematic viscosity of the liquid in which the model is tested if the resistance due to both internal friction and waves are to be considered.
(b) Explain why distorted models of rivers are commonly used?
A tidal river is built to a horizontal scale 1 : 500 and a vertical scale 1 : 50 .Tidal amplitude of 3.0 m, tidal period of 12 hrs and 25 min, and fresh water discharge of 50 m^3 / sec are to be produced in the model, what are the corresponding tidal characterstics and discharge in the model.

Question (II):

(a) Deduce an expression for the specific speed of a hydraulic turbine.
A reaction turbine is supplied with water at a rate of 150 m^3 /sec under a head of 200 m .The runner diameter is 4.5 m at inlet and 3.0 m at outlet its vane angle is 120^o at inlet.Assuming radial discharge at 24 m /sec, breadth of the wheel being constant, total efficiency = 85 %, and hydraulic efficiency = 90 %. Find the horse power produced and the speed of the turbine.

Question (III):

A propeller pump having external and internal diameters as 3.0 m and 1.5 m respectively , it delivers a discharge of 20 m^3 /sec at a speed of 400 r.p.m. and 70 % manometric efficiency. If the S.H.P. = 5200 h.p., find the manometric head, the exit blade angle at the mean diameter and the pump specific speed. Take overall efficiency = 65 %.

Question (IV):

(a) A centrifugal pump of specific speed N_s = 40, and discharges 250 lit / sec of water when running at 600 r.p.m The pump has a suction pipe of 300 mm diameter, 12 m long, and Darcy- Wiesbach coefficient = 0.01. What is the maximum height at which the pump could be set above the suction water level.(σ_c = 0.15, P_{atm} =1.033 kg /cm^2 , and P_{vapor} = 0.06 kg / cm^2)
(b) The Mubarak pumping station (Toshka project) has 24 load-controlled, ajustable speed, vertical centrifugal pumps arranged in two parallel lines, (maximum speed = 298.3 r.p.m), 18 of these pumps run continuously, 3 held for reserve and 3 for maintenance.It has a capacity of 1.2 Mm^3 /hr.The minimum and maximum water levels at the pump house are 147 m asl and 178.5 m asl respetively.The water level in the discharge canal (Sheikh Zayed canal) is 201 m asl.The maximum efficiencies are 90 % and 80 % at maximum and minimum levels respectively. If the coordinates of the operating point at maximum speed are 57 m, and 16.7 m^3 / sec, estimate for each pump at the maximum water level operation : (i) equation of the system curve; (ii) the required pump speed ; and (iii) the power consumed in watts at both the maximum and minimum water levels.

Best Wishes

Question IV :

ⓐ $N_s = 40$

$Q = 250 \text{ lit/sec} = 0.25 \text{ m}^3/\text{sec}$

$Z_s = ??$

$N = 600 \text{ r.p.m}$

$d = 300 \text{ mm} = 0.3 \text{ m}$

$L = 12 \text{ m}$

$f = 0.01$

$\sigma = 0.15$

$P_{atm} = 1.033 \text{ Kg/cm}^2$

$P_v = 0.06 \text{ Kg/cm}^2$

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}}$$

$$40 = \frac{600\sqrt{0.25}}{H_m^{3/4}}$$

$$H_m = 14.68 \text{ m}$$

$$NPSHA = \frac{P_{atm}}{\gamma} - \frac{P_v}{\gamma} - Z_s - losses$$

$NPSHA \rightarrow \sigma \cdot H_m$

$losses \rightarrow \dfrac{32 f L Q^2}{g \pi^2 d^5}$

$$0.15 * 14.68 = \frac{1.033 * 10^4}{1000} - \frac{0.06 * 10^4}{1000} - Z_s - \frac{32 * 0.01 * 12 * (0.25)^2}{9.81 * \pi^2 * (0.3)^5}$$

$$Z_s = 6.51 \text{ m}$$

$Z_s \rightarrow$ اقصى ارتفاع سحب
آمن حتى لا يحدث
تآكل للمضخة

IV (b)

Coordinates at maximum speed $N = 298.3$ r.p.m

at operating point $H = 57$ m $Q = 16.7$ m³/sec

Equation of system curve

max. speed occurs at min. Level (147 m) asL → above Sea Level

$$H = \Delta Z + K Q^2$$

ΔZ: $201 - 147 = 54$

$$57 = 54 + K(16.7)^2 \rightarrow K = 0.0108$$

(i) Equation of system curve at maximum w.L

$$H = \Delta Z + K Q^2$$

ΔZ: $201 - 178.5 = 22.5$

$$H = 22.5 + 0.0108\, Q^2$$

$$Q_{one\ pump} = \frac{1.2 * 10^6}{60 \times 60 \times 18} = 18.52 \ m^3/sec$$

18: عدد الساعات التي تعمل

$$H = 22.5 + 0.0108 (18.52)^2 = 26.2 \ m$$

pump speed at $H = 26.2$ m

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

$$\frac{57}{26.2} = \left(\frac{298.3}{N_2}\right)^2$$

$$\therefore N_2 = 202.25 \ r.p.m$$

at max. w.L $\eta = 90\%$

$$\eta = \frac{\gamma Q H}{P}$$

$$0.9 = \frac{9810 * 18.52 * 26.5}{P}$$

$$\therefore P = 7.76 \ MW$$

at max. speed $\eta = 0.8$ at min. w.L

$$0.8 = \frac{9810 * 16.7 * 57}{P}$$

$$\therefore P = 11.67 \ MW$$