BIRZEIT UNIVERSITY

Faculty of Engineering and Technology

Mechanical Engineering Department

Fluid mechanics Lab

ENME 312

Section 2

Experiment #4 report

Discharge through an orifice meter

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Abstract:

The aim of this experiment is to find the flow rate of liquids by sudden change in the cross sectional area so velocity and pressure will change, it needs two main apparatus which are the hydraulic bench and the glass tank. It is from two parts the first one is the overflow part to take the water and pitot levels also water diameter, the second part is to keep changing the flow rates and record the height of water and the time needed to raise the wight arm of 12 kg. this experiment depends on two main principles which are Bernoulli and continuity principles.

The main results of experiment are: the actual mass flow rate values are around 0.00018 m^3/s, the ideal flow rate values around 0.00029 m^3/s, velocity coefficient values are near to 1, discharge coefficient has 4 values around 0.6 and the contraction coefficient is 0.769.

According to results all coefficient values (Cc, Cd, Cu) need to be less or equal to one also we have approximately linear relation between experimental and ideal flow rate and between the actual flow rate (Q) and the square root of water head (h0^0.5).

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Objectives and measurement methods:

In this experiment we asked to use a sharp orifice with 13 mm diameter and 12 kg weight in two parts, the first one is the overflow level to read the constant level of water H0, then to read Hc which is the height of water when the pitot tube is inserted to the jet, next we need to measure the diameter of water jet using the knife from inner to the outer end while every turn equals 1mm, after that we need to record the time required to raise the weight arm. The second part is to keep repeating the previous steps while changing the flow rate.

The measuring instruments are the sight tube to record pitot head, sight tube to record level in tank, turning screw of the knife to measure the diameter of water, stopwatch to record the time.

There are five main parameters measured, time by stopwatch and weight to find the mass flow rate, water level H0 to find the ideal velocity, pitot tube reading Hc to find the actual velocity and the diameters for orifice and water to find the coefficient of contraction.

Sample calculations:

Data for part 1 by using sharp orifice:

Overflow level reading =H0=383 mm

Pitot tube reading =Hc= 370 mm

Diameter of the orifice= d0= 13 mm

Diameter of water = dc= 11.6 mm

Weight= 12 kg

Time= 53 second

Data for part 2 by using the sharp orifice and 12 kg weight:

Table 1: data for part 2, (run, time (sec.), H0 (mm))

Run	Time (sec)	H0 (mm)
1	53	383
2	55	350
3	61	290
4	65	270
5	66	260
6	77	210
7	81	155
8	94	117

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Calculations:

- Bernoulli equation

$(U_m^2/2g) + (P_m/\rho g) + Z_m = (U_n^2/2g) + (P_n/\rho g) + Z_n$

Where:

ρ: water density (1000 kg/m^3)

Pm: pressure at the top of the tank (KPa)

Pn: pressure at the orifice (KPa)

Um: velocity of water at the top of the tank (m/s)

Un: velocity of water at the orifice (m/s)

g: gravity acceleration equals (9.81 m/s^2)

Zm: height of water at M related to the datum (m)

Zn: height of water at N related to the datum (m)

- The continuity equation

Q = a*u

a: cross sectional area of water flow (m^2)

u: water velocity (m/s)

Q: water discharge (m^3/s)

For part 1:

- To find the coefficient of velocity Cu= Uc/U0= (Hc/H0)^0.5 (as parameters defined in part1 data)

Cu=(370/383)^0.5= 0.967

- To find the coefficient of contraction Cc=ac/a0= (dc^2*3.14/4)/(d0^2*3.14/4)

Where:

ac: the cross section of the vena contracta

a0: the cross section of orifice

Cc=11.6^2/13^2=0.769

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- To find the cofficient of discharge Cd=Cc*Cu

Cd1= 0.769*0.967=0.743

For part 2: (all calculations are for run1 and the same for others)

- The ideal velocity (m/s) U0= (2*g*H0)^0.5

U01=(2*9.81*383/1000)^0.5=2.741 m/s

- The actual velocity (m/s) Uc =(2*g*Hc)^0.5

Uc=(2*9.81*370/1000)^0.5=2.694 m/s

- Coefficient of velocity Cu== Uc/U0= (Hc/H0)^0.5

Cu=(370/383)^0.5= 0.967

- Coefficient of contraction Cc=ac/a0= (dc^2*3.14/4)/(d0^2*3.14/4)=0.769
- The actual (experimental) discharge Q (m^3/s)= mass (kg)/ time(sec.)* density of water

Q act. = 12kg/(53sec.*1000)= 0.000226 m^3/s

- The ideal discharge Q0 (m^3/s)= (2*g*H0)^0.5*a0

Q01=(2*9.81*0.383)^0.5*0.000132= 0.000362 m^3/s

- The coefficient of discharge Cd= Q actual/Q ideal

Cd2= 0.000226/0.000362= 0.624

- The coefficient of discharge Cd=Cc*Cu

Cd3=0.983*0.769=0.756

- Coefficient of discharge Cd from figure 1= slope/(2*g)^0.5*a0

Slope =0.0004

Cd= 0.0004/(0.000133*4.43)=0.679

- Coefficient of discharge Cd from figure 2= slope= 0.61

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Presentation and results:

Table2: results and calculations, (run, time (sec.), water level H0 (mm), ideal velocity (m/s), velocity coefficient, experimental flow rate (m^3/s), ideal flow rate (m^3/s), discharge coefficient 1, discharge coefficient 2, square root of water height (m)).

Run	Time (sec)	H0 (mm)	Ideal Velocity U0 (M/S)	Cu	Q EXP. (M^3/S)	Q0 ideal (m^3/s)	Cd-1	Cd-2	H0^0.5 (M)
1	53	383	2.741	0.983	0.000226	0.000362	0.626	0.756	0.6189
2	55	350	2.620	1.028	0.000218	0.000346	0.631	0.791	0.5916
3	61	290	2.385	1.130	0.000197	0.000315	0.625	0.869	0.5385
4	65	270	2.302	1.171	0.000185	0.000304	0.608	0.900	0.5196
5	66	260	2.259	1.193	0.000182	0.000298	0.610	0.917	0.5099
6	77	210	2.030	1.327	0.000156	0.000268	0.582	1.021	0.4583
7	81	155	1.744	1.545	0.000148	0.000230	0.644	1.188	0.3937
8	94	117	1.515	1.778	0.000128	0.000200	0.638	1.368	0.3421

Table 3: comparison of discharge coefficient values (discharge coefficient from part one, average value of discharge coefficient, discharge coefficient from linear equation in figure 1, discharge coefficient from slope of figure 2).

cd1 (part 1)	0.743
cd2 (avg. of cd-1)	0.620
cd3 from figure 1	0.679
cd4 from figure 2	0.615

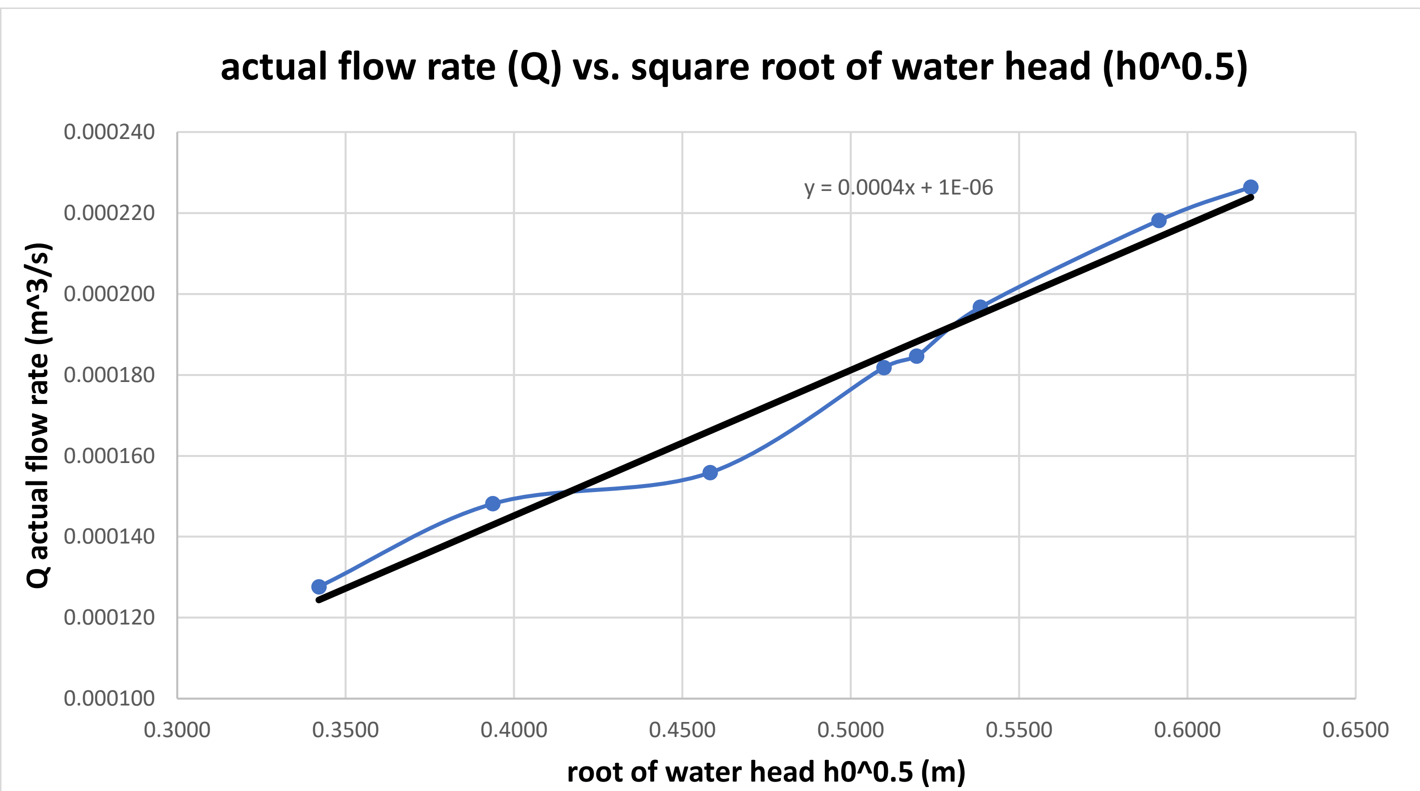

Figure 1: actual flow rate (Q) vs. square root of water head (h0^0.5)

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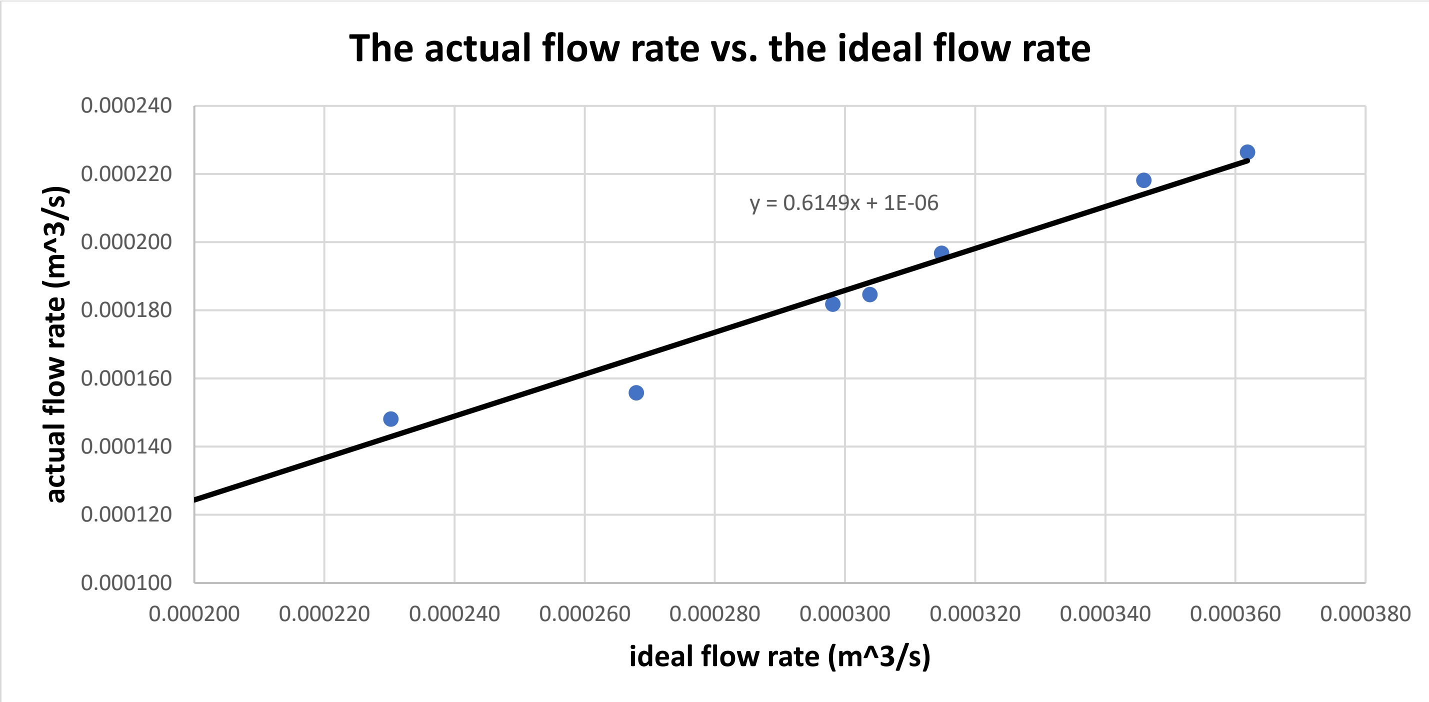

Figure 2: The actual flow rate vs. the ideal flow rate

Discussion of results:

After taking measurements of water level (height), time, weight and diameter it is obvious that there is a relationship between these measurements and the results, so when one of these measurements changed the results will change. In this experiment there is an independent (measured) variable as mentioned above and dependent variables (calculated) like velocity, experimental mass flow rate, ideal flow rate and coefficients (contraction, discharge and velocity), for example when the water level decreases the velocity and the ideal flow rate (discharge) will decrease and the velocity coefficient will increase also there is an inverse relationship between time and the experimental mass flow rate so when time increase the mass flow rate decrease and then the discharge coefficient increase.

After doing all calculations it is obvious that there are four values of discharge coefficient (Cd) as shown in table 2, and all these values are near to each other.

From graph 1 which shows the relation between the actual flow rate (Q) and the square root of water head (h0^0.5**)** we can find Cd value from the equation which equals 0.679 because it is approximately linear relationship. According to graph 2 which shows the relation between the

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actual flow rate and the ideal flow rate the relation is approximately linear so we can find Cd value from the slope of equation.

The experimental results agree to the theoretical results with a little difference for example the experimental and ideal flow rates have a difference of approximately 0.01% (0.0001) and this difference is due to some errors and uncertainty in the experimental method and instruments.

Examples on and uncertainty in the experimental method, uncertainty while reading the water level height from the sight tube and uncertainty from the stopwatch to decrease the amount of these uncertainties we can remove the effect of air bubbles in tubes and we need to use the phone timer instead of the stopwatch because it is more accurate.

According to errors there are two types of them systematic and random, in our experiment there is no systematic error and the random error maybe like different ways of reading the time and height between me and my partner.

Conclusions:

The main results from this experiment are the actual and theoretical flow rate also the coefficients (velocity, discharge and the contraction), most results we got in experiment are acceptable and near to the theoretical ones while there are exceptional cases like some values of Cd and Cc shown in table 2 which are larger than one and it is not logical because all coefficients need to be equal or less than one due to losses in the experiment.

To improve the results we got, we need to be more accurate when record the readings and it is better that more than one person takes the reading also we need to compare the time between the stopwatch and the phone timer additionally while doing the calculations we need to take more significant digits instead of approximation and then we will get better results.

There are a lot of applications in real life on the orifice meter which measures flow rate of different fluids like water supply systems to measure how much water supplied to areas and the water demand of each region also in wastewater treatment stations to measure the influent and effluent amount, additionally to measure the flow of air and gas in different industries.

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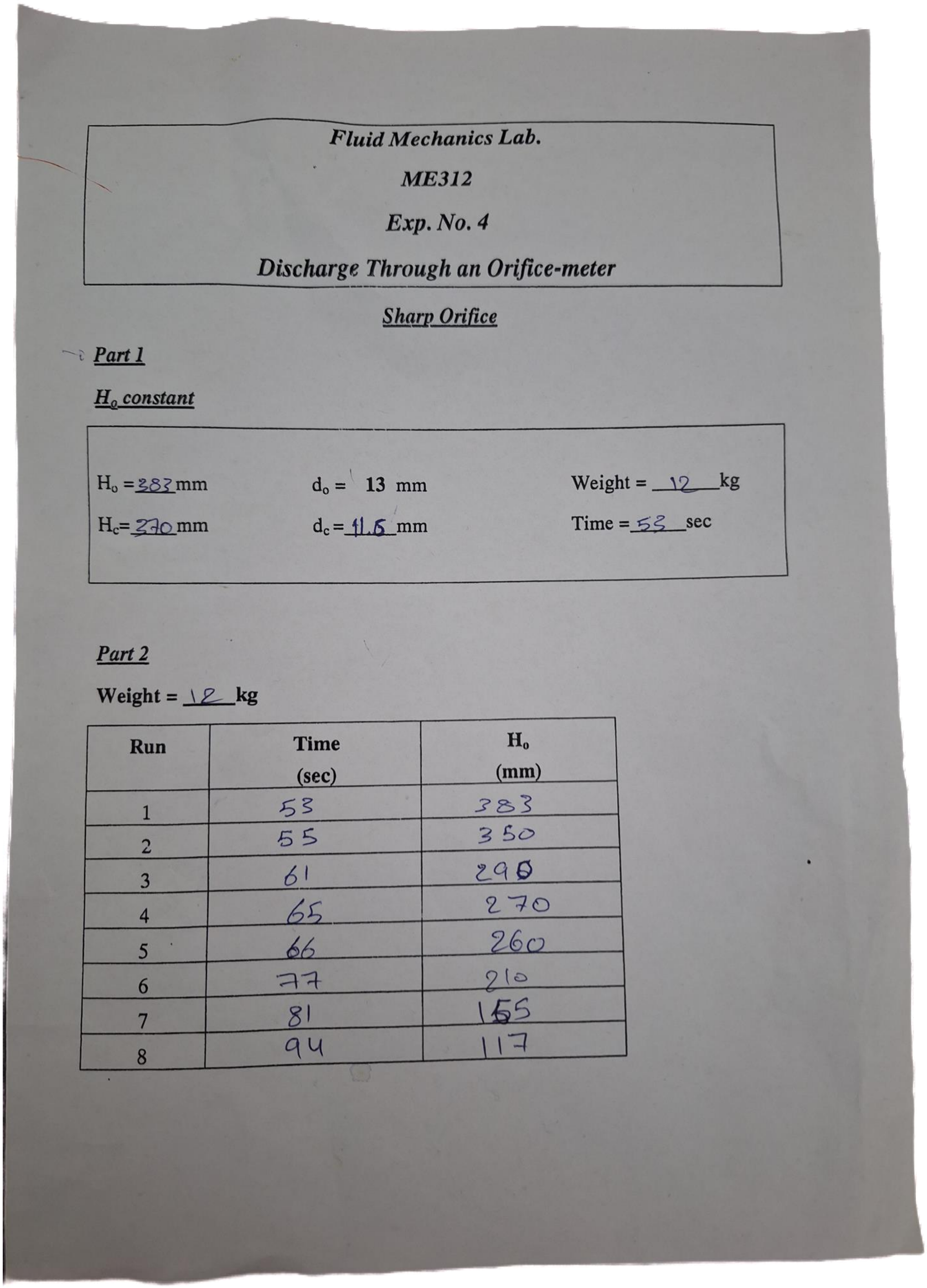
Appendices

- Fluid mechanics laboratory manual-ENME 312, march 2022.



Fluid Mechanics Lab.

ME312

Exp. No. 4

Discharge Through an Orifice-meter

Sharp Orifice

Part 1

H_o constant

H_o = 383 mm d_o = 13 mm Weight = 12 kg

H_c = 370 mm d_c = 11.6 mm Time = 53 sec

Part 2

Weight = 12 **kg**

Run	Time (sec)	H_o (mm)
1	53	383
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Figure 3: original data sheet

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