Aim:-

To study the flowmeters and callibrations of them in hydraulics lab.

Apparatus:-

- Orifice meter
- Venturimeter
- Pipe lines
- Obstruction meters
- Turbine meters
- Ultrasonic flow meters

Results to be presented:-

1) Plot of C and N_R for orifice meter and venturi meter
2) Plot Qactual, Qdisplayed and N_R for all other flow meters

Theory:-

Constant area, variable pressure drop meters, etc OR

Obstruction meters:-

The most widely use flowmetering principle involves placing a fixed area flow restriction of some type in the pipe or duct carrying the fluid. This flow restriction causes a pressure drop which varies with the flow rate. Thus the measurement of the pressure drop by a suitable differential-pressure pick up allows flow rate measurement.

Sharp edge orifice:-

The sharp edge orifice is undoubtedly the most widely used flow metering element, because of its simplicity, its low cost and the great volume of research data available for predicting its behaviour. If one dimensional flow of an incompressible frictionless fluid without work, heat transfer, or elevation change is assumed, theory gives the volume flow rate:-

$$Q = \frac{A_{2f}}{\sqrt{1 - \left(\frac{A_{2f}}{A_{1f}}\right)^2}} \times \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

However, a simplified formula is generally used to obtain Q_a:-

$$Q_a = C A_o \sqrt{\frac{2 \Delta P}{\rho}} \qquad C = \text{flow coefficient}$$

for a given $\beta = \frac{D_o}{D_p} = \frac{\text{orifice diameter}}{\text{Pipeline diameter}}$

The flow nozzle, venturi tube and flow tubes all operate on & exactly the same principle as the orifice. The significant differences lie in the numerical values of certain characteristics. Discharge coefficient of flow nozzles and venturis are larger than those for orifices and also exibit an opposite trend with reynolds numbers varying from about 0.94 at $N_R = 10000$ to 0.99 at $N_R = 106$.

<u>Rotameters</u> :- This is a constant pressure drop, variable area meters. A rotameter consifsts of a variable tube with tapered bore in which a float assumes a vertical position corresponding to each flow rate through the tube. For a given flow rate the flow remains stationary. Since the verticle forces of different pressure gravity, viscosity, and buoyancy are balanced. This balance is self maintaining since the meter flow area varies continuously with the vertical displacement, thus the device may be thought of as an orifice of adjustable area.

The downward force is constant and so the upward force is must be constant. Since the float area is constant the pressure drop is constant

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For a fixed flow area, ΔP varies with the square of flow rate and so to keep ΔP constant for different flow rates, the area must vary. The tapered tube provide this variable area. Rotameter thus have an accurate range of about 10:1, considering better than square root type element.

Turbine meters :- If a turbine wheel is placed in a pipe containing a flowing fluid. It's rotary speed depends on the flow rate of the fluid. By reducing bearing friction and keeping other losses to aminimum, one can design a turbine whose speed varies linearly with flow rate. Thus a speed measurement allows a flow measurement. The speed can be measured simply and with the great accuracy by counting the rate ~~of~~ at which turbine blades pass a given point, Using a magnetic proximity pick up to produce a voltage pulses. By feeding these pulses to an electronic pulse rate meter by acumulating the total number of pulses during a time interval the total flow is obtained. The pressure drop across the meter varies with the square of flow rate and is about 3 to 10 lb/in^2

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at full flow.

Ultra-sonic flow meter :-

A sound wave travelling in the direction of flow of ~~bet~~ fluid requires less time between one fixed point and the other one travelling in opposite direction. This is the principle employed to measure the flow rate with ultrasonic waves.

Vortex-shedding flow meters :-

The phenamemon of vortex shedding down stream of an immersed solid body of blunt shape when a steady flow impinges upstream is well known in fluid mechanics and is the basis of the vortex shedding flow meter. when the pipe reynolds number N_R exceeds about 10000 vortex shedding is reliable and the shedding frequency $f = \frac{N_{st} V}{d}$

V = fluid velocity

d = characteristic dimension of shedding body

N_{st} = Strouhal number.

For theoretical flow rate, we have,

$$Q_{theo} = \sqrt{\frac{25.2\,gh}{\left(\frac{1}{A_0^2} - \frac{1}{A_i^2}\right)}}$$

$$= \frac{\pi}{4}\sqrt{\frac{25.2\,gh}{\frac{1}{d_o^4} - \frac{1}{d_i^4}}}$$

$$= \frac{\pi}{4}\sqrt{\frac{25.2\,gh \times d_i^4 d_o^4}{(d_i^4 - d_o^4)}}$$

$$= \frac{\pi d_i^2 d_o^2}{4}\sqrt{\frac{25.2\,gh}{(d_i^4 - d_o^4)}}$$

$$\therefore \boxed{q_{theo} = \frac{\pi}{4} d_i^2 d_o^2 \sqrt{\frac{25.2\,gh}{(d_i^4 - d_o^4)}}}$$

$$= 3.395 \times 10^{-3}\sqrt{h}$$

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Initial level (H_1)	Final level (H_2)	Difference (H_d)	Time (t)	Actual (m^3/sec) flow rate
1) 4.7 cm	13.1 cm	8.4 cm	1 min	4.83×10^{-4} ~~= 2.8 ...~~
2) 13.1 cm	24.7 cm	11.6 cm	1 min	6.67×10^{-4} =
3) 7.2 cm	21.6 cm	14.4 cm	1 min	8.29×10^{-4}
4) 8.5 cm	25.7 cm	17.2 cm	1 min	9.899×10^{-4}
5) 6.6 cm	26.6 cm	20 cm	1 min	1.151×10^{-3}
6) 6.9 cm	30 cm	23.1 cm	1 min	1.33×10^{-3}
7) 5.9 cm	31.9 cm	26 cm	1 min	1.496×10^{-3}

Cross section of a measuring tank = 759 mm × 455 mm

∴ Volm of water measured = (crosssection area) × (H_d)

$$= \boxed{759\,mm \times 455\,mm \times H_d}$$

∴ Actual flow rate = $\dfrac{\text{Vol}^m \text{ of water measured}}{60 \text{ secs.}}$

Orifice

Left column (H_1)	Right column (H_2)	Column difference	Cd	Flow rate
14	-4	18	0.782	6.176×10^{-4}
18	-12	30	0.775	8.606×10^{-4}
33	-21	54	0.761	10.893×10^{-4}
41	-33	74	0.777	12.740×10^{-4}
59	-47	106	0.769	1.496×10^{-3}
76	-64	140	0.759	~~1.24~~ 1.752×10^{-3}
94	-82	176	0.772	~~1.404 × 10⁻³~~ 1.937×10^{-3}

Given data :- Orifice meter

Orifice diameter : 18.6 mm

Inlet diameter : 26mm

Ventury meter :-

Throat diameter : 16mm

Inlet diameter : 26.5mm

Pipe line diameter = 26mm

kinematic viscosity of water = $10^{-6}\ m^2/s$.

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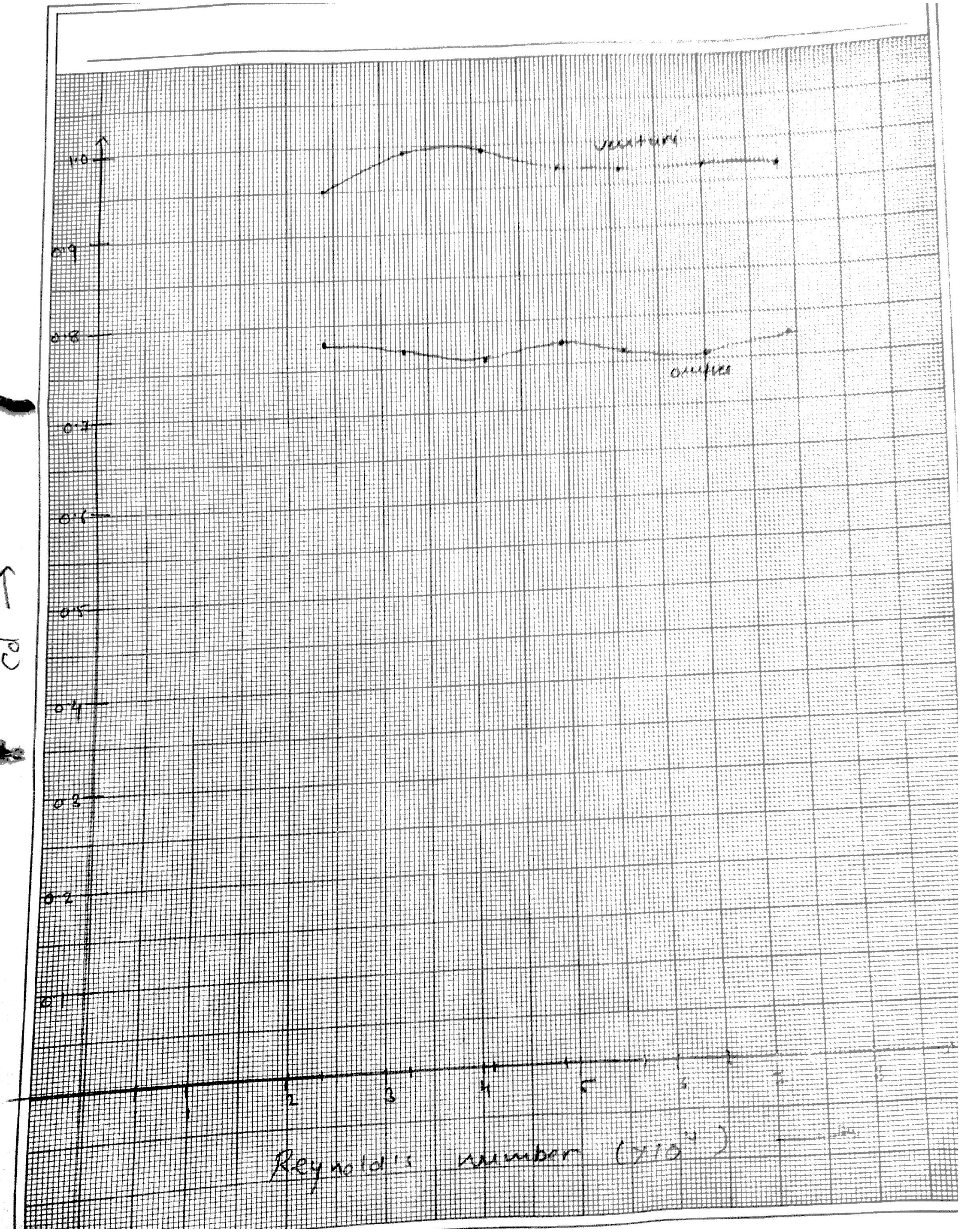
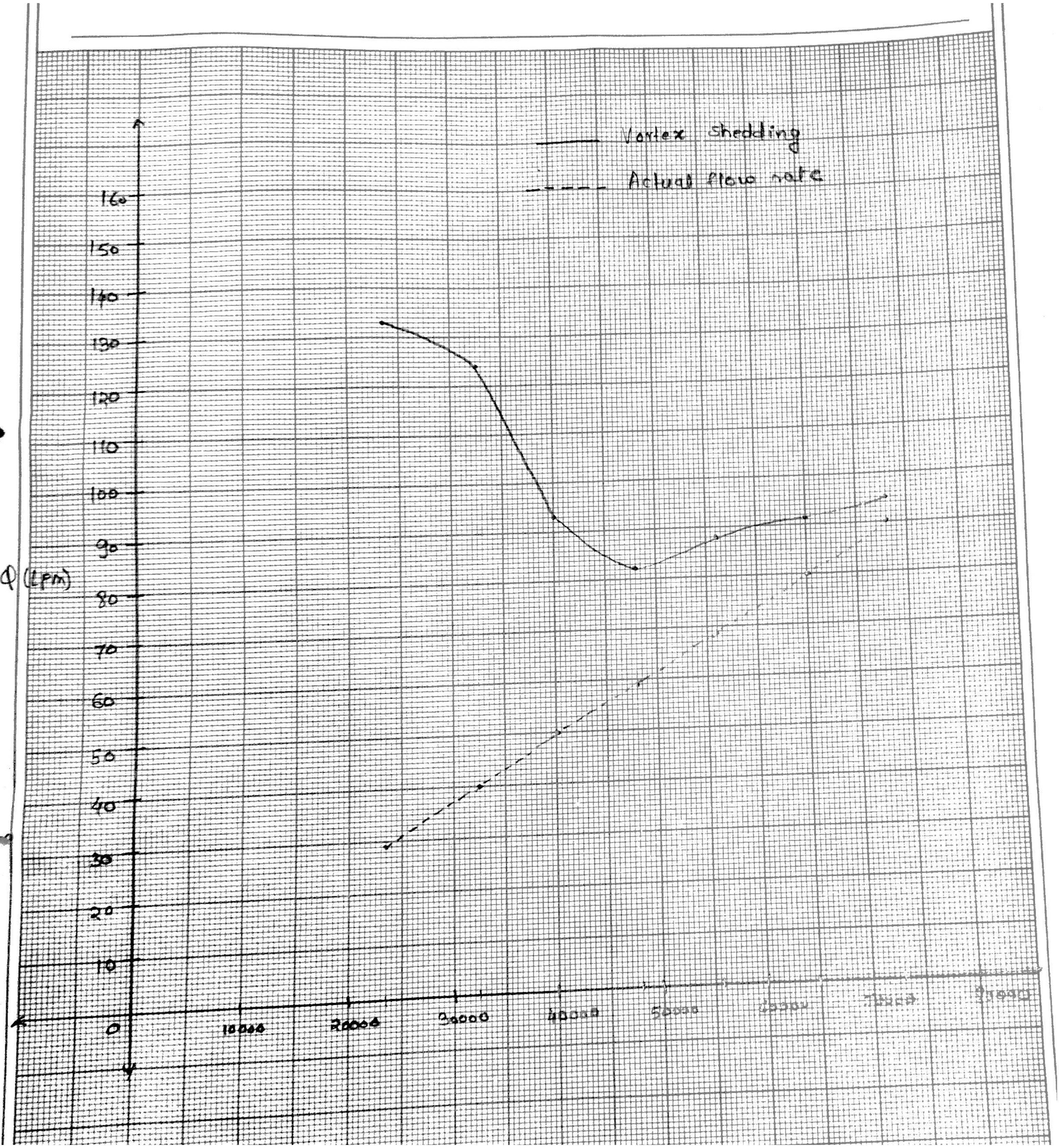
LPM and Reynolds no. calculation

(LPM) Electromagnetic	Vortex Shedding	Ultra Sonic	Actual flow rate (m^3/sec)/LPM	Reynold's number
30	139	29	4.89×10^{-4}/28.98	2.36×10^{4}
40.3	124	41.5	6.67×10^{-4}/40.02	3.26×10^{4}
50.0	93	52.8	8.29×10^{-4}/49.79	4.05×10^{4}
60.2	82	64.2	9.899×10^{-4}/59.39	4.84×10^{4}
70.0	88	73.8	1.151×10^{-3}/69.06	5.63×10^{4}
80.1	91	84.1	1.33×10^{-3}/79.8	6.51×10^{4}
90.3	94.9	94.5	1.496×10^{-3}/89.76	7.32×10^{4}

Venturi

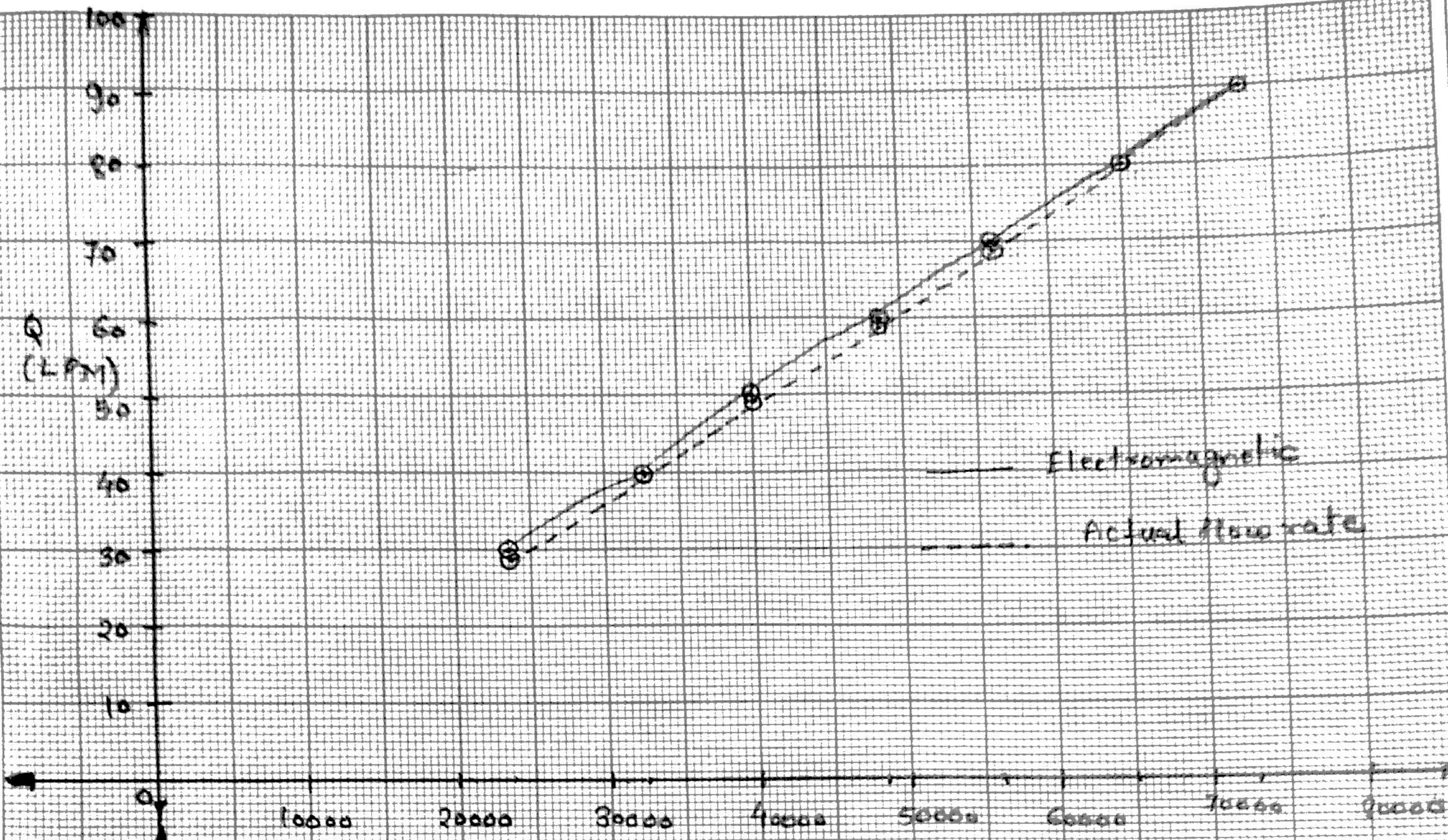
Left column (H_1)	Right column (H_2)	Column difference Hd	Cd	Flow rate (Q_1)
10	−12	22	0.9592	5.035×10^{-4}
19	−20	39	0.9949	6.704×10^{-4}
29	−31	60	0.9968	8.316×10^{-4}
44	−46	90	0.9719	1.0185×10^{-3}
59	−61	120	0.9787	1.176×10^{-3}
79	−81	160	0.9793	1.358×10^{-3}
101	−103	204	0.9758	1.533×10^{-3}

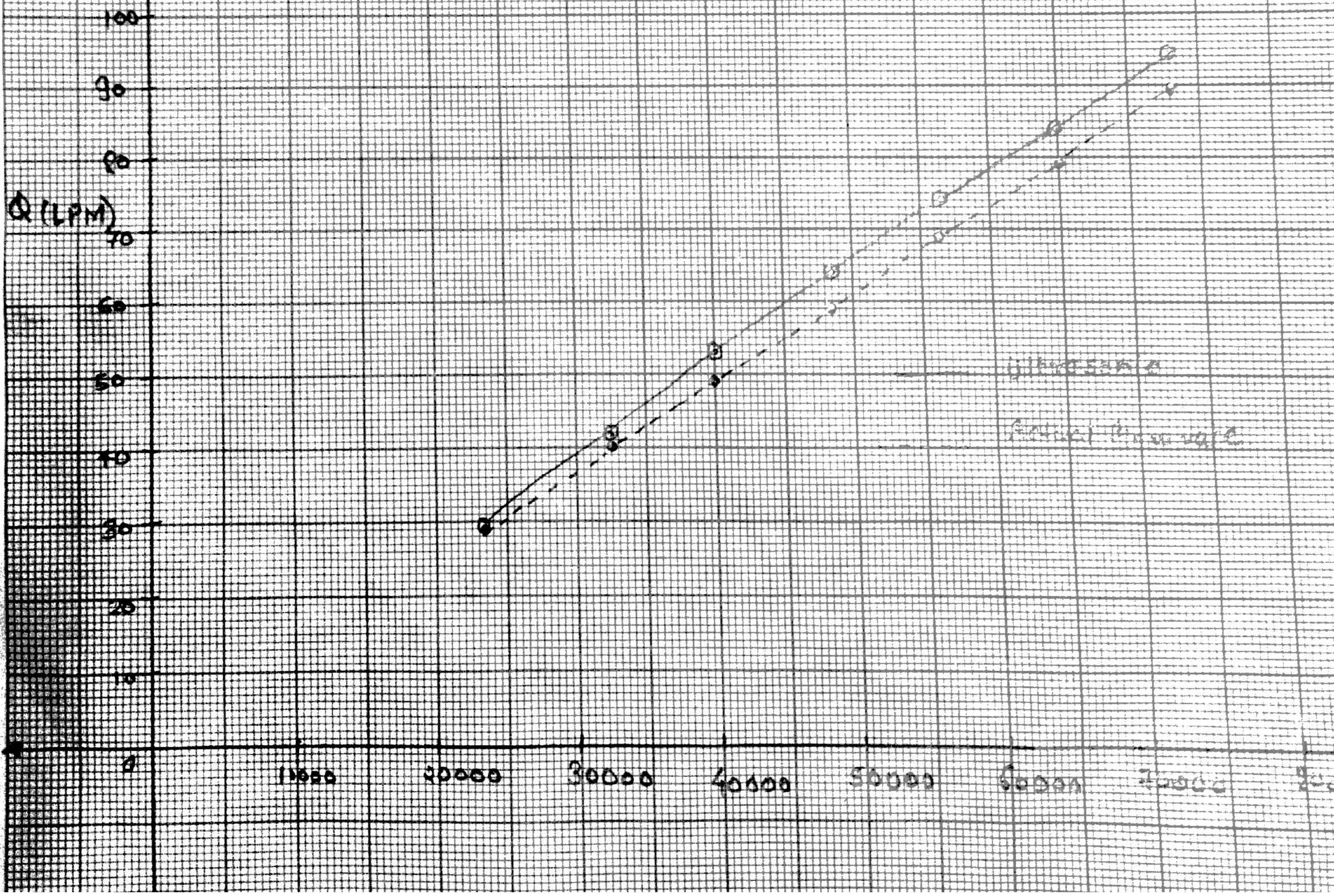

venturi
orifice
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
Cd →
1
2
3
4
5
6
7
Reynold's number (×10⁴)



Scanned by CamScanner

x - Rc
y -


Q (LPM)
0
10
20
30
40
50
60
70
80
90
100
10000
20000
30000
40000
50000
60000
70000
80000
Electromagnetic
Actual flow rate


Q (LPM)
0
10
20
30
40
50
60
70
80
90
100
10000
20000
30000
40000
50000
60000
70000

DISCUSSIONS

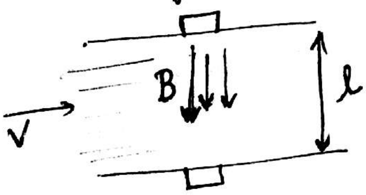
① Flow measurement is the quantification of bulk fluid movement. Flow can be measured in a variety of ways. Positive displacement flow meters accumulate a fixed volume of fluid and then count the number of times the volume is filled to measure flow. Other flow measurements methods rely on forces produced by the flowing stream as it overcomes a known constriction, to indirectly calculate flow.

② We used the following types of flowmeters in our experiment

→ Electromagnetic
→ Vortex
→ Ultrasonic

→ Venturi
→ Orifice
] Pressure Based

③ Magnetic flow meters, often called "mag meter" or "electromag", use a magnetic field applied to the metering tube, which results in a potential difference proportional to the flow velocity perpendicular to the flux lines. The physical principal at work is Faraday's law of electromagnetic induction



$$e = BlV$$

④ A vortex flow meter operates by placing a bluff body (a shedder bar) in the path of the fluid. As the fluid passes this bar, disturbances in the flow called vortices are created. The vortices trail behind the cylinder, alternatively from each side of the bluff body (Von kármán vortex street). The frequency at which these vortices alternate sides is proportional to the flow rate.

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(5) Ultrasonic flow meters utilize ultrasound to make measurements and can be non-invasive.

Ultrasonic transit time flow meters measure the difference of the transit time of ultrasonic pulses propogating in and against the direction of the flow. The time difference is a measure for the average velocity of the fluid along the path of the ultrasonic beam.

$$v = \frac{L}{2\sin\alpha}\,\frac{t_{up} - t_{down}}{t_{up}\,t_{down}} \quad \text{and} \quad c = \frac{L}{2}\,\frac{t_{up} + t_{down}}{t_{up}\,t_{down}}$$

v ↑ fluid velocity c ↑ speed of sound

(6) A venturi meter constricts the flow in some fashion, and the differential pressure is measured.

The coefficient of discharge of venturi meter ranges from 0.93 to 0.97.

(7) An orifice meter is a crude form of venturi meter. It constricts the flow and the differential pressure across the constriction gives the flow rate. $C_d \approx 0.6 \sim 0.7$

(8) ORIFICE METER has more losses than VENTURI METER due to formation of eddies in the orifice meter.