Dream

Book Shop

# تالته مدني

# هيدروليكا

# Part

# (12)

# 2 Pumps المضخات

**Centrifugal pump (radial flow pump)**
المضخه الطارده المركزيه

تستخدم ↓

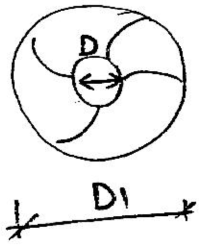
For large head & low discharge

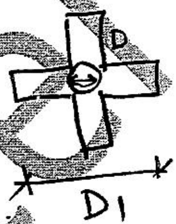
**Propeller pump (axial flow pump)**
المضخه المحورية (المروحيه)

تستخدم ↓

For low head & large discharge

**mixed flow pump**




$$Q = \pi D B V_f = \pi D_1 B_1 V_{f_1}$$

$$Q = \frac{\pi}{4}(D_1^2 - D^2) V_f$$

الجزء الذى يدور فى المضخه يسمى **impeller**

وتستهلك المضخه الطاقة الكهربيه الموصله إليها لتكسب المياه طاقه متمثله فى رفع المياه إلى ضاغط H أو يسمى أحياناً Hm

Hm → manometric head

P → pump (⊗) → w.H.P

P = S.H.P → Suction Horse power

$$\eta = \frac{W.H.P}{S.H.P} = \frac{\frac{\gamma Q H}{75}}{P} \quad (\gamma = 1000,\ P \rightarrow H.P)$$

$$= \frac{\gamma Q H}{P} \quad (\gamma = 9810,\ P \rightarrow watt)$$

$$= \frac{\frac{\gamma Q H}{550}}{P} \quad (\gamma = 62.4,\ P \rightarrow H.P)$$

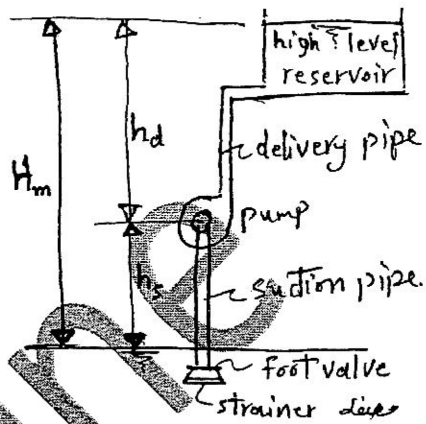
$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

$N_s$ → Specific speed

## Manometric Head ($H_m$):

❶ $H_m$ = the actual head against which the pump has to work

❷ $$H_m = h_s + h_{f_s} + h_d + h_{f_d} + \frac{v_d^2}{2g}$$




Where :
$H_m$= **The manometric Head**
$h_s$ = suction lift
$h_{fs}$ = loss of head in suction pipe due to friction
$h_d$ = delivery lift
$h_{fd}$ = loss of head in delivery pipe due to friction
$v_d$ = velocity of water in delivery pipe

❸ $H_m$ = Energy/kg at outlet of the impeller - Energy/kg at inlet of the impeller

❹ $H_m$ = work done/kg of water – losses within the impeller

$$= \frac{v_w v}{g} - impeller \quad losses$$

## Specific speed ($N_s$):

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

في التربينات $= \frac{N\sqrt{P}}{H^{5/4}}$

## Principle of similarity applied to Pumps :

$$k_1 = \frac{N \cdot D}{\sqrt{H}}$$

$$k_2 = \frac{P \cdot N^2}{H^{5/2}}$$

في التربينات $= \frac{P}{D^2 H^{3/2}}$

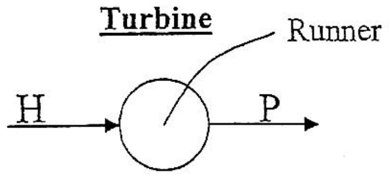
← تستخدم هذه القوانين إذا كانت D معطاه

$$k_3 = \frac{Q}{D^2\sqrt{H}}$$

## Efficiencies of Pumps :

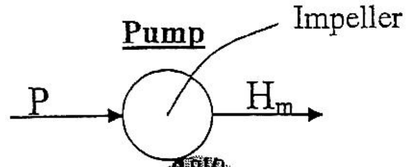
① Manometric efficiency ($\eta_m$)

$$\eta_m = \frac{H_m}{\frac{v_{w1} \cdot v_1}{g}} = \frac{g\,H_m}{V_{w_1} V_1}$$




② Mechanical efficiency

③ Overall (total) efficiency ($\eta = \eta_o = \eta_t$)




$$\eta = \frac{W.H.P}{B.H.P} = \frac{W.H.P}{S.H.P} = \frac{\overset{1000}{\gamma}.Q.H_m / 75}{P \rightarrow h.p} = \frac{\overset{9810}{\gamma}\,Q\,H}{P \rightarrow watt}$$

أقل سرعه تبدأ عندها الطلمبة ترفع مياه

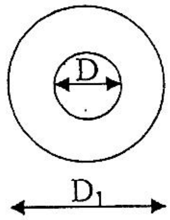
## Minimum speed to start pumping (N) :

$$H_m = \frac{v_1^2}{2g} - \frac{v^2}{2g} \quad \rightarrow N = ?$$

($v_1 = \frac{\pi D_1 N}{60}$, $v = \frac{\pi D N}{60}$)

$$v_1 = \frac{\pi D_1 N}{60}$$

$$v = \frac{\pi D N}{60}$$



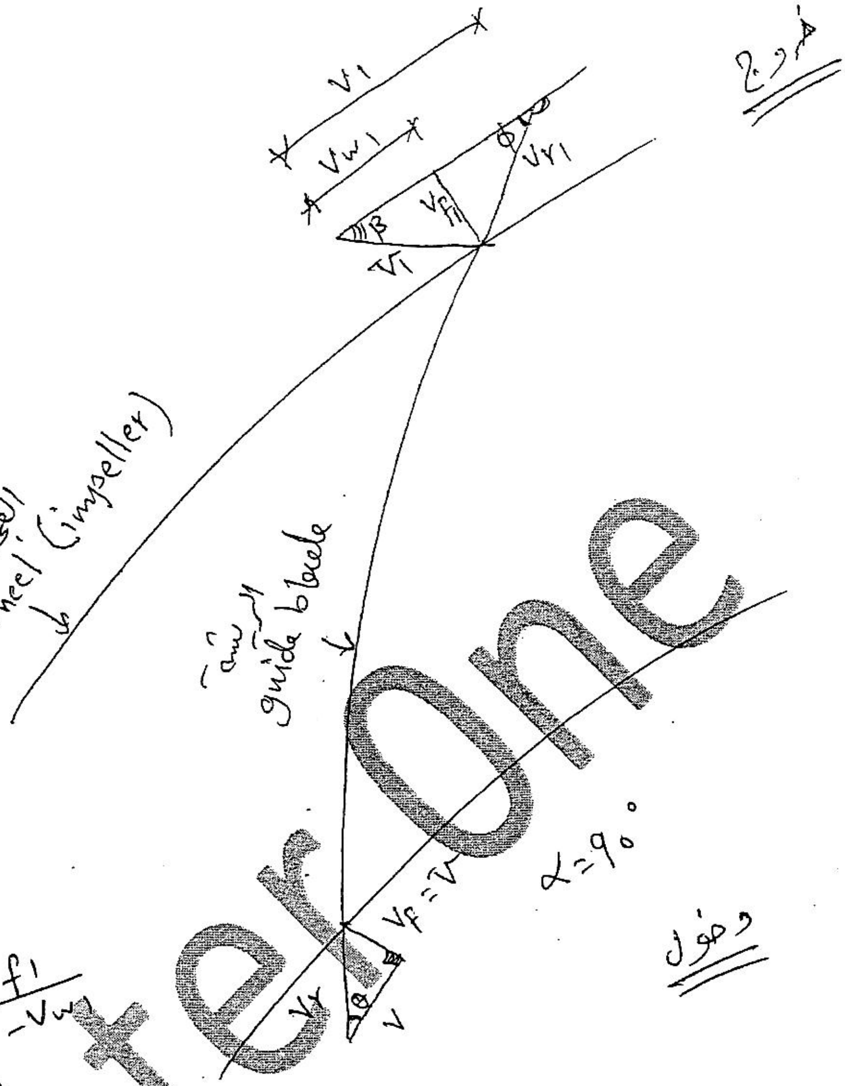

## Variable speed pump operation :

If the pump delivers at a discharge $Q_1$, at a manometric head $H_1$, when running at a speed $N_1$, the corresponding values when the pump is running at a speed $N_2$ are given by :

$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1} \qquad \frac{H_2}{H_1} = \left(\frac{N_2}{N_1}\right)^2 \qquad \frac{P_2}{P_1} = \left(\frac{N_2}{N_1}\right)^3$$

← تستخدم هذه القوانين إذا كانت D غير معطاه

<u>pumps</u>




$$\tan\beta = \frac{V_{f1}}{V_{w1}}$$

$$\tan\phi = \frac{V_{f1}}{V_1 - V_{w1}}$$

$$\tan\theta = \frac{V_f}{V}$$

$P \rightarrow \eta$

$\eta = \eta_m \rightarrow P = \frac{\gamma Q}{75} \cdot \frac{V_{w1} V_1}{g}$

باقي قوانين ال pump هي نفس قوانين التربينات

$$V = \frac{\pi D N}{60}$$

$$V_1 = \frac{\pi D_1 N}{60}$$

$$\Phi = \frac{V}{\sqrt{2gH}}$$

$$\Psi = \frac{V_f}{\sqrt{2gH}}$$

**Ex(1):**

Asix stage centrifugal pump in series delivers 150 lit/sec against a head of 420 m at 1600 r.p.m . Find the specific speed of the pump.

**Sol.**

No. of stages = 6

$Q = 150$ lit/sec $= 0.15\ m^3/sec$

Head per stage = 420/6 = 70 m

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1600\ \sqrt{0.15}}{70^{3/4}} = 25.6$$

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**Ex(2):**

It is required to predict the performance of large centrifugal pump from that of scale model are fourth the diameter . The model absorbs 10 h.p. when pumping under a test head of 8 ft at its best speed of 300 r.p.m. The larger pump is required to pump against a head of 40 ft . What will be its working speed , the horse power required to drive the pump and what will be the the ratio of quantities by the large pump and the model.

**Sol.**

$D_{prototype} = 4\ D_{model}$      $H_{prototype} = 40$ ft

$P_{model} = 10$ h.p      $N_{prototype} = ??$

$H_{model} = 8$ ft      $P_{prototype} = ??$

$N_{model} = 300$ r.p.m      $\frac{Q_{prototype}}{Q_{model}} = ??$

$$\rightarrow k_1 = \left(\frac{N \cdot D}{\sqrt{H}}\right)_{model} = \left(\frac{N \cdot D}{\sqrt{H}}\right)_{prototype}$$

$$\frac{300 * D}{\sqrt{8}} = \frac{N * 4D}{\sqrt{40}} \Rightarrow N = 167.7 r.p.m.$$

$$\rightarrow k_2 = \left(\frac{P \cdot N^2}{H^{5/2}}\right)_{model} = \left(\frac{P \cdot N^2}{H^{5/2}}\right)_{prototype}$$

$$\frac{10 * 300^2}{8^{5/2}} = \frac{P * 167.7^2}{40^{5/2}} \Rightarrow P = 1788.9 h.p.$$

$$\rightarrow k_3 = \left(\frac{Q}{D^2\sqrt{H}}\right)_{model} = \left(\frac{Q}{D^2\sqrt{H}}\right)_{prototype}$$

$$\frac{Q_{prototype}}{Q_{model}} = \frac{\left(D^2\sqrt{H}\right)_{prototype}}{\left(D^2\sqrt{H}\right)_{model}} = 16\sqrt{\frac{40}{8}} = 35.77$$

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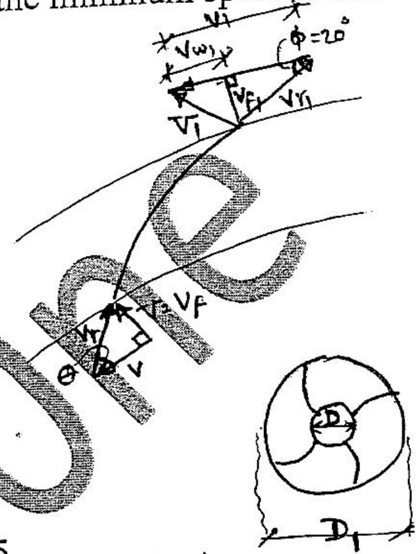
**Ex(3):**

A centrifugal pump has to discharge 3000 lit/sec of water at a total head of 20 m when the impeller rotates at 300 r.p.m. The impeller diameter at outlet is 1.8 m and the velocity of flow at outlet is 5 m/sec . If the vanes are set at an angle $20^\circ$ at outlet, Find :

(1) Manometric efficiency of the pump,

(2) Horse power required to drive the pump,

If the inner diameter is half the outer diameter , find the minimum speed to start pumping.




**Sol.**

$Q = 3000$ lit/sec $= 3.0\ m^3/sec$

$H_m = 20$ m

$N = 300$ r.p.m.

impeller diameter at outlet ( $D_1$ ) = 1.8 m

velocity of flow at outlet ( $v_{f1}$ ) = 5 m/sec

vane angle at outlet ( $\Phi$ ) = $20^\circ$

$$v_1 = \frac{\pi D_1 N}{60} = \frac{\pi * 1.8 * 300}{60} = 28.27 m/\sec$$

From outlet triangle $\quad v_{w1} = v_1 - \frac{v_{f1}}{\tan\phi} = 28.27 - \frac{5}{\tan 20} = 14.54 m/\sec$

$$\rightarrow \eta_m = \frac{gH_m}{v_{w1} \cdot v_1} = \frac{9.81 * 20}{14.54 * 28.27} = 47.7\%$$

$\rightarrow$ Horse power required to drive the pump $= \frac{\gamma Q}{75} \cdot \frac{v_{w1} v_1}{g}$

$$= \frac{1000 * 3}{75} \cdot \frac{14.54 * 28.27}{9.81} = 1676.03 h.p.$$

$\rightarrow$ minimum speed to start pumping ( N ): $\quad D = \frac{D_1}{2} \Rightarrow v = \frac{v_1}{2}$

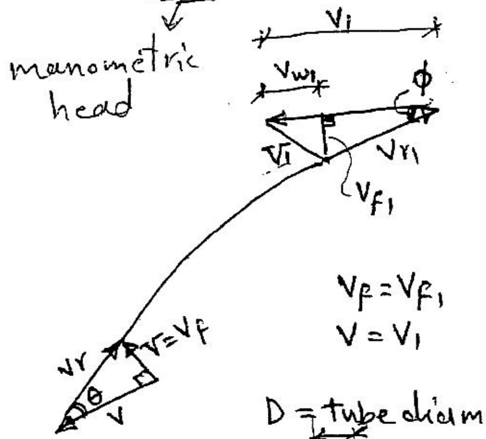
$$H_m = \frac{v_1^2}{2g} - \frac{v^2}{2g} = \eta_m \cdot \frac{v_{w1} \cdot v_1}{g}$$

$$20 = \frac{v_1^2 - \frac{v_1^2}{4}}{2 * 9.81} = \frac{\frac{3}{4} v_1^2}{2 * 9.81} \Rightarrow v_1 = 22.87\ m/\sec$$

$$v_1 = 22.87 = \frac{\pi D_1 N}{60} = \frac{\pi * 1.8 * N}{60} \Rightarrow N = 242.27 r.p.m.$$

**Ex(4):**

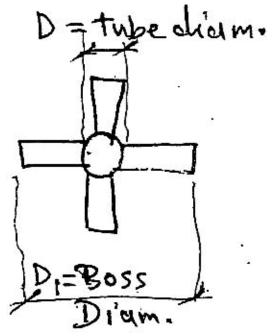
Apropeller pump 3.0 m and 1.5 m boss and tube diameters respectively . It has a discharge of 12 $m^3$/sec at a speed of 320 r.p.m. and 65 % manometric efficiency . If the S.H.P.= 4200 h.p ,overall efficiency = 60 % . Find the gross lift and the blade angle at mean diameter .




**Sol.**

$D_1 = 3.0$ m
$D = 1.5$ m
$Q = 12\ m^3/sec$
$N = 320$ r.p.m
$\eta_m = 0.65$
$P = S.H.P = 4200$ h.p
$\eta = 0.60$

$H_m = ??$
$\Phi = ??$




$$\rightarrow \eta = \frac{W.H.P}{S.H.P} = \frac{\frac{\gamma.Q.H_m}{75}}{P}$$

$$0.6 = \frac{\frac{1000 * 12 * H_m}{75}}{4200} \Rightarrow H_m = 15.75\ m$$

$$\rightarrow Q = \frac{\pi}{4}\left(D_1^2 - D^2\right)v_f$$

$$12 = \frac{\pi}{4}\left(3^2 - 1.5^2\right)v_f \Rightarrow v_f = 2.26\ m/\sec$$

$$D_m = \frac{D + D_1}{2} = \frac{3 + 1.5}{2} 2.25\ m$$

$$v = v_1 = v_m = \frac{\pi \cdot D_m \cdot N}{60} = \frac{\pi * 2.25 * 320}{60} = 37.7 m/\sec$$

$$\eta_m = \frac{gH_m}{v_{w1} \cdot v_1}$$

$$0.65 = \frac{9.81 * 15.75}{v_{w1} * 37.7} \Rightarrow v_{w1} = 6.3 m/\sec$$

$$\tan\phi = \frac{v_{f1}}{v_1 - v_{w1}} = \frac{2.26}{37.7 - 6.3} \Rightarrow \phi = 4.127^{o}$$

إثبات

# Specific Speed in Pumps

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

→ $V_1 \propto \sqrt{H}$ — (1)

→ $V_1 = \frac{\pi D_1 N}{60} \Rightarrow D_1 N \propto V_1$ — (2)

<u>from (1) & (2)</u> $D_1 \propto \frac{\sqrt{H}}{N}$ — (3)

→ $Q = \pi D_1 B_1 V_{f_1}$ ; $B_1 \propto D_1$

$V_{f_1} \propto \sqrt{H}$

$Q \propto D_1^2 \sqrt{H}$ — (4)

<u>from (3) & (4)</u>

$Q \propto \left(\frac{\sqrt{H}}{N}\right)^2 \sqrt{H}$

$Q \propto \frac{H^{3/2}}{N^2} \Rightarrow N \propto \frac{H^{3/4}}{\sqrt{Q}}$

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

$\therefore N_s = \frac{N\sqrt{Q}}{H^{3/4}}$ #

| | |
|---|---|
| **El Mansoura University** | **Second Term Examination** |
| **Faculty of Engineering** | **Hydraulics** |
| **Dept. of Irrigation & Hydraulics** | **June 7, 2005** |
| **Third Year Civil Engrg.** | **Time Allowed : 1.5 hrs.** |

**Answer as much as you can the following questions.** **Illustrate your answers with neat sketches.**

## Question I :

**(a)** Discuss the value of Manning's n in the model with respect to the corresponding value in the prototype for both distorted and undistorted models.
A fixed bed model is to be built for a river subjected to tidal wave with a horizontal scale 1:240 and vertical scale 1:40. The prototype river has a Manning n of 0.03 and so wide that the hydraulic radius equal to the river depth on both prototype and model. The prototype wave period is 12 hours and 25 minutes and the maximum river discharge is 2000 $m^3$/sec. Determine the required model values of wave period, Manning's n and the maximum river discharge.
**(b)** The head loss of water at 20° C, kinematic viscosity = $1\times10^{-6}$ $m^2$/sec in 50 mm diameter pipeline was 0.5 m over a length of 20 m at a discharge of 3 lit/sec. What is the corresponding discharge and hydraulic gradient when oil of kinematic viscosity $8\times10^{-6}$ $m^2$/sec flows through 300 mm diameter pipeline of the same relative roughness.

## Question II :

**(a)** Define the following terms:
Unit speed – Unit power and Unit discharge as applied to hydraulic turbines.
**(b)** Calculate the number of nozzles required for a Pellton wheel which have to develop 12000 h.p under a head of 250 m head at a speed 600 r.p.m. Assume nozzle diameter not to exceed 1/10 wheel diameter. Take efficiency 90%, Cv = 0.98 and speed ratio = 0.46.

If a 1:5 scale model is to be tested under a head of 6 m, what must be its speed, power developed and water consumption to run under conditions similar to the prototype.

## Question III :

**(a)** A centrifugal pump delivers 60 lit/sec against a total head of 32 m running at 1500 r.p.m. The velocity of flow is constant at 2.5 m/sec, the blades are curved back at 30°, the impeller diameter is 300 mm and the inner diameter is half the outer diameter, find:
(i) pump specific speed. (ii) manometric efficiency.
(iii) blade angle at inlet. (iv) velocity and direction of water at outlet.

## Question IV :

**(a)** What do you understand by the term NPSH?
Distinguish between the required and available NPSH and state briefly how they are determined.
**(b)** A pump has the following characteristics when running at 1400 r.p.m.

| | | | | | | |
|---|---|---|---|---|---|---|
| Q $m^3$/sec | 0 | 0.335 | 0.545 | 0.65 | 0.75 | 0.8 |
| H m | 20 | 15 | 10 | 7 | 3 | 0 |

The system curve is given by the following equation $H = 5 + 24.4\ Q^2$ which gives 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 is 0.6 $m^3$/sec and calculate the power consumed if the pump total efficiency at the new operating point is 78%.

***Best wishes***

## Question [II] : (June 7, 2005)

Pelton turbine

$P = 18000$ h.p
$H = 800$ m
$N = 600$ r.p.m
$C_v = 0.97$
$\phi = 0.46$
$d = \frac{1}{15} D$
$\eta = 0.85$

$n = ??$
$d = ??$
$Q = ??$
$N_s = ??$

$$Q = n \frac{\pi d^2}{4} C_v \sqrt{2gH}$$
$$\eta_h = \frac{V_w V}{gH}$$
$$\eta = \frac{P}{\frac{\gamma Q H}{75}}$$
$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$
$$\phi = \frac{V}{\sqrt{2gH}}$$
$$\psi = \frac{V_f}{\sqrt{2gH}}$$
$$V = \frac{\pi D N}{60}$$
$$V_1 = \frac{\pi D_1 N}{60}$$

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

$$0.85 = \frac{18000}{\frac{1000 * Q * 800}{75}} \Rightarrow Q = \underline{1.985} \text{ m}^3/\text{sec}$$

$\rightarrow$ $$\phi = \frac{V}{\sqrt{2gH}}$$

$$0.46 = \frac{V}{\sqrt{2 \times 9.81 * 800}} \Rightarrow V = \underline{57.63} \text{ m/sec}$$

$$V = \frac{\pi D N}{60}$$

$$57.63 = \frac{\pi D * 600}{60} \Rightarrow D = \underline{1.83} \text{ m} \Rightarrow d = \frac{1.83}{15} = 0.122 \text{ m}$$

$\rightarrow$ $$Q = n . \frac{\pi d^2}{4} . C_v \sqrt{2gH}$$

$$1.985 = n . \frac{\pi \left(\frac{1}{15} * 1.83\right)^2}{4} * 0.97 \sqrt{2 \times 9.81 * 800} \Rightarrow n = 1.4$$

take $n = 2$

$\rightarrow$ $$N_s = \frac{N\sqrt{P}}{H^{5/4}} = \frac{600\sqrt{18000}}{(800)^{5/4}} = 18.92$$

model : prototype
1 : 10

| prototype | model |
|---|---|
| $H_p = 800\ m$ | $H_m = 6\ m$ |
| $N_p = 600\ r.p.m$ | $N_m = ??$ |
| $P_p = 18000\ h.p$ | $P_m = ??$ |
| $Q_p = 1.985\ m^3/sec$ | $Q_m = ??$ |

$$K_1 = \frac{D_m N_m}{\sqrt{H_m}} = \frac{D_p N_p}{\sqrt{H_p}}$$

$$\frac{1 * N_m}{\sqrt{6}} = \frac{10 * 600}{\sqrt{800}} \Rightarrow N_m = \underline{519.6}\ r.p.m$$

$$K_2 = \frac{P_m}{D_m^2 H_m^{3/2}} = \frac{P_p}{D_p^2 H_p^{3/2}}$$

$$\frac{P_m}{1^2 \times 6^{3/2}} = \frac{18000}{10^2 * 800^{3/2}} \Rightarrow P_m = \underline{0.1169}\ h.p$$

$$K_3 = \frac{Q_m}{D_m^2 \sqrt{H_m}} = \frac{Q_p}{D_p^2 \sqrt{H_p}}$$

$$\frac{Q_m}{1^2 \sqrt{6}} = \frac{1.985}{10^2 \sqrt{800}} \Rightarrow Q_m = \underline{1.72 * 10^{-3}}\ m^3/sec$$

## Question III [June 7, 2005]

Centrifugal pump

$Q = 60\ lit/sec = 0.06\ m^3/sec$

$H_m = 32\ m$

$N = 1500\ r.p.m$

$V_f = V_{f_1} = 2.5\ m/sec$

$\phi = 30^\circ$

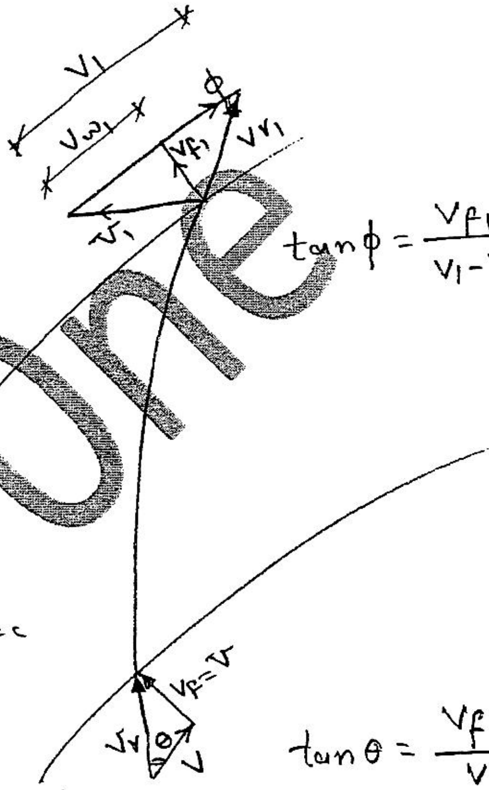
$D_1 = 300\ mm = 0.3\ m$

$D = 0.5\ D_1 = 0.15\ m$

$N_s = ??$

$\eta_m = ??$

$\theta = ??$




$$\tan\phi = \frac{V_{f_1}}{V_1 - V_{w_1}}$$

$$\tan\theta = \frac{V_f}{V}$$

$$V = \frac{\pi D N}{60} = \frac{\pi * 0.15 * 1500}{60} = \underline{11.78\ m/sec}$$

$$V_1 = \frac{\pi D_1 N}{60} = \frac{\pi * 0.3 * 1500}{60} = \underline{23.56\ m/sec}$$

$$\rightarrow \tan\theta = \frac{V_f}{V} = \frac{2.5}{11.78} \Rightarrow \underline{\underline{\theta = 11.98}}$$

$$\tan\phi = \frac{V_{f_1}}{V_1 - V_{w_1}}$$

$$\tan 30 = \frac{2.5}{23.56 - V_{w_1}} \Rightarrow V_{w_1} = 19.23\ m/sec$$

$$\rightarrow \eta_m = \frac{g H_m}{V_{w_1} V_1} = \frac{9.81 * 32}{19.23 * 23.56} = 0.693 = \underline{\underline{69.3\ \%}}$$

$$\rightarrow N_s = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1500\sqrt{0.06}}{(32)^{3/4}} = 27.31$$

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

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

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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° 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):

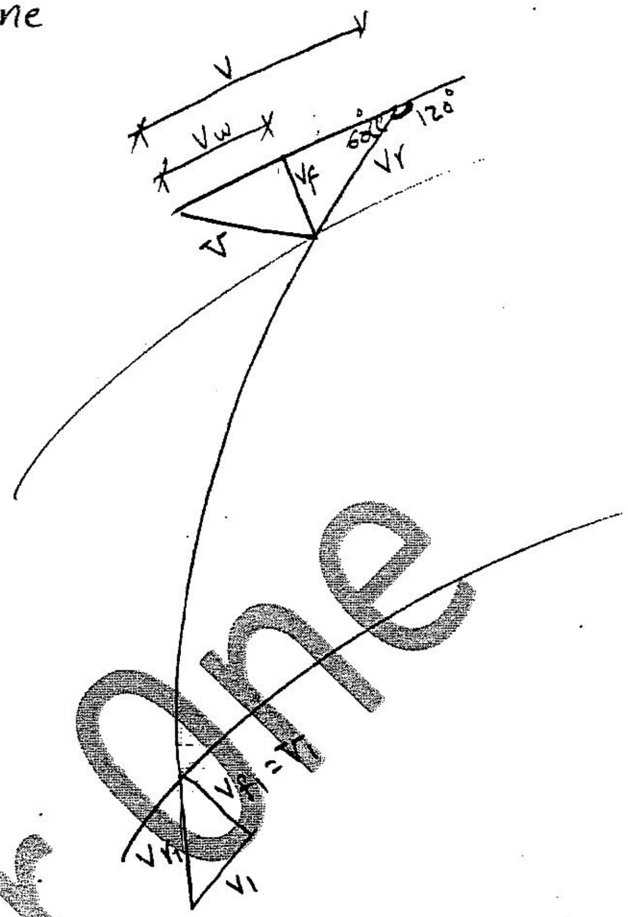
A propeller pump having external and internal diameters as 3.0 m and 1.5 m respectively , it delivers a discharge of 20 $m^3$ /sec at a speed of 400 r.p.m. and 70 % manometric efficiency. If the S.H.P. = 5200 h.p., find the manometric head, the exit blade angle at the mean diameter and the pump specific 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. ( $\sigma_c$ = 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 [II] : Francis Turbine




$Q = 150\ m^3/sec$

$H = 200\ m$

$D = 4.5\ m$

$D_1 = 3.0\ m$

$\theta = 120^\circ$

$V_1 = 24\ m/sec = V_{f1}$

$B = B_1$

$\eta = 0.85$

$\eta_h = 0.9$

$P = ??$

$N = ??$

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

$0.85 = \dfrac{P}{\frac{1000 * 150 * 200}{75}} \Rightarrow P = 340000\ h.P$

$\rightarrow Q = \pi D B V_f = \pi D_1 B_1 V_{f1}$

$4.5\ V_f = 3.0 * 24 \Rightarrow V_f = 16\ m/sec$

$\tan 60 = \dfrac{V_f}{V - V_w} \Rightarrow V - V_w = \dfrac{16}{\tan 60} \Rightarrow V_w = V - 9.24$

$\eta_h = \dfrac{V_w V}{g H}$

$0.9 = \dfrac{(V - 9.24) V}{9.81 * 200} = \dfrac{V^2 - 9.24 V}{1962}$

$V^2 - 9.24 V - 1765.8 = 0 \Rightarrow V = 46.89\ m/sec$

$V = \dfrac{\pi D N}{60}$

$46.89 = \dfrac{\pi * 4.5 N}{60} \Rightarrow N = 199\ r.p.m$

## Question III :

Propeller pump

$D_1 = 3.0$ m

$D = 1.5$ m

$Q = 20$ m³/sec

$N = 400$ r.p.m

$\eta_m = 0.7$

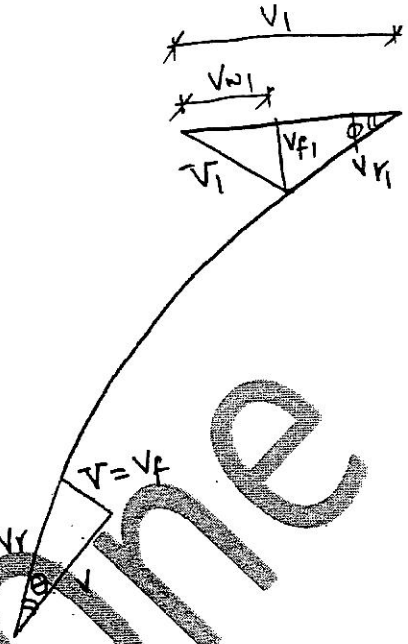
S.H.P = 5200 h.p

$\eta = 0.65$

$H_m = ??$

$\phi = ??$

$N_s = ??$




$$\rightarrow \eta = \frac{\frac{\gamma Q H_m}{75}}{P}$$

$$0.65 = \frac{\frac{1000 * 20 * H_m}{75}}{5200} \Rightarrow H_m = 12.675 \text{ h.p}$$

$$Q = \frac{\pi}{4}(D_1^2 - D^2)\, V_f$$

$$20 = \frac{\pi}{4}(3^2 - 1.5^2)\, V_f \Rightarrow V_f = 3.77 \text{ m/sec}$$

$$D_m = \frac{D + D_1}{2} = \frac{1.5 + 3}{2} = 2.25 \text{ m}$$

$$V = V_1 = \frac{\pi D_m N}{60} = \frac{\pi * 2.25 * 400}{60} = 47.12 \text{ m/sec}$$

$$\eta_m = \frac{g H_m}{V_{w_1} V_1}$$

$$0.7 = \frac{9.81 * 12.675}{V_{w_1} * 47.12} \Rightarrow V_{w_1} = 3.77 \text{ m/sec}$$

$$\tan\phi = \frac{V_{f1}}{V_1 - V_{w_1}} = \frac{3.77}{47.12 - 3.77} \Rightarrow \phi = 4^\circ 58'$$

$$N_s = \frac{N\sqrt{Q}}{H_m^{3/4}} = \frac{400 * \sqrt{5200}}{(12.675)^{3/4}} = 4293.9$$

التآكل

## Cavitation in Pumps :

→ The *propeller pump (Axial flow Pump)* is more liable to cavitation than other pumps ***because of its high speed***

المضخه المحوريه قابله للتآكل أكثر من المضخه الطارده المركزية

It causes :
- physical damage
- Reduction in discharge
- Noise
- Limiting the head

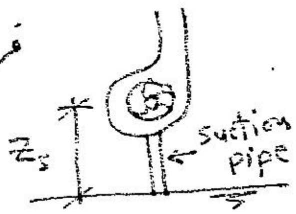
### NPSHA {Net Positive Suction Head Available}:

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

➤ ***Suction lift*** **($z_s$)** : is the elevation difference between the water surface of the source reservoir and the eye of the pump.

فرق المنسوب بين مياه المصدر و ال eye of pump

تعريف نظري




➤ ***Atmospheric (barometric) pressure head*** $\left[h_b = \frac{P_{atm}}{\gamma}\right]$

➤ ***Vapour pressure head*** $\left[h_v = \frac{P_v}{\gamma}\right]$

➤ ***NPSHA*** **= σ . $H_m$**

σ = Thoma No. (cavitation No.) or (cavitation parameter)

$H_m$ = H = total head of the pump (manometric head) .

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### NPSHR {Net Positive Suction Head Required} :

is the amount of energy required to move the water into the impeller

كمية الطاقة اللازمة لتحريك المياه داخل المضخه

تعريف نظري

→ *To prevent cavitation* ***NPSHA > NPSHR***

* procedure to eliminate or minimize cavitation :

١- نحافظ على درجة حرارة المياه قليله حتى يقل ضغط البخار

٢- نقلل سرعة السريان في ماسورة السحب حتى تقل الفواقد

٣- نتجنب الإنحناءات الحادة في ماسورة السحب حتى تقل الفواقد

**Ex:**

A centrifugal pump of specific speed $N_s = 25$ , discharges 120 lit/sec of water when running at 800 r.p.m. If the losses in suction pipe are 1.63 m of water . Find the maximum allowable suction static head in order to avoid cavitation . Take : $\sigma_c = 0.2$ , $P_{atm} = 1.033$ kg/cm$^2$ & $P_{vapour} = 0.076$ kg/cm$^2$ .

**Sol.**

$N_s = 25$ $\qquad$ $z_s = ??$

$Q = 120$ lit/sec

$N = 800$ r.p.m

Losses = 1.63 m

$\sigma_c = 0.2$

$P_{atm} = 1.033$ kg/cm$^2$

$P_{vapour} = 0.076$ kg/cm$^2$

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}} \qquad 25 = \frac{800\sqrt{0.12}}{H_m^{3/4}} \Rightarrow H_m = 24.72\,m$$

$$NPSHA = \sigma_c \cdot H_m = 0.2 * 24.72 = 4.944\,m$$

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

$$4.944 = \frac{1.033 * 10^4}{1000} - \frac{0.076 * 10^4}{1000} - z_s - 1.63 \Rightarrow z_s \approx 3m$$

كلما قربنا المضخة من سطح الماء يكون أفضل ، بينما إذا بعدناها أكثر من zs سيحدث لها تآكل و تلف.

Ex : ***(June, 11, 2002):***

A pump is used to deliver 0.453 $m^3$/sec of water from a river against a total head of 40 m at 40° C (vapour pressure head = 0.76 m). The water level will normally be 1.0 m below the chosen pump site, through extreme draughts the level can be 4.0 m below the pump. The suction pipe has 600 mm diameter and f = 0.004 If the pump cavitation parameter is 0.15, will the pump be free from cavitation effects ? and if not what precautions do you suggest ? Atmospheric pressure at the pump site is 0.92 kg/$cm^2$

$Q = 0.453\ m^3/sec$

$H_m = 40\,m$

$\frac{P_v}{\gamma} = 0.76\ m$

$d = 600\ mm$

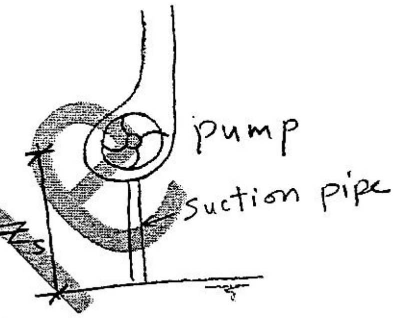
$f = 0.004$

$\sigma = 0.15$

$P_{atm} = 0.92\ kg/cm^2$

$Z_s = 1.0\,m$ normal

$= 4.0\,m$ extreme draughts




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

$$\sigma \cdot H_m = \frac{P_{atm}}{\gamma} - \frac{P_v}{\gamma} - Z_s - \frac{32 f L Q^2}{g \pi^2 d^5}$$

$$0.15 * 40 = \frac{0.92 * 10^4}{1000} - 0.76 - Z_s - \frac{32 * 0.004 * 1.0 * 0.453^2}{9.81 * \pi^2 * 0.6^5}$$

$\therefore Z_s = 2.437\,m > 1.0\,m$ (No cavitation)

$$0.15 * 40 = \frac{0.92 * 10^4}{1000} - 0.76 - Z_s - \frac{32 * 0.004 * 4.0 * 0.453^2}{9.81 * \pi^2 * 0.6^5}$$

$Z_s = 2.426\,m < 4.0\,m$ (Cavitation occurs)

لتقليل التآكل في المضخة :

١- المحافظة على درجة حرارة المياه أقل ما يمكن حتى يصبح ضغط البخار أقل ما يمكن

٢- تقليل الفواقد بتقليل سرعة السائل في ماسورة السحب عن طريق (استخدام ماسورة ذات قطر أكبر

٣- " " " بتجنب الانحناءات الحادة في ماسورة السحب