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HYDRULIC ENGG. LAB MANUAL

LIST OF EXPERIMENTS

1. To determine the coefficient of drag by stokes law for sphere.
2. To study the phenomenon of cavitation in pipeflow.
3. To determine the critical Reynolds number for flow through commercial Pipes.
4. To determine the coefficient of discharge for flow over a broad crested weir.
5. To study the characteristics of a hydraulic jump.
6. To study the scouring phenomenon around a bridge pier model.
7. To determine headloss dueto various pipe fittings.

Experiment:01

- AIM: **Todetermine the coefficient of a drag by Stoke law for spherical bodies.**
- **THEORY:**
- When a body moves through any fluid, it experiences resistance, which acts in a directionopposite to that of the motion of the body. This resistance is called the drag force (F_D) and it depend on thesize of the body, velocity with which it moves and the viscosity of the fluid. According to stoke, the dragforce acting on a sphere moving through a fluid due to its weight is given by the following expression:

$$F_D=3\pi\mu U_o D \qquad (i)$$

- Where D isthe diameter of sphere,is the μ viscosity of fluid,an dis called U_o the terminal fall velocity.Terminal velocity is defined as the velocity attained by a body in falling through a fluid at rest, when the drag force on the body is equal to The submerged weight of the body.It may be noted tha tEq.(I)is

applicable only if Reynolds number (Re), defined as D/v, U_o is less than 0.2. Further, the various force acting on the sphere falling in an infinite fluid of mass density ρ with a velocity U

Where

W=weight of the sphere acting vertically downwards

=specific weight×volume of the sphere=$\frac{\pi}{6}D^3(\rho_{s,g})$

F_B=buoyant force acting upward=weight of fluid displaced by the body=($\frac{\pi}{6}D^3(\rho_{s,g})$ F_D=the drag force acting upward.

Here,$\rho_{s,}$ is the mass density of the sphere and,ρ_f is the mass density of the fluid.

Drag force plus the buoyantforce mustbe equal to the weight of the sphere,i.e.for equilibrium condition $F_D+F_B=W$

$$`(\frac{\pi}{6}D^3)(\rho_{f,g}) + F_D = \frac{\pi}{6}D^3(\rho_{s,g})$$

$$F_D=\frac{\pi}{6}D^3 g(\rho_s - \rho_f) \qquad (ii)$$

Theterm $\frac{\pi}{6}D^3 g(\rho_s - \rho_f)$ represent the submerged weight of the fluid.

EquatingEqs.(i)and(ii),weget

$$3\pi\mu U_o D=\frac{\pi}{6} D^3 g(\rho_s - \rho_f)$$

$$U_o = \frac{D^2}{18\mu} g(\rho_s - \rho_f)= \frac{D^2}{18\mu} (\rho_s - \rho_f) \quad \text{(iii)}$$

Equation(iii) is the required expression for terminal velocity.

Also,drag force acting on the bodymoving In a fluid of density ρ_f is given by the following expression.

$$F_D=C_D A \frac{\rho_f U_0^2}{2} \quad \text{(iv)}$$

Where C_D is the coefficient of drag and A is the project ed area of the object on a plane normal to the direction of flow.For a sphere,projected areaA= $\frac{\pi D^2}{4}$

.

$$C_D= \frac{24}{Re} \text{ ,where } Re = \frac{\rho_f U_o D}{\mu} \quad \text{(v)}$$

Thus,coefficient of a drag C_D varies with Reynolds number.

- Experiment has shown thatEq.(v)hold good for Re $<$0.2,and the sphere is falling in an infinite fluid.If the Fluid is not infinite in extent but is confined with a container (finitedimension) ,then the resistance to motion is increased ,and in such a case the modified value of drag coefficient ,as given by the following expression ,should be used:

$$C_D= \frac{24}{Re}(1+2.1\frac{D}{D_1}) \quad \text{(vi)}$$

- Where D1is the smallest lateral dimension of the container and Disthe diameter of the sphere.

Also the observed fall velocity U is correctedi nEq. (iii) by using the following expression in order to get all the fall velocity corresponding to infinite fluid medium:

$$\text{Correctedvelocity, } U_o=U(1+2.4\frac{D}{D_1}) \quad \text{(vii)}$$

Where D_1 is the diameter of ontainer.

- **EXPERIMENTAL SET-**The setup consists of a transparent vertical cylinder.A hopper with a valveis

Provided at the bottom of the ylinder to collect thesphere .Thecylinder is supported by fourverticalpost and fixed to Stable .A vertical scale is fixed on the surface of a cylinder.The cylinder is filled with highly viscous fluid such as glycerin.

- **PROCEDURE:**

1. Measure the diameters of sphere and note down their materials.
2. Determine the mass of the sphere on electronic balance.
3. Mark two line on the cylinder for measurement of the vertical distance (L) for the determination of terminalvelocity.The upper lines houldbe at a depth of 100 mm or more from the free surfaces ot hat the termina velocity is achieved.
4. Hold the sphere with a finger and a thumb and bring it with up to the fluid level. Leave the spheregently (wetthespherebeforedroppingit).
5. Note down the time taken by thesphere in Falling through distance L.
6. Repeat steps(4)and(5)for other diameter of sphere(Set1).
7. Repeat step(4)to(6) For sphere of other material(Set2)

- **OBSERVATIONS AND CALCULATIONS:**

Liquid in the cylinder =Mass

density of liquid ρf =

Kineticviscosity of liquidatT °C

,v=

Diameter of cylinder, D1

=Distanceoffall,L=

Materialofsphere

RunNo.	DiameterD	Projectedarea,A	Massdensity,ρ	F_D	U_o	$C_D$byeq (iv)	Re=	$C_D$by eq(v)
1.								
2.								
3.								

- **GRAPH:**PlotCDversusReasabscissaonanordinarygraphpaper.

Experiment: 02

- **AIM:** **To study the phenomenon of cavitation in pipe flow**
- **THEORY:**

- **Cavitation** is the formation and then immediate implosion of cavities in liquid – i.e. small liquid-free zones("bubbles") – that are the consequence of forces acting upon the liquid. It usually occurs when a liquid issubjected to rapid changes of pressure that cause the formation of cavities where the pressure is relativelylow.
- Cavitation is a significant cause of wear in some engineering contexts. When entering high pressure areas,cavitation bubbles tha tim plodeonametal surface cause cyclic stress.The se results in surface fatigue of the metal causing at Type of wear also called"cavitation".The most common examples of this kind of wear are pump impellers and bends when a sudden change in the direction of liquid occurs. Cavitation is usually divided into two classes of behavior:inertial(ortransient) cavitation and non-inertial cavitation.
- Inertial cavitation is the process where a void or bubble in a liquid rapidly collapses, producing a shockwave.Inman-madeobjects,itcanoccurincontrolvalves,pumps,propellersandimpellers.
- Non inertial cavitation is the process in which a bubble in a fluid is forced to oscillate in size or shape due tosome form of energy input, such as an acoustic field. Such cavitation is often employed in ultrasonic cleaning baths and canals observed in pumps,propellers,etc.
- Since the shock waves formed by cavitation are strong enough to significantly damage moving parts,cavitation is usually an undesirable phenomenon .It is specifically avoided in the Design of machine ssuch as turbines orpropellers ,and eliminating cavitation is a major field in the study of Fluid dynamics.
- Hydrodynamic cavitation describes the process of vaporization, bubble generation and bubble implosionwhichoccursinaflowingliquidasaresultofadecreaseandsubsequentincreaseinpressure.Cavitationwill only occur if the pressure declines to some point below the saturated vapor pressure of the liquid. Inpipe systems, cavitation typically occurs either as the result of an increase in the kinetic energy (through anareaconstriction)oran increaseinthepipeelevation.
- Hydrodynamic cavitation can be produced by passing a liquid hrough a constricted channel at a specific velocity or by mechanical rotation through a liquid. In the case of the constricted channel and based on thespecific (or unique) geometry of the system, the combination of pressure and kinetic energy can be createdwhen the hydrodynamic cavitation cavern downstream of the local constriction generating high energy cavitation bubbles.
- The process of bubble generation, subsequent growth and collapse of the cavitation bubbles results in veryhigh energy densities, resulting in very high temperatures and pressures at the surface of the bubbles for averyshorttime. Theoverall liquid medium environment, therefore,remainsatambient conditions.

- When uncontrolled, cavitation is damaging; however, by controlling the flow of the cavitation the power isharnessed and non-destructive. Controlled cavitation can be used to enhance chemical reactions orpropagate certain unexpected reactions because free radicals are generated in the process due to disassociation of vaporstrapped in The cavitating bubbles.
- Cavitation is, in many cases, an undesirable occurrence. In devices such as propellers and pumps,cavitation causes a great deal of noise,damage to components,vibrations,and a loss of efficiency.When the cavitation bubbles collapse,they force energetic liquid into very small volumes ,there by creating spots of high temperature and emitting shockwaves, the latter of which are a source of noise.Thenoise createdby cavitation is a particular problem formilitary submarines,as it increases the chances of being detected by passive sonar. Although the collapse of a cavity is a relatively low-energy event, highly localizedcollapses can erode metals, such as steel, over time. The pitting caused by the collapse of cavitiesproduces great wear on components and can dramatically shorten a propeller or pump's lifetime. After asurface is initially affected by cavitation, it tends to erode at an accelerating pace. The cavitation pitsincrease the turbulence of the fluid flow and create crevasses that act as nucleation sites for additional cavitation bubbles. The pits also increase the components' surface area and leave behind residual stresses.This makes the surface more prone to stress corrosion.

Experiment: 03

- **AIM:** **To determine the critical Reynolds number for flow throughcommercial pipes.**
- **THEORY:**

- Depending upon the relative magnitude of inertia and viscous forces,theflow of fluid in a pipe may be either laminar or turbulent.In laminar flow,viscous effect s are more predominan then the inertial effects.But when the velocity offl ow is increased, the flow become turbulent as shear and normal stress are added to the flow.A convenient measure of the two types off lowi s Reynolds number,denoted by Re.It is defined as the ratio of inertia for cet o the viscous force and is given by the expression VD/v, where V is the average velocity of flow, D diameter of pipe, and visthe kinematic viscosity of the fluid.For pipes, if Re2000, flow is laminar and for Re 4000 the flow is turbulent. For Re lying between 2000-4000,theflow is in the transition state, which refer to the change of flow laminar to turbulent occurring in some limitedregionofflow.

- Osborne Reynolds was the first who demonstrated the existence of the two types of flow, viz. laminar and turbulent, experimentally.Reynolds injected dye as filament at the center of a transparent tube and studied its behavior. He observed that at low flow velocities, the dye remained in the form of straight and stable filament so steadily that it hardly seemed to be in motion.This corresponds to laminar flow conditions.With the increase in velocity of flow, a critical state was reached at which the filament of dye showed signs ofirregularities and began to wavers. This show that the flow is no longer laminar but in transitional state.With further increase in velocity of flow, the dye completely diffused over the cross section of the tube and mixed with water.This corresponds to the turbulent flow conditions.

- The velocity at which the flow changes from laminar to turbulent is called the upper critical velocity, and thecorresponding Reynolds number as the upper critical Reynolds number. The velocity at which the flowchanges back from turbulent to laminar is called the lower critical velocity, and the corresponding Reynolds number as the lowe rcritical Reynold number.The upper critical Reynolds number is not a fixed quantity as it depend upon a number of factor such as initial disturbance of low,the shape of entry to the tube,etc.On the other hand, the lower critical Reynolds number is well established and its value is usually about2000.

- **EXPERIMENTAL SETUP:**

- The set up consists of a constant head supply tank mounted on a steel plate and placed on MS stand. APerspex tube is attached to the tank to visualize the different flow conditions. The tank has the provision for supplying dye through a need leat the center of the tube in the form of a jet.The entry of water in Perspex tube is through anelliptical bell mouthen trancesoas to have a smoothen try to theflow.Water is supplied to the tank through an inlet valve provided in the supply pipeline. A regulating valve is provided on thedownstream side of the tube to regulate the flow gradually. A collecting tank is provided to measure thedischarge.Alternatively,smaller discharge can be measured in the cylinder.

- **PROCEDURE:**

1. Open the inlet valve slightly and maintain constant head in the supply tank by adjusting the inflow. Let the flow become steady.
2. Inject dye slowly and study its characteristic/behavior.
3. Measure discharge.
4. Increase the discharge slightly by opening the outlet valve.Again maintain constant head in the supplytank.
5. Repeat the above step for different discharges till dye gets completely diffused over the cross section of the tube.

   (Encircle the reading for which the dye filament wavers fort he first time near the outletend of the tube.)

6. Repeat the experiment with decreasing rate of flow and encircle the reading for which the dye filament wavers for the last time near the outlet end of the tube,as the flow changes back from laminar to turbulent.

- **OBSERVATIONSANDCALCULATIONS:**

DiameterofPerspextube,d =

Areaofconduit,a =

Temperatureofwater,T

°C =

Kinematic viscosity of water at T =Area

of collecting tank,A =

- **Increasingdischarge**

RunNo.	Discharge,Q	V=$\frac{Q}{a}$	Re= $\frac{Vd}{v}$	Characteristicofdye	Remarks
1.					
2.					
3.					

- **Decreasingdischarge**

RunNo.	Discharge,Q	V=$\frac{Q}{a}$	Re=$\frac{Vd}{v}$	Characteristicofdye	Remarks
1.					
2.					
3.					

Experiment: 04

- **AIM:** **To determine thecoefficient of discharge of a Broadcrested weir.**
- **APPARATUSREQUIRED:**

1) A channel or flume to provide a flow passage.
2) A broad crested weir.
3) Hook-gauge to measure the head over the cres over the crest of weir.
4) A collecting tank to fit with apyrometer,to the discharge over the weir and to find out actual discharge.
5) Stopwatch to note the timeofcollection of water for a known rise of water level in the collecting tank.
6) Meter scale to measure the internal plan dimensions of the collecting tank.

- **PROCEDURE:**

Start the experiment by pressing start button with default values of length of the collecting-tank,width of the collecting,pauset he experiment after few cycles and note the observation.

- **Observation:01**

1) Open the control valve and allow the water level to rise upto the skilllevel of the weir.
2) Adjust the tip of the hook gauge such that it coincides with water surface and note the reading

on hook gauge scaleash1onu/s.

- **Observation:02**

1) Operate the control valves such that water flows over the weir to some height.
2) Again adjustt he tip of the hook gauge such that it coincides with watersurface and note the water level by means of hook gauge ash2.

- **Observation3:**

1) Note the time required for known rise of water level.
2) Keeping the length and width of the collecting tank as default values repeat the experiment by adjusting flow of water and hookgauge.

Calculation:

Theoretical discharge,Qt=1.705LH$^{3/2}$inm^3/secWhere,

L=Length of the wei measured parallel to width of channel in meters

H=Constant head over the crest on the upstream of channel in meters.H=(h2-

h1).

Actual discharge,Q=Internal plan area of collecting tank xrise in collecting tank/time of

collection(t)inm^3/sec.

Internal plan areaofthetank,A=LxB=Actual

discharge,Qa=AxH$_t$=

T=Time taken for

riseof10cms,H=Riseofwater(10cms)

Then,Co-efficientofdischargeCd=*Qa/Qt*=

- ## Graph:

Draw a graph between Q and H$^{3/2}$takingH$^{3/2}$on the x-axis.

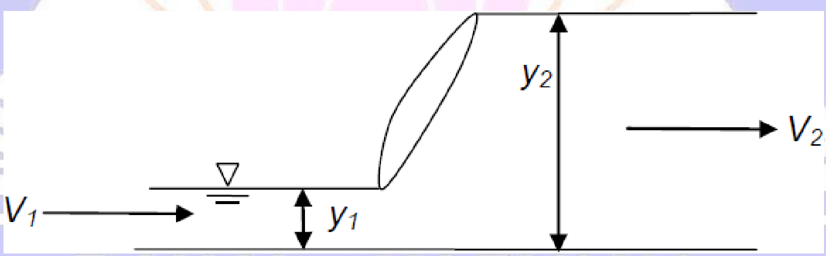
EXPERIMENTNO-0 5

- **AIM:** **To study the characteristics of a hydraulic jump on a horizontal floor and sloping glacis including friction blocks.**

- **THEORY:**

  - Hydraulicjump,alsoknownasastandingwave,isthesuddenriseofwaterlevelthattakesplaceduetothetransformationofunstable (supercritical)flowtostable(subcritical)flow.Hydraulicjumpoccurs whenever the depth of flow is less then the critical depth. The flow situations where the hydraulicjumpmayoccurare:Thechannelwidthissuddenlyincreasedordecreased,steepchannelbottomslopesuddenlychangetoaflatslope,flowbelowasluice,flowatthefootofaspillway,etc.

  - The flow in a hydraulic jump is rapidly varied and is accompanied by large scale turbulences, in which aportionoftheenergypossessedbytheflowingwatergetsdissipatedasheatenergy.Ifthisenergyisnotallowedtodissipate,itmaycausedamagestodownstreamprotectionworkornaturalerodiblebedofthechannel,causingdeepscourandsometimeevenfailureofthestructureconstructedonthechannel.Thephenomenon of hydraulic jump is used in the design of hydraulic structure as a mean of energy dissipationdevice. Consider hydraulic jump formation in a rectangular channel of unit width, take two section andimmediately before andafter theformation of jump.The depth beforejump at(say y1) is calledinitial depthorpre-jump.Afterthejumpaty2iscalledsequentdepthorpost-jumpdepth.



HydraulicJump

- Themomentumequationforhydraulicjumpinrectangularchannelandcanbeexpressedas

$$\frac{y2}{y1} = \frac{1}{2}\left(-1+\sqrt{1+8fr_1^2}\right) \quad \text{or} \quad \frac{y2}{y1} = \frac{1}{2}\left(-1+\sqrt{1+8fr_2^2}\right) \qquad \text{(i)}$$

Fr1 = incoming Froude s' number, i.e. Froude s number just before jump formation.Fr2 =

outgoing Froude s number, i.e. Froude s number just before jump formation.Fr1andFr2canbewrittenas

$$Fr1=\frac{q}{\sqrt{gy_1^3}} \quad andFr2=\frac{q}{\sqrt{gy_2^3}} \qquad (ii)$$

Specificenergybeforejump, $E1=y1+\frac{q^2}{2gy_2^2}$

Specificenergyafterjump, $E2=y_2+\frac{q^2}{2gy_2^2}$

Therefore,lossofenergy

$$\Delta E=(E1-E2)$$

Lossofenergycanalsobeexpressedas

$$\Delta E=\frac{(y1-y2)^3}{4y1y2} \qquad (iii)$$

Theheightofthejump(hj)isdefinedasthedifferencebetweenthedepthafterandbeforethejump,i.e.

$$hj=(y2-y1) \qquad (iv)$$

Lengthofthejump(Li)

$$Li=7hj \qquad (v)$$

- **EXPERIMENTALSETUP:**
- The set up consists of a recirculating and tilting rectangular flume. The sidewall of the flume are made of aglass and held between vertical angle iron posts fitted to a steel bottom. The flume has bell shape dentranceto minimize the separation of flow;two honeycomb wall at the in lettoen sure uniform flowanda

sluicegate.The in flow of water in the channel is controlled by using sluice gate provided at the entrance.A tail gate is provided at the downstream end of the flume. The flume has a two circular rail at top forpositioning the pointer gauges on wooden platforms and trolleys. Water is supplied to the flume through asupply valve (delivery valve) and a venturimeter are provided in the supply pipe for regulating andmeasuringthedischarge,respectively.

- **PROCEDURE:**

1. Start the pump and open the delivery valve gradually.
2. Adjust the delivery valve,sluice gate and the tail gate so that there forms stable hydraulic jumps in the flume.
3. Measure water depth at the prejump section and the post jump section.
4. Measure discharge by using venturimeter.
5. Repeat step(2)and(4) for other discharges by regulating the supply.

- **OBSERVATIONSANDCAMPUTATIONS:**

Widthofflume,B =

Pointergaugereadingatbed,y0 =

RunNo.	Discharge,q	y2/y1	Fr1	y2/y1	hj	Lj	E
1.							
2.							
3.							

- **GRAPH:**

1. Plot(y2/y1)versus Fr1on an ordinary graph paper. On the same plot, draw a liner epresented byEq.(IV) and

note the scatter of the observed data.

2. Plotagraph between hj andFr1.
3. Plotagraph between ΔE ANDFr1.

EXPERIMENTNO-06

- **AIM:** To study the scouring phenomen on around a bridge pier model
- **THEORY**:-

- **Bridge scouring** is the removal of sediment such ass and and rocks from around bridge a butment sorpiers .Scour, caused by swiftly movingwater,can scoopoutscour holes,compromising the integrity of structure. Bridge scour is oneof the three main causes of bridge failure. It has been estimated that 60% ofall bridge failures result from scour and other hydraulic related causes.

- Water normally flows faster around piers and abutments making them susceptible to local scour. At bridgeopenings, contraction scour can occur when water accelerates as it flows through an opening that isnarrower than the channel upstream from the bridge. Degradation scour occurs both upstream anddownstream from a bridge over large areas. Over long periods of time, this can result in lowering of thestreambed.

- Stream channel instability resulting in river erosion and changing angles-of-attack can contribute to bridgescour. Debris can also have a substantial impact on bridge scour in several ways. A build-up of materialcan reduce the size of the waterway under a bridge causing contraction scour in the channel. A build-up ofdebrisontheabutmentcanincreasetheobstructionareaandincreaselocalscour.Debriscandeflectthewaterflow,changingtheangleofattack,increasinglocalscour.Debrismightalsoshifttheentirechannelaround the bridge causing increased water flow and scour in another location. During flooding, although thefoundations of a bridge might not suffer damage, the fill behind abutments may scour. This type of damagetypicallyoccurswithsingle-spanbridgeswithverticalwallabutments.

- The examination process is normally conducted by hydrologists and hydrologic technicians, and involves areview of historical engineering information about the bridge, followed by a visual inspection. Information isrecorded about the type of rock or sediment carried by the river, and the angle at which the river flowstowardandawayfromthebridge.Theareaunderthebridgeisalsoinspectedforholesandotherevidenceof scour. Bridge examination begins by office investigation. The history of the bridge and any previousscour related problems should be notified. Once a bridge is recognized as a potential scour bridge, it willproceedtofurtherevaluationincludesfieldreview,scourvulnerabilityanalysisandprioritize.Bridgeswillalsoberated in different categories and prioritize for scour risk.Future implementation of scour counter measures includes monitoring plans, inspections after flood events, and procedures for closingbridges if necessary. Alternatively, sensing technologies are also being put in placefor scour assessment.The scour-sensing level can be classified into three levels: general bridge inspection, collecting limited dataand collecting detailed data. There are three different types of scour-monitoring systems: fixed, portableand geophysical positioning. Each system can help to detect scour damage in an effort to avoid bridge failure,thus increase public safety.Bend way weirs, spurs and guide banks can help to align the upstream flow while riprap, gabions,articulated concrete blocks and grout filled mattresses can mechanically stabilize the pier and abutmentslopes.Riprapremains the most common counter measure used to prevent scourat bridge abutments.Anumber of physical additions to the abutments of bridges can help prevent scour, such as the installation ofgabions and stone pitching upstream from the foundation. The addition of sheet piles or interlockingprefabricated concrete blocks can also offer protection. These countermeasures do not change the scouring flow and are temporary since the component sare known to move or be washed away in a flood.

- Trapezoidal-shaped channels through a bridge can significantly decrease *local scour* depths compared tovertical wall abutments, as they provide a smoother transition through a bridge opening. This eliminates abrupt corners that cause turbulent areas. Spur dikes, barbs, groynes, and vanes are river training structures that changes stream hydraulics to mitigate undesirableerosion or deposits.They are usually use don unstable stream channels to help redirect stream flow to more desirable locations through the bridge.The insertion of piles or deeper footings is also used to help strengthen bridges.

EXPERIMENTNO-07

- **AIM:** **To determine headloss due to various pipe fittings**

- **THEORY:**

- The losses of energy, or head, in full-flowing conduits can be classified into two components: (1) energy loss due to the frictional resistance of the conduit walls to flow,and(2)energy loss due to the pipefittings and appurtenances(e.g.,bends,contractions,andvalves).The latter is referred to as minor,orform,loss and is associated with a change in magnitude and/or direction of the flow velocity. Generally, the more abrupt the change,thehigher the associate denergy loss.For along pipeline(*L*/*D*>2000),the energyloss is predominantly associated with friction and minor losses are small.However,minor losses would comprise a considerable part of the total energy loss forasystemthat is relatively short and has a large number of fittings. Therefore, it is important for a designer to carefully consider both types of losses in the design of distribution systems.

To determine the head loss across a pipe appurtenance, consider the energy equation written between two sections:immediately before(1),and after(2)the pipe appurtenance

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_l \qquad \text{(i)}$$

where *z* is the elevation of the centerline of the pipe relative to an arbitrary datum, *V* is flow velocity, *g* is thegravitationalconstant,*p* is pressure at the centerline of the pipe, □ is the specific gravity of the fluid, and *hl* is the head loss between sections *1* and *2*. When only a short distance separates sections *1* and *2, hl* is adirect measure of minor loss. The velocities in equation (i) can be evaluated if the flowrate and pipe dimensions are known.If the pressure at sections *1*and*2* can be measured, the energy equation can then be used to evaluate the unknown headloss throught he pipe.

The energy loss that occurs through a pipefitting,is commonly expressed intermsof velocity head in the form

$$h_l = k\frac{V^2}{2g} \qquad \text{(ii)}$$

where K is the dimensionless minor loss coefficient for the pipe fitting, and V is the mean velocity of flowintothefitting.

Because of the complexity of flow through various fittings, K is usually determined by experiment. In this case,the head loss is calculated fromt woman ometer readings,taken before and after eachfitting, and Kisthen determinedas

$$k = \frac{\Delta h}{\frac{V^2}{2g}} \quad \text{(iii)}$$

- For contractions and expansions,an additional change in static pressure is experienced due to the change in pipe cross-sectional area through the enlargement and contraction. To eliminate the effects of this areachange on the measured head losses, this value should be added to the head loss reading for anenlargement,and subtracted from the headloss reading fora contraction.

For agate valve,pressure difference before and after a valve can be measured directly using a pressure gauge.This can be converted to an equivalent headloss using the equation.

- **Procedure:**

1. Open the bench valve, the gate valve and the flow control valve and start the pump to fill the test rig withwater.
2. Bleedair,ifpresent,fromthepressuretappointsandthemanometersbyadjustingthebenchandflowcontrolvalvesandair bleedscrew.
3. Check that all the manometer levels lie within the scale when all the valves are fully opened. Adjust thelevels,ifnecessary,usingtheairbleedscrewandthehandpump.
4. For a selected flow rate, record the reading from all the manometers (that are tapped before and aftereachappurtenance:enlargement,contraction,longbend,shortbend,elbow,miter)afterthewaterlevelshavesteadied.
5. Determine the flow rate by accumulating a fix volume of water in the volumetric tank with help of astopper. Use a digital stopwatch to record time and the sight window of the bench to find the volume ofwater.
6. Repeatsteps(4)and(5)fortwomoreflowrates.
7. Clamp off the connecting tube sto the miter bend pressure tappings (topreventairfrombeingdrawnintothesystem).Start with the gate valve fully close dand the bench valve and control valvefully open.Open the gate valve 50% of its total opening (after taking up any backlash). Record the gauge reading for the halfopencondition.
8. Adjust the flow rate with the control valve and measure pressure drop across the gate valve from the pressure gauge.Also,measure the volume flow rate by timed collection ofwater.
9. Repeat the step(8)for two more flow rates.

- **Results:**

1. Calculate headloss (hl)across the fittings for each flow rate in step(4)-(6).
2. Calculate the velocity head for each flow rate. Then calculate K for each bend using equation (iii); for thecontraction and the enlargement using equations (iii) and (iv); and for the gate valve using equations (iii)and(v).

3. For each pipe fitting ,plot head loss(*hl*)vs.$V^2/2g$,and *K*vs.volumetric flowrate,*Q*.
4. Discuss your results. Specifically, comment on whether it is justifiable to treat the loss coefficient as aconstant for a given fitting.