الإمبراطور

في

لاب الهيدروليك

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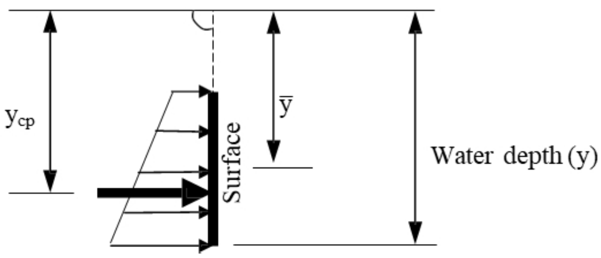
Exp. 1: Hydrostatic Force and Center of Pressure

Notes:

below shows the hydrostatic pressure (p), hydrostatic force (F) and its point of application (the center of pressure: y_{cp}), the submerged surface inclination angle (a) from the horizontal and the water depth to an axis that passes through the centroid (y) of the submerged surface.



Theoretically, the magnitude of the hydrostatic force is F = p × A, where p is the hydrostatic pressure at an axis that passes through the centroid of the submerged surface and A is the area of the submerged surface. Knowing the water depth at the centroid of the submerged surface (y), then the force hydrostatic F is:

F = p g ´ y sin a ´ A (1)

The depth (y_{cp}) at which the hydrostatic force applies on the submerged surface (the center of pressure) is:

$$y_{cp} = \bar{y} + \frac{\bar{I}}{\bar{y} \times A}$$

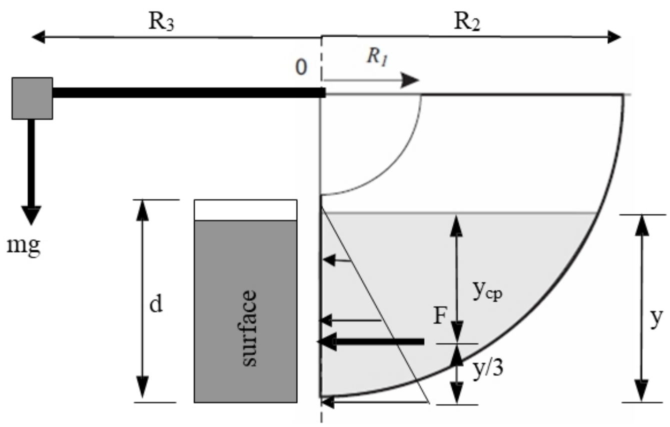
<u>Case 1: partially submerged surface: water depth (y) < surface depth (d)</u>

taking the sum of moments about the pivot point (0) and knowing that F

applies at (y/3) from the surface bottom, then: $F \times (R_2 - y/3) = mg \times R_3$. Therefore the experimental F is:

$F_{exp} = mg \times R_3/(R_2 - y/3)$

where R_1 = 100mm, R_2 = 200mm and R_3 = 200mm.

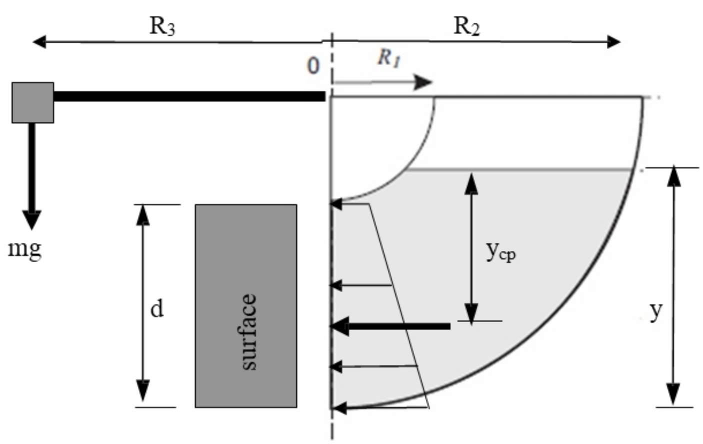


F = p × A

$$y_{cp,exp} = \left(\frac{2m \times R_3}{\rho \times by^2}\right) - R_2 + y$$

theoretical Ycp=2/3y

Case 2: Fully submerged surface: water depth (y) > surface depth (d)



$$F_{exp} = mg \times R_3/(R_2 - [\ \frac{(yd/2) - (d^2/6)}{y - (d/2)}$$

$$y_{cp,exp} = \left|\left(\frac{2m \times R_3}{\rho \times (2ybd - bd^2)}\right|\right) - R_2 + y$$

$$y_{cp} = \bar{y} + \frac{\bar{I}}{\bar{y} \times A}$$ **theo**

Fully submerged surface of width (b = 75mm) and depth (d = 100mm)

خطوات حل التجربة :

<u>Totally immersed:</u>

<u>1-Y</u>**=y-d/2**

2- F = p g ´ y sin a ´ A   A=b*d   remember b=0.75 d=0.1

3-

$$F_{exp} = mg \times R_3/(R_2 - [\ \frac{(yd/2) - (d^2/6)}{y - (d/2)}$$

4- $$y_{cp} = \bar{y} + \frac{\bar{I}}{\bar{y} \times A}$$ **theo**

5- $$y_{cp,exp} = \left|\left(\frac{2m \times R_3}{\rho \times (2ybd - bd^2)}\right|\right) - R_2 + y$$

<u>Partially immersed:</u>

<u>1-Y=y/2</u>

2- F = p g ´ y sin a ´ A   A=b*d   remember b=0.75 d=from exp <u>not 0.1</u>

<u>3-</u> F_{exp} = mg×R_3/(R_2 – y/3)

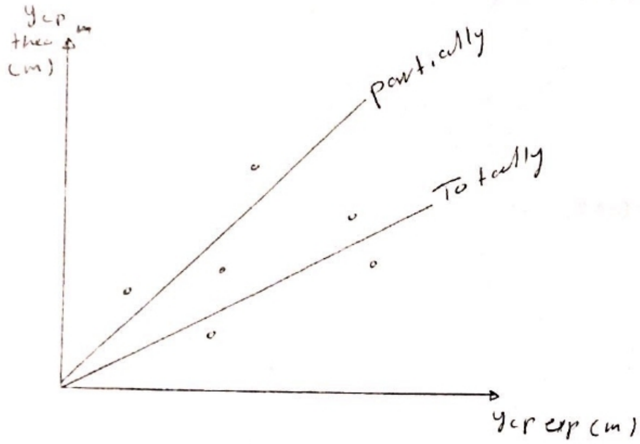
4- theoretical Ycp=2/3y

$$y_{cp.exp} = \left|\left(\frac{2m \times R_3}{\rho \times by^2}\right)\right| - R_2 + y$$

5

DRAWINGS:

$y_{cp\,theo}$ Vs $y_{cp\,exper}$

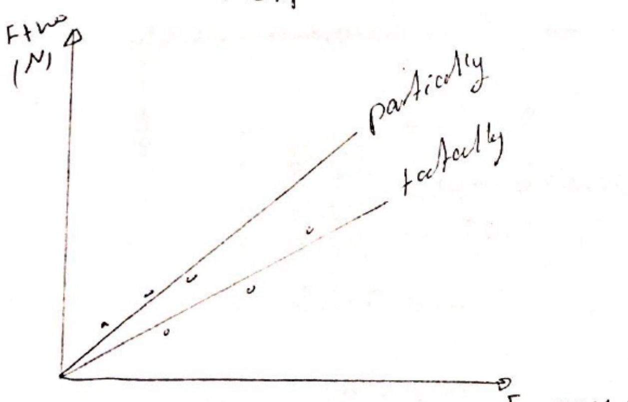


مه بيستفت لاين
best fit ~~line~~ Line

① get θ partially = slope
θ = tan⁻¹(slope)
θ => (40° - 47) accepted

② get θ totally
θ = tan⁻¹(slope)
θ => (40-47) accepted

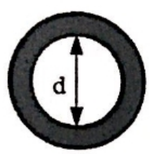
F_{theo} Vs F_{exp}



get θ as above ↑
↳ partially
↳ totally

Exp. 2: Orifice and Jet Flow

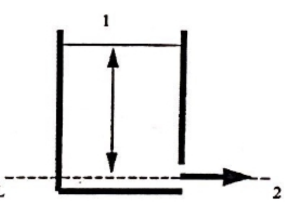
-NOTES: The orifice is a sudden contraction setup of circular shape (Fig. 1) that can be used to measure the actual flow rate leaving reservoirs, tanks or flow in pipes. When water flows through an orifice, the energy that causes the water flow is converted from one form to the other, which forms the basis of measuring the flow rate (Q) and the flow velocity (v).



-water flow leaves the orifice as trajectory of well known path, because it obeys the net force formed by the horizontal force due to the momentum when it leaves the orifice and the vertical gravitational force (downwards). At any point in the space, the trajectory path can be located after measuring the horizontal (X) and the vertical (Y) distances the flow travels. Such distances can be measured using needles, 10cm apart of each others, attached to the experimental

-considering the dashed line passing through the orifice center as an energy reference line and applying the energy conservation principle between point 1 (the constant water surface in the tank) and point 2 (flow at orifice under the atmospheric pressure), then:

$$E_1 = E_2 + h_L$$



Equation (1) is reduced to: $h = v^2/2g + h_L$

$v_{the} = \sqrt{2gh}$

$Q_{the} = \frac{\pi}{4} d^2 \sqrt{2gh}$

orifice diameter (d) then flow area (a) = 1/4 p d^2 and the theoretical flow rate (Q = a × v) is:

VERY IMPORTANT NOTE:

Equation ABOVE computes the theoretical flow rate passing through an orifice as a function of the head

(h) producing the water flow assuming that the head loss h_L is negligible, i.e. it gives the maximum possible Q. However, the h_L is always greater than zero, therefore the actual flow velocity is always less than the theoretical velocity and the actual flow rate (Q_a) is always less than the theoretical flow rate. Introducing the discharge coefficient (C_d) as the ratio of the actual flow rate to the theoretical flow rate that is always < 1:

$C_d = Q_a / Q_{theo}$

The discharge coefficient:

Therefore, to compute the actual jet velocity, has to be multiplied by a correction factor to compensate for the area reduction at the vena contracta. Introducing the velocity coefficient (C_v) as the ratio of the actual flow velocity to the theoretical velocity (C_v is always < 1), then:

$$C_v = \frac{V_a}{\sqrt{2gh}}$$

The actual flow rate (Q_a) can be measured in the lab by collecting known water volume (V) in a given time (t), $Q_a = V / t$. Given that the flow jet is traveling horizontal distance (X) while falling vertical distance (Y) measured using the attached needles, then the actual flow velocity is:

$$V_a = \frac{X}{\sqrt{\frac{2Y}{g}}}$$

$$C_v = \frac{X}{2\sqrt{Yh}}$$

خطوات حل التجربة:

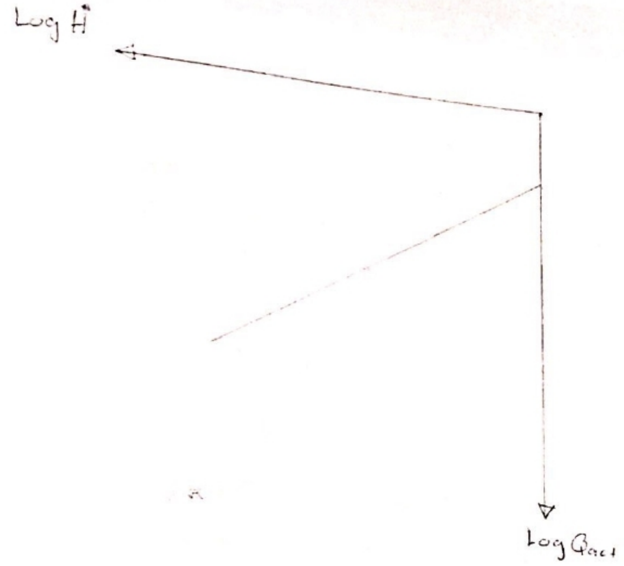
1- $Q_a = V / t$
2- 2-Q= $\frac{\pi}{4} d^2 \sqrt{2gh}$

$$C_v = \frac{X}{2\sqrt{Yh}}$$

3- 3-
4- 4-AVG cv=cv1+cv2+....../n of cv computed   note eliminate cv more than 1
5- $C_d = Q_a / Q_{theo}$

DRAWINGS:

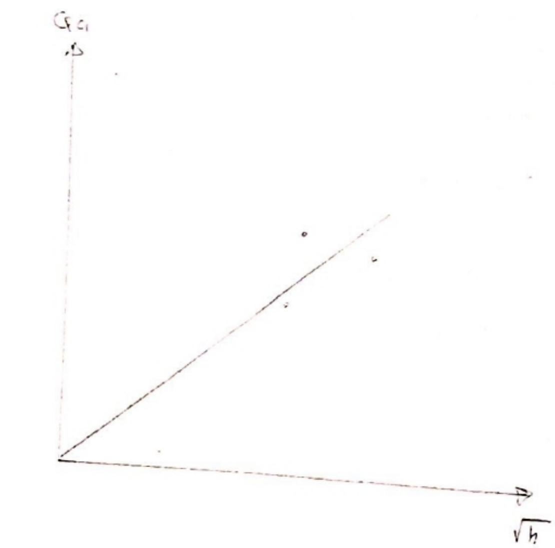
Qa Vs Log H



get slope
slope must be (0.6 - 0.4)

$Q_a \propto H^{slope}$

Q_a Vs $\sqrt{h}$



① get slope

② $slope = C_D \sqrt{2g} \frac{\pi}{4} d^2$

③ get CD

Exp. 3: Bernoulli's Theorem and Venturi Meter

NOTES: The total energy for steady, incompressible and frictionless flow consists of three forms: potential energy (z) due to elevation, kinetic energy ($v^2/2g$) due to motion and energy due to pressure (p/rg). The total energy (E) expressed in units of meter (Joule / unit weight) is:

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

VERY IMPORTANT:

1-the pressure head (p/Pg) is called the static head.

2-manometers at different points to measure the static head

3-Pitot tube to measure the total head at any point.

4-VENTURE METER that can be used to measure the actual flow rate in pipes

The Bernoulli equation represents the conservation of the energy. It simply says: the total energy for steady, incompressible and frictionless flow in a system is conserved (constant) assuming no energy loss due to friction occurs, however the energy may convert from one form to the other. For example it may convert from pressure energy (p/rg) to kinetic energy ($v^2/2g$) and vice versa. To demonstrate that the total energy is conserved, the total head probe will be used. The total head probe or pitot tube consists of steel tube of stagnation point (v = 0) that slides horizontally along the venturi tube. At any point, the total head probe makes the kinetic energy head zero ($v^2/2g$

= 0) thus that kinetic energy is converted to pressure head (p/rg)

-$v_1^2/2g$ = total head probe reading – static head reading = H_{total} – p_1/rg

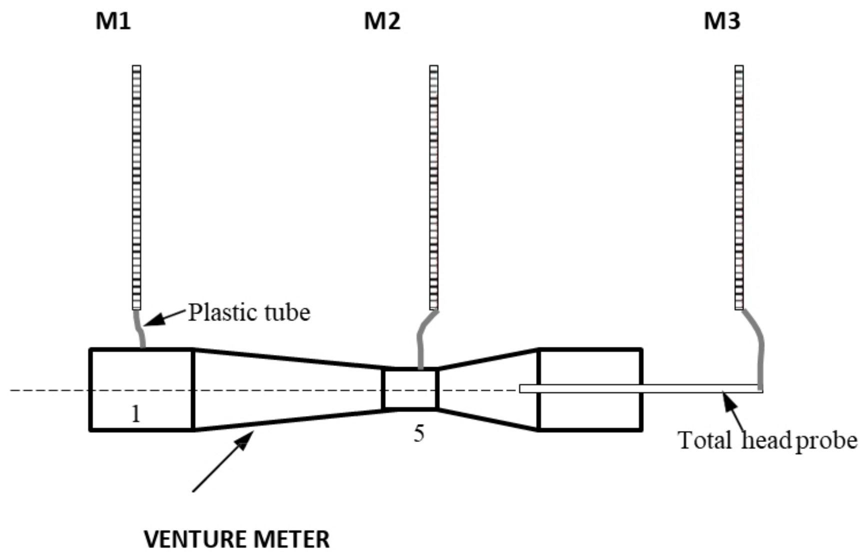
$$\frac{v_1^2}{2g} + \frac{p_1}{\rho g} = \frac{v_5^2}{2g} + \frac{p_5}{\rho g}$$

From the conservation of mass (continuity): $Q = A_1 \times v_1 = A_5 \times v_5$, then:

$$v_1 = \frac{A_5}{A_1} v_5$$

$$Q = A_5 \sqrt{\frac{2g(h_1 - h_5)}{1 - (A_5/A_1)^2}}$$

$$Q_a = C_d A_5 \sqrt{\frac{2g(h_1 - h_5)}{1 - (A_5/A_1)^2}}$$



مهم DIAMETER 5 لاحظ مكان وجود

خطوات حل التجربة:

1-COMPUTE A1 AND A5

2- $Q_a = V / t$

3-h1-h5

4- $$Q = A_5 \sqrt{\frac{2g(h_1 - h_5)}{1-(A_5/A_1)^2}}$$

5-$C_d = Q_a / Qtheo$

6- V5=Qact/ A5

7- RE=V5A5 / 10^-6

8- (h1-h5)^0.5

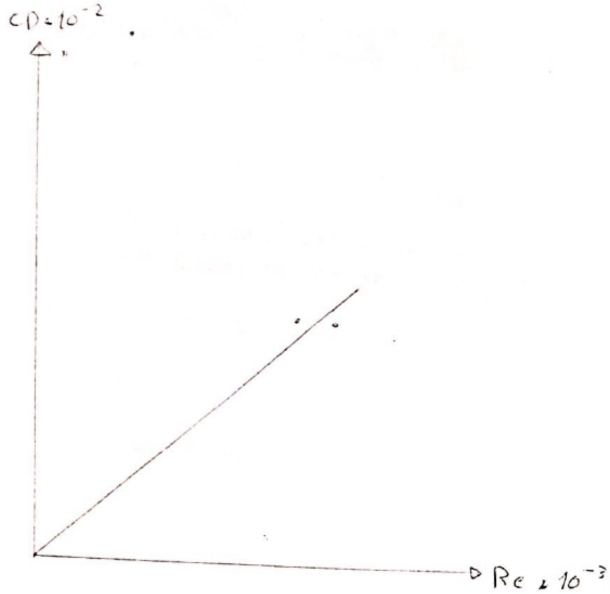
Important Notes :

-the relation between RE and CD is not direct

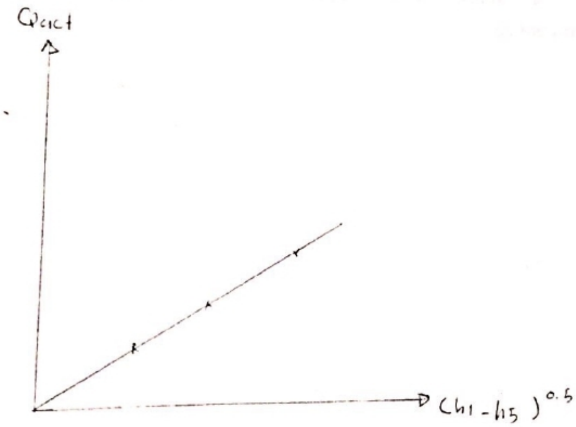
-CD <1 due to losses in exp

DRAWINGS:

CD vs Re



Qact vs $(h_1 - h_5)^{0.5}$



① get slope

② $slope = C_D A_5 \sqrt{\frac{2g}{1-\left(\frac{A_5}{A_1}\right)^2}}$

③ get CD

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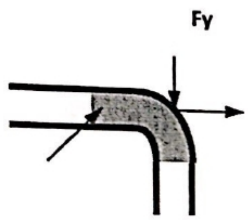
Exp. 4: Impact of Water Jet

The momentum conservation principle says: the change in the momentum rate will appear as an external force in the direction where the momentum has changed. This external force is called the impact of water jet



In the experiment, the water flow from a pump will pass through a small nozzle (d = 8mm) that creates a vertical jet The vertical jet will hit an object (target of deflection angle either of 30°, 90°, 120° or 180°) and based on the deflection angle an external force applies on the target surface lifting the target up. The external force on the target can be equalized experimentally by an external weight (mass in the weight pan) upon which the target is balanced

$v_c^2 = v_n^2 - 2gS$

ρσ ρn

the momentum $M = m \times v$

$M = \rho Q v_o$,

$$\sum F = \frac{\Delta M}{\Delta t}$$

$$F = m \times v_1 \cos\theta - m \times v_o = m \times v_o (\cos\theta - 1)$$

REPLACE M*V WITH ρQV حسب المعطيات

Important:

For fat plate, الزاوية= 90, therefore from Equation (4), $F = mv_o$.

For hemisphere, الزاوية= 180, therefore from Equation (4), $F = 2mv_o$

خطوات حل التجربة :

1- $Q_a = V / t$

2- $V_n = Q/A$ remember d=8mm

3- $v^2 = v^2 - 2gS$

4- M= m × v OR $M = \rho Q v_o$,

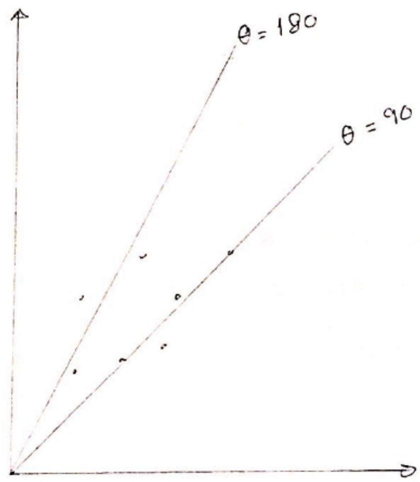
5-Fmeasured=m*g

6- Fcalcuated الزاوية= 90, therefore from Equation (4), $F = mv_o$.

, الزاوية= 180, therefore from Equation (4), $F = 2mv_o$

DRAWINGS:

F measured Vs Momentum



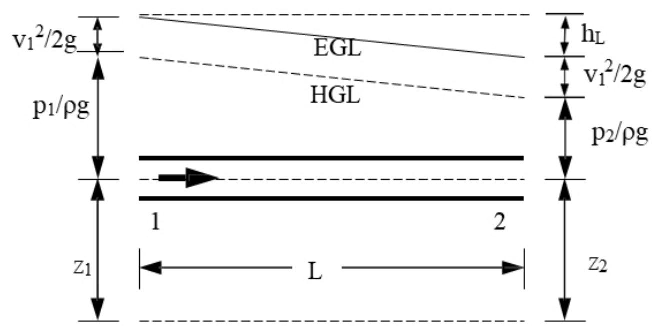
① slope (90°) ≈ 1 (عزم)

② slope (180°) ≈ 2 (عزم)

note: $V_1 \rightarrow$ $V_2 \rightarrow$ نفس الاتجاه $V_1 - V_2$

$V_1 \rightarrow$ $\leftarrow V_2$ عكس $V_1 + V_2$

Exp. 5: Friction in Pipes and Losses from Fittings and Bends



$E_1 = E_2 + h_L$

$h_L = h_1 - h_2$.

$$h_L = \frac{f \times L}{D}\frac{v^2}{2g}$$

-f is the Darcy friction factor (function of the flow Re # and the pipe relative roughness)

-If the pipe internal surface is extremely smooth (relatively no internal roughness) and the flow has a very low velocity then the flow is said to be nearly laminar. In that case the Darcy friction factor (f) is function of the Re # only, i.e. the water viscosity only. For the laminar flow, f = 64 / Re, and the Re = PvD/m

$$h_L = \frac{32\mu L v}{\rho g D^2}$$

-If the pipe internal surface is rough and the flow has high velocity then the flow is said to be turbulent and in that case the Darcy friction factor (f) is function of the Re # (water viscosity) and the pipe relative roughness (type of material)

$$h_L = K\frac{v^2}{2g}$$

where K is the energy loss factor that depends on the bend angle and radius of bending or the nominal size of the valve and its relative opening

hL تتناسب مع v^2 for the turbulent flow

hL تتناسب مع v for the laminar flow.

خطوات حل التجربة :

1-Q_a = V / t

2-V=Q/A

3-RE=VD/v

4-flow type > 4000 turbulant

5- $$h_L = \frac{f \times L}{D}\frac{v^2}{2g}$$

Notes:

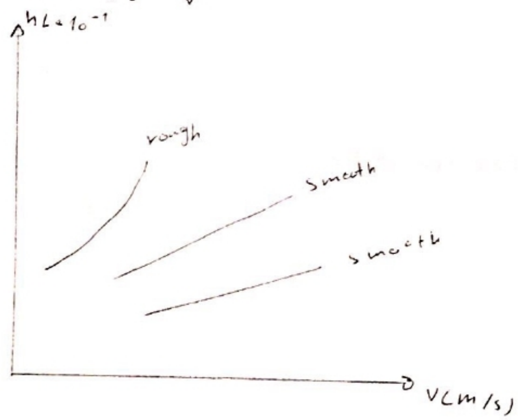
1-f تتناسب مع 1/RE

2-pipe is rough and flow has high velovity turbulent and vise virsa.

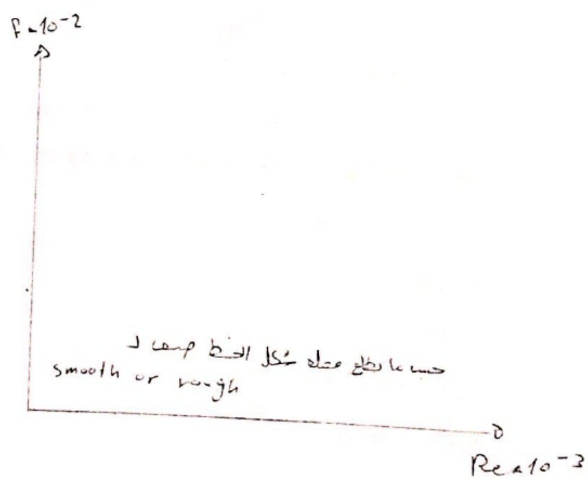
3- the value of head loss in smooth material is ~~lea~~ than rough material
Less

DRAWINGS:

hL vs V



f vs Re



Exp. 6: Pumps in Parallel and Series

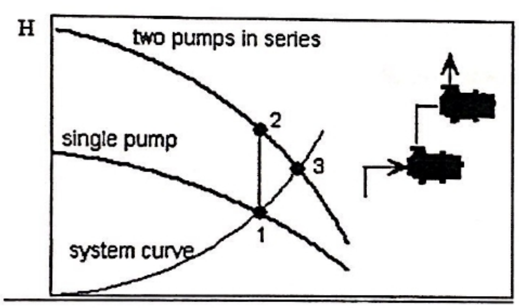
Pumps are hydraulic machines that convert the traditional power (electrical or mechanical) to a hydraulic power. The duty required by a pump is submit the targeted flow rate (Q) to the targeted total head (H) which are the components of the hydraulic power (P_{ow}). The hydraulic power in units of watt is:

P_{ow} = rgQH (1)

Equation (1) describes the two loads (Q, H) that affect the pump performance. The relationship between the pump two loads is unique and inversely proportional, i.e. as the flow rate Q is increased the delivered head (H) decreases. Since the pump duty is to convert the traditional power to a hydraulic power then the pump efficiency (e) can be computed as:

$$\varepsilon = \frac{\text{output power}}{\text{input power}} = \frac{\rho g Q H}{2\pi T (N/60)}$$

where T is the torque generated (N.m) and N is the pump rotating speed (rpm).



The performance of two pumps in series versus the single pump performance.

خطوات حل التجربة :

parallel

1-hA= $\frac{\Delta P}{\rho g}$

2-QT=Q1+Q2 3600 اقسم على الناتج

HAVG=H1+H2/2

SERIES:

1-ha = $\frac{\Delta P}{\rho g}$

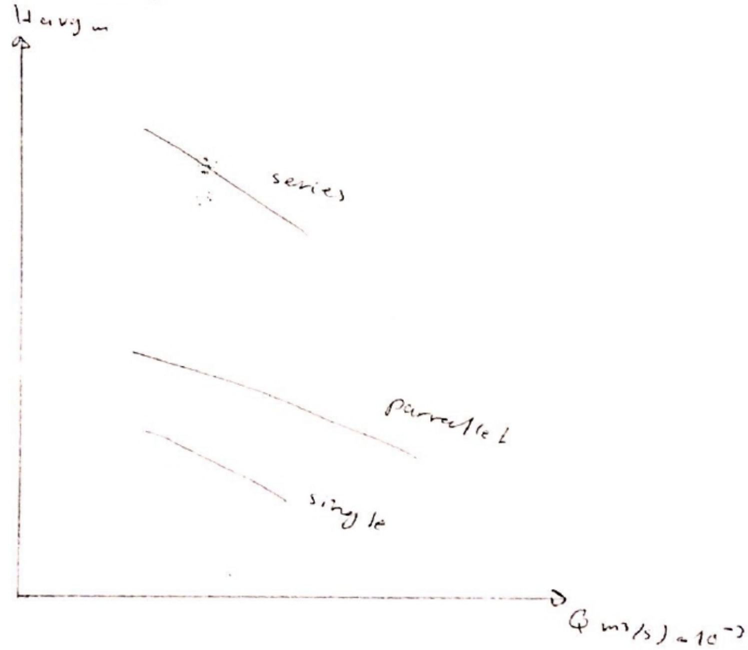
2-HT=H1+H2

3-QT=Q1=Q2

SINGLE

1-HA= $\frac{\Delta p}{\rho g}$

DRAWINGS:



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ملاحظااااااااات مهمة جدا جدا جدا

اسئلة السنوات

1) As the surface submergences depth increases the the differnce between Y_{cp} and $\bar{y}$ ....
Ans : slightly increases   increase => غلط

2) for deflected water jet as the flow deflection angle increases the resulted force.
Ans : increase

3) the pitot static tube is used directly to measure the ...
Ans : total head

4) usually the orifice of known low discharge coefficient (Low C_D) measure the actual flow
Ans : ~~less~~ more accuracy

5) For turblent flow in pressurized pipe the flow rate is 50% reduced the hl is ...
Ans :- reduced 4 times

6) As the orifice material getting aged (becomes rougher) the Cd ...
Ans decreases

7) in the energy equation the pressure head ($P/\rho g$) is called the .....
Ans static head

8) The venture meter is used mainly to measure the ...
Ans Actual flow rate

9) The seintific concept that demonstrates the impact of water jet is ....
Ans momentum conservation

~~10~~

Q_2 :- The horizontal pipe ($D = 200$ mm) discharges flow of 5600 L/m the flow is deflected by 25° compute the resultant force

$$Q = \frac{5600 \times 10^{-3}}{60} = 0.0933 \text{ m}^3/\text{s}$$

$$A = \frac{\pi}{4}(0.2)^2 = 0.0314 \text{ m}^2$$

$$V = \frac{Q}{A} = 2.97 \text{ m/s}$$

خطأ

$$F_1 = \rho Q V (1 - \cos 25) = 25.96 \text{ N}$$

خطأ

$$F_2 = \rho Q V (1 - \sin \theta) = 277.1$$

$$F_{resultant} = \sqrt{(25.96)^2 + (277.1)^2} = 278.3 \text{ N}$$

Q3 :- During the impact of water jet the following data was ~~obtained~~ obtained
the diameter of the nozzle is 7 mm and the distance from the nozzle up to target 3 cm

Mass (g)	collected water volume	Time (s)	Q	Vnozzle	V_o	F measured	Momentum
100	8	41	1.95×10^{-9}	5.07	5	0.981	0.975
500	7	16	4.375×10^{-4}	11.4	11.87	4.905	5

$A = \frac{\pi}{4}(0.07)^2 = 3.842 \times 10^{-5}\ m^2$

$Q = \frac{8 \times 10^{-3}}{41} = 1.95 \times 10^{-4}\ m^3/s$

$V_{nozzle} = \frac{Q}{A} = \frac{1.95 \times 10^{-4}}{3.842 \times 10^{-5}} = 5.07\ m/s$

$V_o = \sqrt{V_{noz}^2 - 2gs} = \sqrt{5.07^2 - 2 \times 9.81 \times 0.03} = 5$

$F_m = 0.1 \times 9.81 = 0.981$

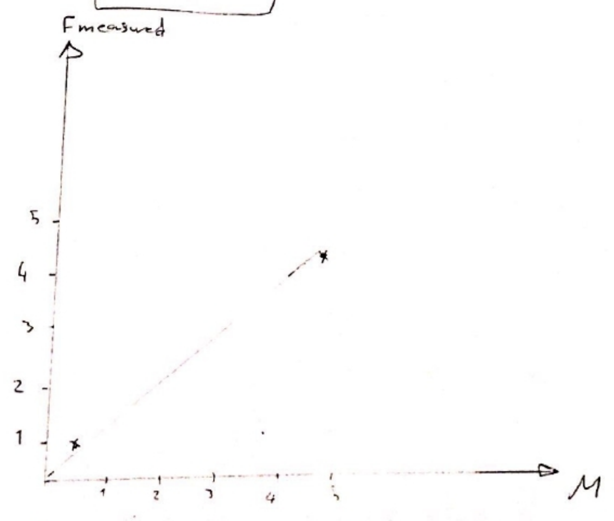
$F_M = \rho Q V_o = 1000 \times 1.95 \times 10^{-4} \times 5 = 0.975$

$slope = \frac{4-3}{4-3} = 1$

$= 1 - \cos\theta$

$1 = 1 - \cos\theta$

$\cos\theta = -0.1 = 90 =$ Flat plate



Compared to orifice of cd = 0.9 the actual answered using orifice Cd = 0.4 is
Ans more Accurate

2- The flow in pressurized pipe always moves from the point of the highest pressure

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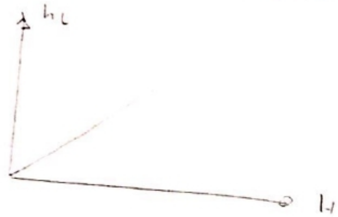
Draw an approximate relationship between hL for small orifice versus water head H



direct relation

$\uparrow V = \sqrt{2gh} \uparrow$

$V \uparrow \quad h_L \uparrow$

Q3 : - water jet leaves a tank trough small orifice the trajectory of the jet travels 72 cm horizontal distance while drops vertical distance of 55 cm if the coefficient of velocity in 0.88 calculate the water head and hL

$Cv = \frac{x}{2\sqrt{yh}}$

$0.88 = \frac{720}{2\sqrt{550\,h}}$

$h = 304.28$ mm

$V_a = \sqrt{2gh}$

$= \sqrt{2 \times 9.81 \times 0.30428}$

$= 2.44$ m/s

~~H~~ $h = \frac{V^2}{2g} + h_L$

compute hL

في شغلة مش حاكه صح
- في احتمال Va or Vtheo
اذا Va احتمال 2.44
اذا Vtheo ⇐ $Cv = \frac{V_{ac}}{V_{the}}$
ضروري

---

venture meter D1 = 25 mm DS = 10 mm inside was use to collect flow ∀. versus Manometer head

calculate CD

h1 mm	hs mm	∀ L	Time sec	Qact	$(h_1-h_s)^{0.5}$
50	30	1.3	29	4.48×10^{-5}	4.472
80	50	1.5	27	5.55×10^{-5}	5.477
140	90	2.4	33	7.27×10^{-5}	7.071

$Q_{act} = \frac{1.3}{1000 \times 29} = 4.48 \times 10^{-5}$

ارسم الرسمة واحسب CD

slope ①
②

لازم Cd أقل من 1

$slope = C_d A_s \sqrt{\frac{2g}{1-(\frac{A_s}{A_1})^2}}$

P2 8. water flow from a tank through small orifice of 6mm diameter the water drains from the tank is collected producing 42 L in 82 seconds calculate the water head produce such flow given that the velocity Cv = 0.85

$Q_{act} = \frac{V}{t} = \frac{42/1000}{82} = 5.12\times10^{-6}\ m^3/s \qquad A = \frac{\pi}{4}(0.006)^2 = 2.827\times10^{-5}$

$Cv = \frac{V_{act}}{V_{the}} \qquad V_a = \frac{Q}{A} = 1.81154\ m/s$

$V_{theo} = \frac{1.81154}{0.85} = 2.13122\ m/s$

$v = \sqrt{2gh}$

$2.13122 = \sqrt{2\times9.81\times h}$

$h = 0.2315\ m$

A 30 mm diameter horizontal water jet has a velocity of 6 m/s as it strikes a flat blade the blade horizontally along the positive x-axis at velocity of 2 m/s water is deflected at 90° from the positive x-axis what is the force on the blade

$F = \rho Q v$

$F = 1000 \times V_o \times Q \Rightarrow \qquad Q = V \times A \qquad V = 6-2\ m/s$

$= 4\times\frac{\pi}{4}(0.5)^2 \qquad = 4$

$= 0.7854$

$= 1000\times4\times0.7854$

$= 3141\ N$

---

if we increase the nozzle diameter by 1mm how will momentum force will be affected ?

$D\uparrow\ A\uparrow\ v\downarrow$

$\downarrow F = \rho Q v \downarrow$ force will decrease

The storage tank 60×60×60 cm filled with water if the tank has rectangular gate 20 width and 30cm height at the bottom on side of tank calculate the resultant force ?

$\bar{y} = 0.6 - \frac{0.3}{2} = 0.45\ m$

$A = 0.2\times0.3 = 0.06\ m^2$

$F = \rho g \bar{y} A = 1000\times9.81\times0.45\times0.06 = 264.87\ N$

$y_{cp} = \frac{bd^3/12}{\bar{y}\cdot A} + \bar{y} = \frac{0.2\times0.3^2/12}{0.45(0.06)} + 0.45 = 0.467\ m$

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Q : in the friction loss experiment the diameter of a horizontal pvc pipe is 2.5 cm and three pressure tapping (manometers) are connected to the surface with water level equal 20, 15, 5 cm respectively The distance between tapping 1 and 2 is 1.25 m and tapping 2 and 3 separated by valve assuming friction factor = 0.01 and viscosity 1×10^{-6} find:

1. The velocity of water in the pipe

$f = hL \times \frac{D}{L} \times \frac{2g}{V^2}$

$0.01 = (0.2 - 0.15) \times \frac{0.025}{1.25} \times \frac{2 \times 9.81}{V^2}$

$V = 1.4$ m/s

2. The pressure loss between 1 and 2

$P_1 - P_2 = \delta w (h_1 - h_2)$

$= 9810 (0.2 - 0.15) = 490.5$ Pa

3. if the flow is Laminar or turbulent

$Re = \frac{VD}{\nu} = \frac{1.4 \times 0.025}{10^{-6}} = 35000 > 4000$ so turbulent

4. The loss coefficient of the valve (k)

$k = \frac{hL \times 2g}{V^2} = \frac{(0.15 - 0.05) 2 \times 9.81}{1.4^2} = 1$

5. if the pvc replaced with cast iron pipe with same Diameter and friction factor 0.02 what would be water Level in tapping 2 ?

$f = h_{L(1-2)} \times \frac{D}{L} \times \frac{2g}{V^2}$

$0.02 = (0.2 - X) \times \frac{0.025}{1.25} \times \frac{2 \times 9.81}{1.4^2}$

$\boxed{X = 0.1}$

A pitot tube installed in a pipeline of 10 cm Diameter before instaling pitot tube the static pressure head was 1.815 m After installing the tube stagnation point pressure head reads 2.666 m If the water discharged from the pipe producing volume of 122 L in 4 seconds

① CV ??

$E_1 = E_2$

$Z_1 + \frac{P_1}{\delta} + \frac{V_1^2}{2g} = Z_2 + \frac{P_2}{\delta} + \frac{V_2^2}{2g}$ → stagnation point

$1.815 + \frac{V_1^2}{2g} = 2.666$

$\frac{V_1^2}{2g} = 0.851$

V_{Theo} 4 m/s

$V_a = \frac{Q}{A} = \frac{\frac{122}{1000 \times 4}}{\frac{\pi}{4}(0.1)^2} = 2.39 \Rightarrow Cv = \frac{V_a}{V_{th}} = \frac{2.39}{4} = 0.58 < 1$ ok

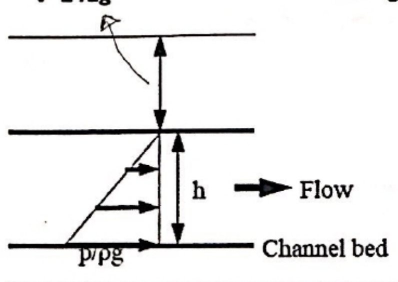
② Brifly use of pitot tube?

measure total head at any point

Exp. 6: Specific Energy: Slow and Fast Flow

Notes:

the specific energy is defined as the total energy measured at a point lies on the channel bed (the energy reference line is taken as the channel bed.



$$E = z + \frac{v^2}{2g} + \frac{P}{\rho g}$$

$$E = h + \frac{v^2}{2g}$$

replacing the flow velocity (v) by Q/A, where A is the flow cross sectional area and Q is the steady flow, then

$$E = h + \frac{Q}{2gA^2}$$

The specific energy takes a minimum value (E_{min}) when the flow is critical (the flow depth h = the critical depth h_c). When $h > h_c$, then the flow is subcritical (slow stream $v < v_c$), and when $h < h_c$, then the flow is supercritical (fast stream $v > v_c$).

$$Fr^2 = \frac{Q^2 T}{gA^3}$$

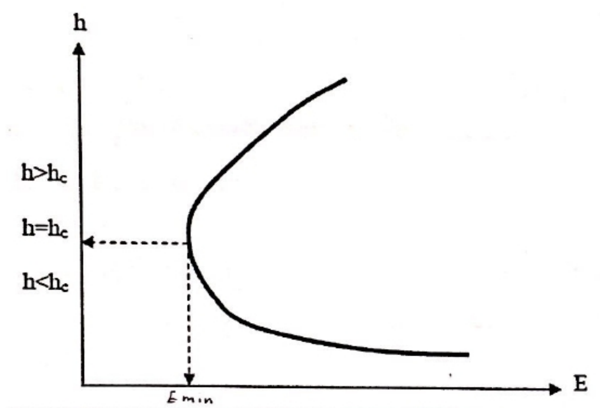
where T is the flow top surface width. The Fr = 1 for the critical flow, >1 for supercritical and < 1 for the subcritical flow. From Equation (4), the reduced form of the Fr # becomes:

$FR = \frac{V}{\sqrt{g h_m}}$

where h_m is the mean hydraulic depth = A / T. For rectangular flow cross sectional area in rectangular channels, then T = b (the bottom width) and the critical depth (h_c) becomes

hc= $\left(\frac{q^2}{g}\right)^{1/3}$

where q is the distributed flow rate, i.e. q = Q / b. Also, it can be shown that the theoretical E_{min} for rectangular section flow, i.e. $E_{min} = (3/2)\, h_c$.



خطوات حل التجربة :

1- $A = h * b$

2- $V = \frac{Q}{A}$

3- $E = h + \frac{V^2}{2g}$

4- $Fr = \frac{V}{\sqrt{g h_m}}$

5- flow type < 1 subcritical

6- $h_{c\,theo} = \left(\frac{q}{g}\right)^{1/3}$

7- $E_{min\,theo} = \frac{3}{2} h_c$

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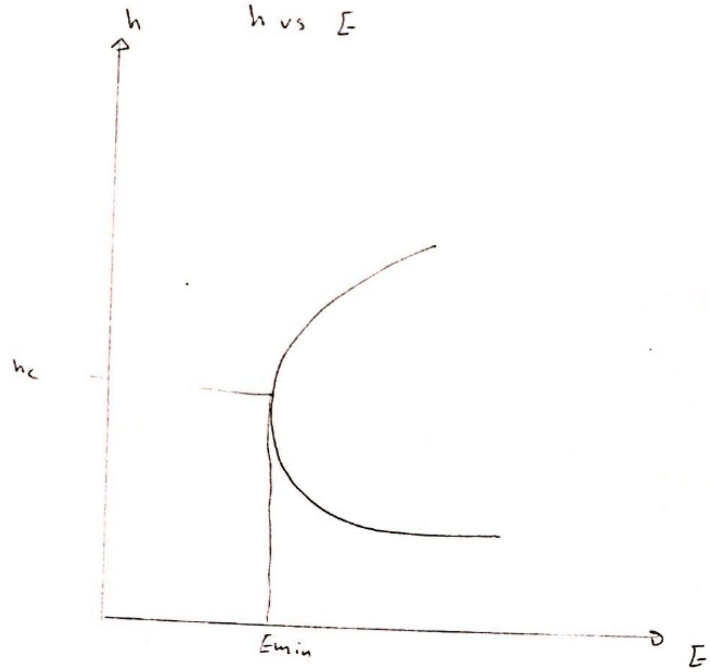
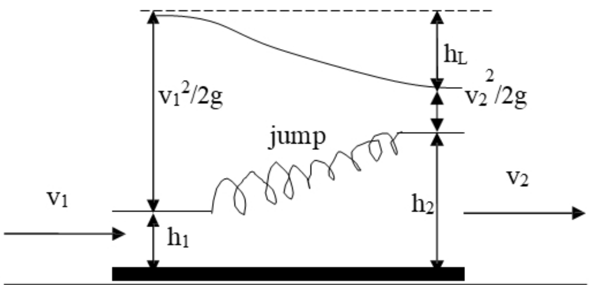


from figure you will get experimental value like $h_{c_{exp}}$, $E_{min_{exp}}$.

Exp. 7: Hydraulic Jump

The hydraulic jump is a natural phenomenon of turbulence occurs when the open channel flow is forced to change its status from supercritical (fast stream) to subcritical (slow stream). Over the jump, a huge reduction in the flow velocity occurs, i.e. before the jump the flow has high velocity and low flow depth while after the jump the flow has low velocity accompanied with high depth, therefore, the flow depth has jumped from low to high value. In the jump turbulence, the flow stream paths will strongly collide with each other causing a considerable reduction in the flow velocity and a huge loss in the energy. Fig. 1 shows the development of the hydraulic jump between point 1 (before) and point 2 (after).



$p_1A_1 + rQv_1 = p_2 A_2 + rQv_2$

$$h_2 = \frac{h_1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right) \qquad h_1 = \frac{h_2}{2}\left(\sqrt{1 + 8Fr_2^2} - 1\right)$$

$h_L = E_1 - E_2$

$$h_L = \frac{(h_2 - h_1)^3}{4 h_1 h_2}$$

The height of the jump is calculated as $Hj = h_2 - h_1$.

خطوات حل التجربة :

1- **Q= Q*10^-3/60**
2- **2-compute A1 and A2**

3-V1=Q1/A1 AND V2=Q2/A2

4-Fr1=V1/(gh1)^0.5 flow type if Fr >1 super <1 sub

5-E1=h1+(V1^2/2g) E2=h2+(V2^2/2g)

6-

$$h_2 = \frac{h_1}{2}\left(\sqrt{1 + 8Fr_1^2} - 1\right) \qquad h_1 = \frac{h_2}{2}\left(\sqrt{1 + 8Fr_2^2} - 1\right)$$

7-hl=E2-E1

8-

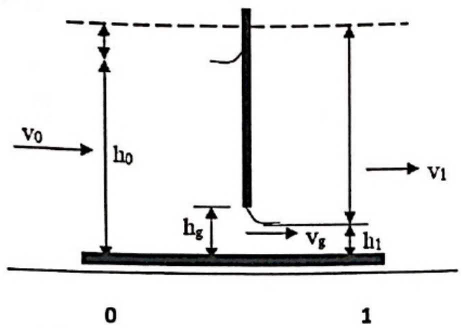
$$h_L = \frac{(h_2 - h_1)^3}{4 h_1 h_2}$$

Notes:

1- **Hl exp depend on energy**
2- **Hl theo depend on depth value**
3- **E2 always less than E1**
4- **AFTER THE JUMP THE FLOW HAS LOW VELOCITY AND HIGH FLOW DEPTH**
5- **FLOW DOWN STREAM THE JUMP IS SUPERCRITICAL**

Exp. 8: The Flow Beneath a Sluice Gate (An Undershot Weir)

The sluice gate is a tool that can be used to control and regulate the open channel flow. In addition, it can be used to measure the flow rate when acting as an undershot weir (inverted weir).



The flow upstream the gate is subcritical and v is actually very low, therefore the term v / 2g can be assumed zero. Furthermore, the flow depth downstream the gate (h_1) is also very low (supercritical flow) which can be neglected under the fact that the majority of the energy after the

gate is due to the velocity head ($v^2 / 2g$) only. Given that the velocity head $v^2 / 2g \approx v^2 / 2g$, then

V_g = (2g ´ h_o)^0.5

Q = bh_g (2g ´ h_o)^0.5

Q_a = C_d bh_g (2g ´ h_o)^0.5

خطوات حل التجربة :

1. **Qact=Q*10^-3/60**

2-Qth= bh_g (2g ´ h_o)^0.5

3-Cd=Qa/Qth

4-Compute ho^0.5

Note: the relation between Cd and hg is inverse relationship because as hg decrease the cd increase so hl ~~increase~~. decrease

DRAWINGS :

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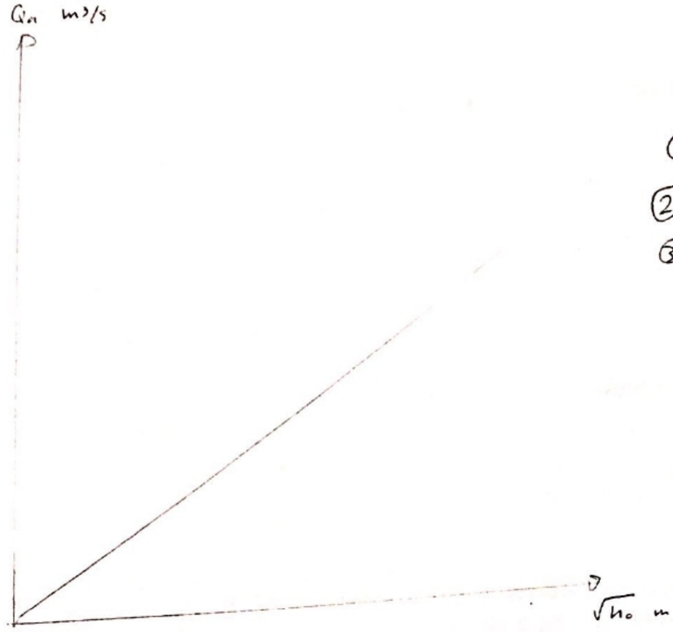
Q_a vs $\sqrt{h_o}$ m

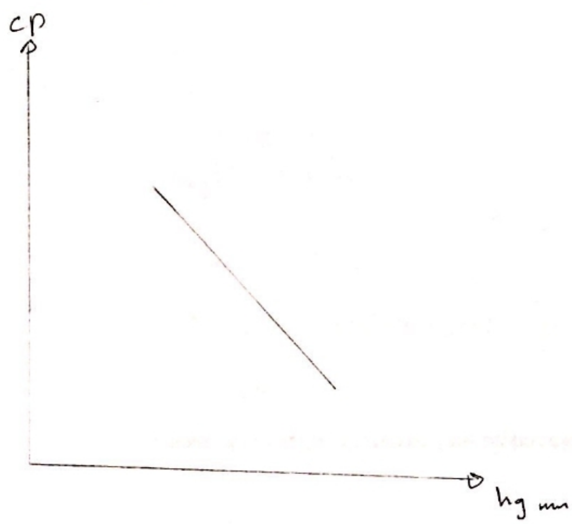


① get slope

② slope = $\underline{C_D} \cdot b \cdot \sqrt{2g} \cdot h_g$

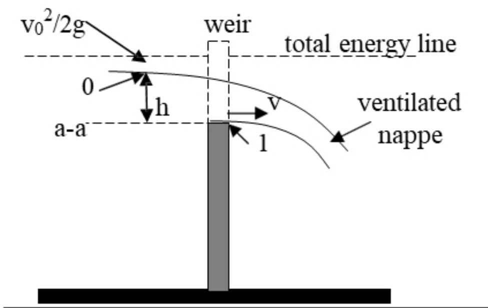
③ get C_D

C_D vs h_g



Exp. 9: The Flow Through Rectangular Sharp Crested Weir

Sharp and broad crested weirs are tools used to measure the open channel flow. In general, the flow rate in small channels is measured using sharp crested weirs while the flow in large channels is measured using the broad crested weir



V= $\sqrt{2g}\, h^{1/2}$

$$Q_a = \frac{2}{3} C\, b_d \sqrt{2g}\, H^{3/2}$$

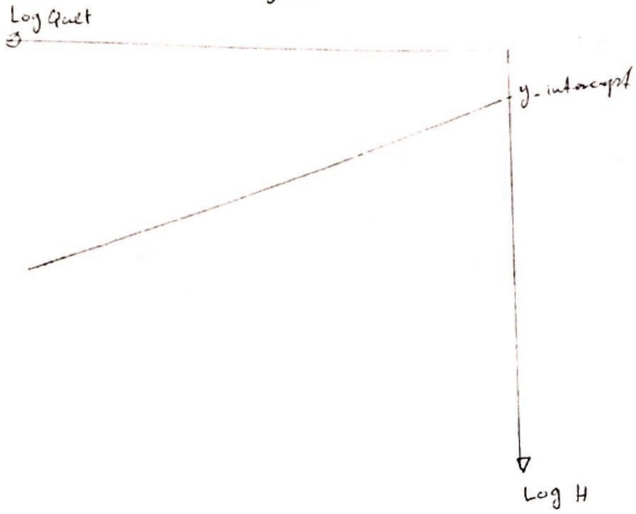
خطوات حل التجربة :

1- **Qact=Q*10^-3/60**
2- **Qth=2/3 b (2g)^0.5 H^2/3**
3- **Cd=Qact/Qth**
4- **Log H**
5- **LOG Qact**
6- **H^2/3**

Note : the relation between cd and H is direct relation as H increase the Cd decrease.

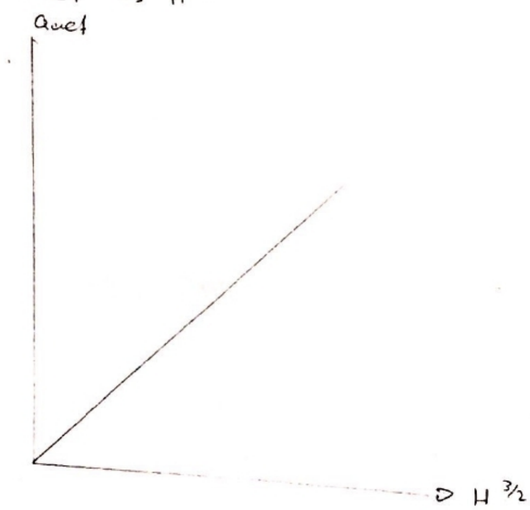
DRAWINGS:

Log Qact Vs Log H

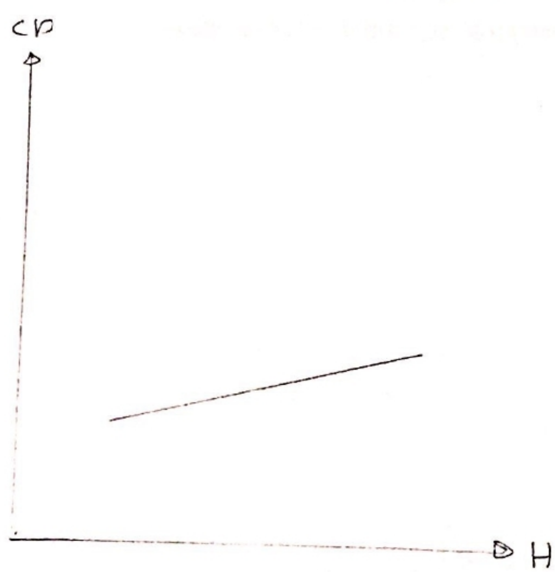


① get slope
② $Q \propto H^{slope}$
③ y-intercept
④ y-intercept = $\text{Log}\left[\frac{2}{3} C_D \cdot b\sqrt{2g}\right]$
⑤ get C_D

Qact Vs $H^{3/2}$



① get slope
② slope = $\frac{2}{3} C_D \cdot b \cdot \sqrt{2g}$
③ get C_D



غايال

1- for flow in open rectangular channels as the flow rate increases the flow minimum Energy -

Ans. increase

2- for flow in open rectangular channels as the flow depth increases the mean hydraulic depth - - -

Ans increase

3- for the same flow rate and b.c. the flow depth decreases the flow specific energy

Ans increase

4- for the same flow depth before the jump decreases the flow depth after the jump

Ans increase

5 for small orifice the actual energy head loss increase the Cd decrease

6- As depth increase the bed slope So - -

Ans decrease

Q2: Horizontal pipe of 8 cm diameter discharge flow of 300 L/minute The pipe friction factor is 0.02 if the pipe total length is 155 m and has 50° bend in the middle calculate the head loss coefficient K ? assume total energy losses is 2 m ?

h_L = major + minor

$$V = \frac{Q}{A} = \frac{5 * 10^{-3}}{(8 * 10^{-2})^2 * \frac{\pi}{4}} = 0.994 \text{ m/s}$$

$$2 = f * \frac{L}{D} \frac{v^2}{2g} + k \frac{v^2}{2g}$$

$$2 = 0.02 * \frac{155}{8 * 10^{-2}} * \frac{0.994^2}{2 * 9.81} + k \frac{* 0.994^2}{2 * 9.81}$$

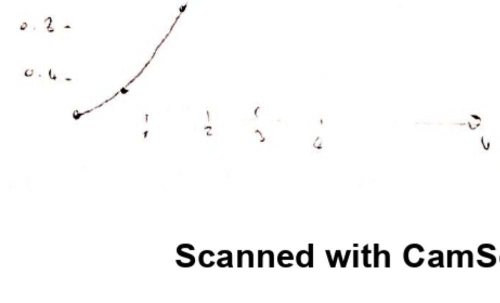
$$\boxed{k = 0.965}$$

Q3: The following table shows ~~exp~~ experimental results for a pipe velocity and its associated head loss what type of flow exists Justify your Answer ?

velocity (m/s)	0	1	2	3
h_l (cm)	0	0.2	0.2	1.2

معطى

The flow is turbulent because the relation between hL & v is non Linear



Q4: A sluice gate was used to regulate the flow in 7.5 cm bottom width small open channel The flow depth before and after the gate were 3 cm and 6cm respectively compute the flow minimum energy assuming no energy loss occurs?

$E_1 = 0.03 + \frac{q^2}{2 \times 9.81 \times 0.03^2} = 0.03 + 56.63q^2$

$E_2 = 0.06 + \frac{q^2}{2 \times 9.81 \times 0.06^2} = 0.06 + 14.157q^2$

$E_1 = E_2 + h_L$ (zero)

$0.03 + 56.63q^2 = 0.06 + 14.157q^2$

$q = 0.0265 \ m^3/s/m$

$h_c = \left(\frac{q^2}{g}\right)^{1/3} = \left(\frac{0.0265}{9.81}\right)^{1/3} = 0.0416 m$

$E_{min} = \frac{3}{2} h_c$

$= \frac{3}{2} \times 0.0416 m = \boxed{0.062}$

Q5: Three identical pumps connected in series deliver flow of 10 L/s to 30 m head if the pumps are parallel Calculate the resulted flow rate and total head?

series $\longrightarrow Q_T = Q_1 = Q_2 = Q_3 = 10 L/s$

$H_T = H_1 + H_2 + H_3 = 30 \Rightarrow$ identical كل pump = 10 تعطي
بنوع تلقائيا

parallel

$Q_T = Q_1 + Q_2 + Q_3 = 30 L/s$

$H_T = H_1 = H_2 = H_3 = 10 m$

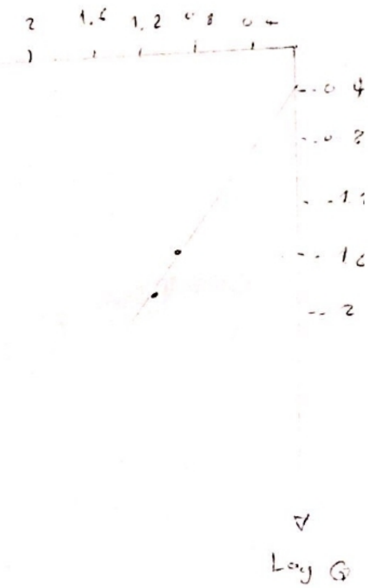
Small sharp crested rectangular weir of 25 cm width is calibrated in the Laboratory

Vlitre,	T sec,	H cm	Q	Log Q	Log H
350	21	7.5	0.016	-1.78	-1.12
700	28	10	0.025	-1.6	-1

Given that $Q \propto H^n$ = Lbm

① The value of the exponent n

② Cd



$Q_1 = \frac{350 \times 10^{-3}}{21} = 0.016$

slope $= \frac{-1.78 + 1.6}{-1.12 + 1} = \boxed{1.5 = n}$ ...... ①

② $-0.4 = Log\,(Cd \times 2/3 \times \sqrt{2 \times 9.81} \times 25 \times 10^{-2})$

$\boxed{CD = 0.54}$

water flows in a rectangular of 5 m bottom width at rate of 5 m³/s if the water depth is 35 cm what is the alternative depth? (same energy)

$v = \frac{Q}{A} = \frac{5}{5 \times 0.35} = 2.857$ m/s

$E = h_1 + \frac{v^2}{2g}$

$0.35 + \frac{(2.857)^2}{2 \times 9.81} = \boxed{0.766\ m = E}$

$E = h_2 + \frac{v^2}{2g}$

$0.766 = h_2 + \frac{q^2}{h_2^2\, 2g} \Rightarrow \frac{Q}{b}$

$0.766 = h_2 + \frac{(\frac{5}{5})^2}{h_2^2\, 2g}$ ...... complete

find h_2 Just

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Q: Two parallel identical pumps deliver flow of 24 L/s to ahead of 20 m if two pumps are to be connected on series what is resulted flow and total head? If the pressure at the single pump 20 kPa what is the pressure in pump outlet?

parallel $Q_T = Q_1 + Q_2 = 24\ L/sec$ $\boxed{Q_1 = 24\ Q_2}$

$\frac{h_1 + h_2}{2} = h_1 + h_2 = 40$ $\boxed{h_1 = 40 - h_2}$

series $Q_t = Q_1 = Q_2 = 24 - Q_2 = 2Q_2 = 24$ $Q_T = 12\ L/sec$

$h_1 + h_2 = h_T = 40 - h_2 + h_1 = 0$ $h_{total} = 40m$

$P_2 - P_1 = h(\rho g) = P_2 - 200000 = 20(9810)$ $\boxed{P_2 = 216.21\ kPa}$