Fabrication and analysis of reynolds experiment setup

FABRICATION AND ANALYSIS OF REYNOLDS EXPERIMENT SETUP Mini Project Report Submitted in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Mechanical Engineering by SHRI HARSH (Roll No.: B060278ME) PRABHAKAR (Roll No.: B060264ME) RAVI KUMAR (Roll No.: B060225ME) ASHISH KUMAR (Roll No.: B060205PE) Department of Mechanical Engineering NATIONAL INSTITUTE OF TECHNOLOGY CALICUT CERTIFICATE This is to certify that the report entitled “ FABRICATION AND ANALYSIS OF REYNOLDS EXPERIMENT SETUP" is a bonafide report of the Mini Project done by SHRI HARSH (Roll No.: B060278ME), PRABHAKAR KUMAR(Roll No.: B060264ME), RAVI KUMAR (Roll No.: B060225ME) and ASHISH KUMAR(Roll No.: B060205PE) under my supervision, in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Mechanical Engineering from National Institute of Technology Calicut, and this work has not been submitted elsewhere for the award of a degree. Dr. R. VIJAYAKUMAR (Guide) Professor Dept. of Mechanical Engineering Professor & Head Dept. of Mechanical Engineering Place : NIT Calicut Date : 20TH APRIL 2009 ABSTRACT FABRICATION AND ANALYSIS OF REYNOLD’S EXPERIMENT SETUP. SIGNIFICANCE OF WORK The purpose of the project is to study the effect of Reynolds number, a dimensionless quantity, on pipe flow. Reynolds number aids in classifying the flow as laminar, transition or turbulent. OBJECTIVE OF THE WORK 1. 2. 3. The first objective of the project is fabrication of Reynolds experiment setup. The second objective is to find the critical velocity; that is, the velocity at which laminar flow changes to turbulent. The final objective is to experimentally determine the range of Reynolds’s number for laminar flow. METHODOLOGY The set up consist of an upper water reservoir to which water is continuously fed. The water level is kept constant by means of an overflow system, where excess water is allowed to leave at the top of the reservoir. From the bottom of the reservoir water is led to a straight pipe made of Plexiglas. The water is then led through a valve which is used to regulate the flow rate and further through a flow meter to measure the flow rate. Finally the water goes to the drain. To visualize the flow, a dye is injected in the bell mouth tube by a needle injector and its flow in the tube is monitored whether it is flowing in straight line or it is disturbed. CONTENTS 1. 1 1. 2 1. 3 Introduction Experiment setup requirements Description of work completed 1-3 4-5 5-10 CHAPTER 1 INTRODUCTION Purpose of experiment The purpose of this experiment is to illustrate the influence of Reynolds number on pipe flows. Reynolds number is a dimensionless quantity (the ratio of dynamic forces to viscous forces) that aids in classifying certain flows. For incompressible flow in a pipe, Reynolds number based on the pipe diameter, Re = V DÏ�/µ, serves well. Generally, laminar flows correspond to Re < D avg D 2100, transitional flows occur in the range 2100 < Re < 4000, and turbulent flows exist for Re D D > 4000. However, disturbances in the flow from various sources may cause the flow to deviate from this pattern. This experiment will illustrate laminar, transitional, and turbulent flows in a pipe. Background of experiment In fluid mechanics and heat transfer, the Reynolds number Re is a dimensionless number that gives a measure of the ratio of inertial forces (pV2 A) to viscous forces (µ VA/ L) and, consequently, it quantifies the relative importance of these two types of forces for given flow conditions. Reynolds numbers frequently arise when performing dimensional analysis of fluid dynamics and heat transfer problems, and as such can be used to determine dynamic similitude between different experimental cases. They are also used to characterize different flow regimes, such as laminar or turbulent flow: laminar flow occurs at low Reynolds numbers, where viscous forces are dominant, and is characterized by smooth, constant fluid motion, while turbulent flow occurs at high Reynolds numbers and is dominated by inertial forces, which tend to produce random eddies, vortices and other flow fluctuations. Reynolds number is named after Osborne Reynolds (1842—1912), who proposed it in 1883. Flow in Pipe For flow in a pipe or tube, the Reynolds number is generally defined as Where: - - is the mean fluid velocity in (SI units: m/s) D is the diameter (m) - - - - - µ is the dynamic viscosity of the fluid (Pa·s or N·s/m²) Î½ is the kinematic viscosity (Î½ = µ / Ï�) (m²/s) Ï� is the density of the fluid (kg/m³) Q is the volumetric flow rate (m³/s) A is the pipe cross-sectional area (m²) Flow in a Rectangular Duct - For shapes such as a square or rectangular duct (where the height and width are comparable) the characteristic dimension is called the 'hydraulic diameter, DH, defined as 4 times the cross-sectional area, divided by the wetted perimeter. (For a circular pipe this is exactly the diameter.): Flow in a Wide Duct For a fluid moving between two plane parallel surfaces (where the width is much greater than the space between the plates) then the characteristic dimension is the distance between the plates. Flow in an Open Channel For flow of liquid with a free surface, the hydraulic radius must be determined. This is the crosssectional area of the channel divided by the wetted perimeter. For a semi-circular channel, it is half the radius. The characteristic dimension is then 4 times the hydraulic radius (chosen because it gives the same value of Re for the onset of turbulence as in pipe flow.) Transition Reynolds number In boundary layer flow over a flat plate, experiments can confirm that, after a certain length of flow, a laminar boundary layer will become unstable and become turbulent. This instability occurs across different scales and with different fluids, usually when , where x is the distance from the leading edge of the flat plate, and the flow velocity is the 'free stream' velocity of the fluid outside the boundary layer. For flow in a pipe of diameter D, experimental observations show that for 'fully developed' flow, laminar flow occurs when ReD < 2300 and turbulent flow occurs when ReD > 4000. In the interval between 2300 and 4000, laminar and turbulent flows are possible ('transition' flows), depending on other factors, such as pipe roughness and flow uniformity). This result is generalized to non-circular channels using the hydraulic diameter, allowing a transition Reynolds number to be calculated for other shapes of channel. These transitions Reynolds numbers are also called critical Reynolds numbers, and were studied by Osborne Reynolds around 1895. Osborne Reynolds (1842-1912) Osborne was born in Belfast, Ireland on 23rd August where his father was Principal of the Collegiate School. But, he moved with his parents soon afterward to Dedham, Essex. His father worked as a school headmaster and clergyman, but was also a very able mathematician with a keen interest in mechanics. The father took out a number of patents for improvements to agricultural equipment. He began his schooling at Dedham when his father was headmaster of the school in that Essex town. After that he received private tutoring to complete his secondary education. He did not go straight to university after his secondary education, however, but rather he took an apprenticeship with the engineering firm of Edward Hayes in 1861. Reynolds, after gaining experience in the engineering firm, studied mathematics at Cambridge, graduating in 1867. As an undergraduate Reynolds had attended some of the same classes as Rayleigh who was one year ahead of him. As his father had before him, Reynolds was elected to a scholarship at Queens' College. He again took up a post with an engineering firm, this time the civil engineers John Lawson of London, spending a year as a practicing civil engineer. In 1868 Reynolds became the first professor of engineering in Manchester (and the second in England). Reynolds held this post until he retired in 1905. His early work was on magnetism and electricity but he soon concentrated on hydraulics and hydrodynamics. He also worked on electromagnetic properties of the sun and of comets, and considered tidal motions in rivers. After 1873 Reynolds concentrated mainly on fluid dynamics and it was in this area that his contributions were of world leading importance. He studied the change in a flow along a pipe when it goes from laminar flow to turbulent flow. In 1886 he formulated a theory of lubrication. Three years later he produced an important theoretical model for turbulent flow and it has become the standard mathematical framework used in the study of turbulence. His studies of condensation and heat transfer between solids and fluids brought radical revision in boiler and condenser, while his work on turbine pumps permitted their rapid development. A paper published in 1883 entitled " An experimental investigation of the circumstances which determine whether the motion of water in parallel channels shall be direct or sinuous and of the law of resistance in parallel channels" introduced what is now known as the 'Reynolds number', a variable commonly used in modeling fluid flow. Reynolds became a Fellow of the Royal Society in 1877 and, 11 years later, won their Royal Medal. In 1884 he was awarded an honorary degree by the University of Glasgow. By the beginning of the 1900s Reynolds health began to fail and he retired in 1905.

Not only did he deteriorate physically but also mentally, which was sad to see in so brilliant a man who was hardly 60 years old. Despite his intense interest in education, he was not a great lecturer. His lectures were difficult to follow, and he frequently wandered among topics with little or no connection. Lamb, who knew Reynolds well both as a man and as a fellow worker in fluid dynamics, wrote: - “ The character of Reynolds was like his writings, strongly individual. He was conscious of the value of his work, but was content to leave it to the mature judgment of the scientific world. For advertisement he had no taste, and undue pretension on the part of others only elicited a tolerant smile. To his pupils he was most generous in the opportunities for valuable work which he put in their way, and in the share of cooperation. “ He died on 21st February1912. Fluid Mechanics Reynolds most famously studied the conditions in which the flow of fluid in pipes transitioned from laminar flow to turbulent flow. From these experiments came the dimensionless Reynolds number for dynamic similarity – the ratio of inertial forces to viscous forces. Reynolds also proposed what is now known as Reynolds-averaging of turbulent flows, where quantities such as velocity are expressed as the sum of mean and fluctuating components. Such averaging allows for 'bulk' description of turbulent flow, for example using the Reynolds-averaged Navier-Stokes equations. His publications in fluid dynamics began in the early 1870s. His final theoretical model published in the mid 1890s is still the standard mathematical framework used today. Examples of titles from his more groundbreaking reports: - - Improvements in Apparatus for Obtaining Motive Power from Fluids and also for Raising or Forcing Fluids. (1875) An experimental investigation of the circumstances which determine whether the motion of water in parallel channels shall be direct or sinuous and of the law of resistance in parallel channels. (1883) On the dynamical theory of incompressible viscous fluids and the determination of the criterion. (1895) - Reynolds' contributions to fluid mechanics were not lost on ship designers (" naval architects"). The ability to make a small scale model of a ship, and extract useful predictive data with respect to a full size ship, depends directly on the experimentalist applying Reynolds' turbulence principles to friction drag computations, along with a proper application of William Froude's theories of gravity wave energy and propagation. Reynolds himself had a number of papers concerning ship design published in Transactions of the Institution of Naval Architects. Other works Reynolds published about seventy science and engineering research reports. When towards the end of his career these were republished as a collection they filled three volumes. Areas covered besides fluid dynamics included thermodynamics, kinetic theory of gases, condensation of steam, screw-propeller-type ship propulsion, turbine-type ship propulsion, hydraulic brakes, hydrodynamic lubrication, and laboratory apparatus for better measurement of Joule's mechanical equivalent of heat. Derivation of Reynolds Number The Reynolds Number plays a very significant role in dealing with the fluid mechanics which is based on the conservation of mass, momentum and energy. The Reynolds Number can be derived from the Constitutive Equation for Newtonian fluid and the Cauchy’s equation of motion for the Newtonian fluid. Cauchy’s equation of motion We know that stress at a point can be completely defined by the nine components of the stress tensor . Now; we consider an infinitesimal rectangular parallelepiped with faces perpendicular to the coordinate axis. On each face there is a normal stress and a shear stress, which can be further resolved into two components in the direction of the axes. The first index of indicate the direction of the normal to which to the surface on which the stress is considered, and the second index indicates the direction in which the stress acts. The diagonal elements , , and of the stress matrix indicate the normal stress and the off-diagonal elements are the tangential or the shear stress. We also can prove that the stress tensor is symmetric. i. e.; . We can deduce Cauchy’s equation from an integral statement of Newton’s law for a material volume V. The surface force on an area element dA is (dA. . Newton’s law for a material volume V requires that the rate of change of its momentum equals the sum of body forces throughout the volume, plus the surface force at the boundary. Therefore, ... (a) Where is over whole volume and is over whole area. Transforming the surface integral to a volume integral, the equation (a) becomes, = 0 Constitutive Equation for Newtonian fluid The relation between the stress and deformation in a continuum is called a constitutive equation. In a fluid at rest there are only normal components of stress on a surface, and the stress does not depend on the orientation of the surface. In other words, the stress tensor is isotropic or spherically symmetric. The only second-order isotropic tensor is Kronecker delta, Any isotropic second-order tensor must be proportional to the in a static fluid is isotropic, it must be of the form . Therefore, because the stress Where p is the thermodynamic pressure related to and T by the equation . A moving fluid develops additional components of stress due to viscosity. The diagonal terms of now become unequal, and shear stress develops. For a moving fluid, we can split the stress into a part, , that would exist if it were at rest and a part due to the fluid motion alone: The nonisotropic part gradient called the deviatoric stress tensor is related to the velocity . The velocity gradient tensor can be decomposed into symmetric and antisymmetric parts: The antisymmetric part represents fluid rotation without deformation, and cannot by itself generate stress. The stresses must be generated by the strain rate tensor alone. The deviatoric stress tensor depend on and Î». Î» The equation can be written as, Î» ....(b) The two scalar constants and Î» can be further related as follows. Setting i= j, summing over the repeated index, and noting that , we obtain Î» From which the pressure is found to be , ... (c) Now the diagonal terms of in a flow may be unequal. In such a case stress tensor can have unequal diagonal terms because of the presence of the term proportional to µ in equation (a). We can therefore take the average of the diagonal terms of and define the mean pressure as . Substitution into equation (b) gives For the incompressible fluid . as, . , therefore the constitutive equation takes the simpler form For a compressible fluid, we define stokes assumption Î»+ , as the coefficient of bulk viscosity. For the , the constitutive equation (b) reduces to, ... (d) This linear relation between and e is consistent with the Newton’s definition of viscosity coefficient in a simple parallel flow u (y) for which this equation gives a shear stress of . Therefore a fluid obeying this equation (d) is called a Newtonian Fluid. This is the Constitutive Equation for Newtonian fluid. Navier — Stokes Equation The equation for motion for a Newtonian fluid is obtained by substituting the constitutive equation into Cauchy’s equation to obtain . Where, we have noted that ………….. (3a) . . This is the general form of Navier — Stokes Equation. Viscosity in this equation can be a function of the thermodynamic state, and indeed , for the most fluids depend strongly on temperature, decreasing with T for liquids and increasing with T for gases. However, if the temperature differences are small within the fluid, then the derivative in the equation (3a), which then reduces to can be taken outside . = where, . . …………………. (3b) . , is the Laplacian of . For, the incompressible fluids . Navier — Stokes Equation, reduces to 0, and using vector notation, the (Incompressible) Obtaining Reynolds number The Reynolds number can be obtained when one uses the dimensional form of the incompressible Navier-Stokes equations: , (now, we are writing v in place of u and converting Du/Dt into its two parts, because D/Dt:-The total rate of change D/Dt is generally called the material derivative (also called the particle derivative) to emphasize the fact that the derivative is taken following a fluid element. It is made of two parts: âˆ‚ f/âˆ‚ t; local rate of change of F at a given point, and âˆ‚ f/âˆ‚ xi, is called the conductive derivative. In vector notation it is written as, .) Using the above relations, the Navier's stokes equations can be rewritten as, . Each term in the above equation has the units of a volume force or, equivalently, an acceleration times a density. Each term is thus dependant on the exact measurements of a flow. When one renders the equation non dimensional, that is we multiply it by a factor with inverse units of the base equation, we obtain a form which does not depend directly on the physical sizes. One possible way to obtain a non dimensional equation is to multiply the whole equation by the following factor: Where the symbols are the same as those used in the definition of the Reynolds number. If we now set: , . , . , , We can rewrite the Navier-Stokes equation without dimensions; â€². Where the term, â€² â€² . ; Finally, dropping the primes for ease of reading: . This is why mathematically all flows with the same Reynolds number are similar. Thus, we have been introduced with the Reynolds Number Re as, Where, Re is the Reynolds Number is the density of the fluid at room temperature. V is the average velocity of flow in the pipe. D is the diameter of the pipe. μ is the dynamic viscosity of fluid at the room temperature. Thus, we have been introduced with the dimensionless number called the Reynolds Number. The Practical Significance of the Reynolds Number - The similarity of flows In order for two flows to be similar they must have the same geometry, and have equal Reynolds numbers and Euler Number. When comparing fluid behavior at homologous points in a model and a full-scale flow, the following holds: Where, quantities marked with 'm' concern the flow around the model and the others the actual flow. This allows engineers to perform experiments with reduced models in water channels or wind tunnels, and correlate the data to the actual flows, saving on costs during experimentation and on lab time. - Reynolds number sets the smallest scales of turbulent motion In a turbulent flow, there is a range of scales of the time-varying fluid motion. The size of the largest scales of fluid motion (sometime called eddies) are set by the overall geometry of the flow. For instance, in an industrial smoke stack, the largest scales of fluid motion are as big as the diameter of the stack itself. The size of the smallest scales is set by the Reynolds number. As the Reynolds number increases, smaller and smaller scales of the flow are visible. In a smoke stack, the smoke may appear to have many very small velocity perturbations or eddies; in addition to large bulky eddies. In this sense, the Reynolds number is an indicator of the range of scales in the flow. The higher is the Reynolds number, the greater the range of scales. The largest eddies will always be the same size; the smallest eddies are determined by the Reynolds number. Explanation: - A large Reynolds number indicates that viscous forces are not important at large scales of the flow. With a strong predominance of inertial forces over viscous forces, the largest scales of fluid motion are undamped -- there is not enough viscosity to dissipate their motions. The kinetic energy must " cascade" from these large scales to progressively smaller scales until a level is reached for which the scale is small enough for viscosity to become important (that is, viscous forces become of the order of inertial ones). It is at these small scales where the dissipation of energy by viscous action finally takes place. The Reynolds number indicates at what scale this viscous dissipation occurs. Therefore, since the largest eddies are dictated by the flow geometry and the smallest scales are dictated by the viscosity, the Reynolds number can be understood as the ratio of the largest scales of the turbulent motion to the smallest scales. - Testing of Air- wing If an airplane wing needs testing, one can make a scaled down model of the wing and test it in a wind tunnel using the same Reynolds number that the actual airplane is subjected to. If for example, the scale model has linear dimensions one quarter of full size, the flow velocity would have to be increased four times to obtain similar flow behaviour. Alternatively, tests could be conducted in a water tank instead of in air (provided the compressibility effects of air are not significant). As the kinematic viscosity of water is around 13 times less than that of air at 15 °C, in this case the scale model would need to be about one thirteenth the sizes in all dimensions to maintain the same Reynolds number, assuming the full-scale flow velocity was used. The results of the laboratory model will be similar to those of the actual plane wing results. Thus there is no need to bring a full scale plane into the lab and actually test it. - Calculation of Drag Characteristics Reynolds number is important in the calculation of a body's drag characteristics. A notable example is that of the flow around a cylinder. Above roughly 3Ã—106 Re the drag coefficient drops considerably. This is important when calculating the optimal cruise speeds for low drag (and therefore long range) profiles for airplanes. - Reynolds number in physiology Poiseuille's law on blood circulation in the body is dependent on laminar flow. In turbulent flow the flow rate is proportional to the square root of the pressure gradient, as opposed to its direct proportionality to pressure gradient in laminar flow. Using the Reynolds equation we can see that a large diameter with rapid flow, where the density of the blood is high, tends towards turbulence. Rapid changes in vessel diameter may lead to turbulent flow, for instance when a narrower vessel widens to a larger one. Furthermore, an atheroma may be the cause of turbulent flow, and as such detecting turbulence with a stethoscope may be a sign of such a condition. - Reynolds number in viscous fluids Where the viscosity is naturally high, such as polymer solutions and polymer melts, flow is normally laminar. The Reynolds number is very small and Stokes Law can be used to measure the viscosity of the fluid. Spheres are allowed to fall through the fluid and they reach the terminal velocity quickly, from which the viscosity can be determined. - Laws of fluid friction Frictional resistance offered to the flow depends on type of flow. Different laws obey by the frictional resistance in laminar and turbulent flows. On the basis of experimental observation two types of laws may be narrated as follows: a) Laws of fluid friction for laminar flow: The frictional resistance in the laminar flow is…. 1) Proportional to velocity of flow, 2) Independent of pressure, 3) Proportional to area of surface in contact, 4) Independent of nature of surface in contact, 5) Greatly affected by variation in temperature of flowing fluid. The reason for frictional resistance in case of laminar flow being independent of nature of surface of contact is that when a fluid flow past a surface with velocity less than critical velocity, a film of almost stationary fluid is formed over the surface, which prevents the flowing fluid to come in contact with the boundary surface. In case of laminar flow resistance is due to viscosity only and the viscosity of fluid depends on its temperature. b) Laws of fluid friction for turbulent flow: The frictional resistance in case of turbulence flow is– 1) 2) 3) 4) 5) 6) Proportional to (velocity)â�¿, where index n varies from 1. 72 to 2. 00, Independent of pressure, Proportional to density of flowing fluid, Slightly affected by variation of the temperature of flowing fluid Proportional to area or surface in contact, Dependent on nature of surface in contact. EQUIPMENTS - - - - - Water supply tank with clear test section tube and " bell mouth" entrance. Dye injector with needle valve control for precision metering of dye. Measuring tank measure water flow rate. One bottle of dye. Laboratory instructions/notes. Work accomplished: - - - - - - - - - - Stand for holding measuring tank Measuring tank with scale and head measurement arrangement Bent tube for dye flow Bell mouth Dye holding tank. Transparent PVC pipe Dye Injector connection Collecting tank Water supply connection Final assembly DESCRIPTION OF WORK DONE IN DETAIL 1. MEASURING TANK. Dimensions: - 21. 5cm* 21. 5 cm* 81. 0 cm Tools required: - spanner, scale Materials required: - wood, elbow, M-seal, feviquick, metering scale Procedure:-We have a tank of dimension 21. 5*21. 5*81. 0 cm3; in which the water is supplied from the ground using a pump. The dye tank containing the dye is attached with the top part of the tank. To one of the vertical wall of the tank, bell-mouth tube is attached through an opening. The opening is a square 7*7 cm2. The centre of the square is 15 cm above the bottom of the tank. Around the opening, there are 4 holes of 8mm diameter to fix the Bell-mouth tube to the opening. The distance between the centers of the two opposite hole (holes to opposite edges of the square) is 10. 6 cm. To the adjacent wall outside surface the scale is fixed using a feviquick; to measure the head. The lower end of the scale is just above a hole, which is at one base corner. We have an iron elbow; having outer threading at one end; and a nut. Using a spanner the iron elbow and nut are tightened with the tank, having the iron elbow at the outer surface. To prevent leakage, these parts are completely sealed using M- seal. Glass pipe is fixed to the elbow with the help of a cork. Thus we have an adjustment for measuring the head of the tank Ideal Velocity corresponding to the head= 2 g h But the actual velocity is less than the ideal velocity. The actual velocity is Cd times the ideal velocity. 2. BELL MOUTH TUBE: Bell mouth tube is a cone type structure having smaller inlet diameter and large outlet diameter. We are using bell mouth tube for the connection of main tank to the transparent PVC (poly vinyl chloride) pipe. Transparent pipe is use for the purpose of view the flow, whether it is laminar/transition/turbulent. Here we are using bell mouth having inlet diameter 24mm and outlet diameter is 70mm. length is 110mm and slant length is 130mm. Suppose the maximum head = h cm. Material: GI sheet Dimensions: inlet dia.-24mm, outlet dia.-70mm, length-110mm Procedure:-For making bell mouth, first we made the development of the surface of bell mouth for the given dimension as indicated in figure. At one side of developed surface we left a margin of 5mm and 4mm. This margin is for making groove joint. At the other side we have left margin of 4mm for the same purpose. Now, we cut a piece of paper having size same as developed surface. A GI (galvanized iron) sheet having size same as developed surface is cut out from main sheet. By help of rammer the sheet is slowly folded in the shape of bell mouth. Then, we made groove at the both edge, and these groove attach and fix it properly using rammer. On the developing surface, we have taken a 7mm margin for making socket, as indicated in diagram. This socket is made at the larger diameter side, and makes it folded such that it is perpendicular to bell mouth axis. By the help of a joiner bell mouth tube is joined with the ¾ inch (20mm) transparent pipe. To avoid the leakage of water, joining of tube and pipe is fixed by using M-seal. M seal is taking at least 90 minute to set. There is a square hole in the main tank of size70mmx70mm. Inlet diameter of bell mouth is 70mm which is sufficient for the proper covering of hole so that when water flow through this opening, flow is not interrupted, and hence dye will not mix with water. Now we cut a rubber packing material of size such that it can completely cover the small holes made outside the square hole. We have used a rectangular GI sheet having same size of packing material and made four drill of 8mm diameter on the GI sheet so that this plate can be tight by using nut-bolt with main tank. Then, we made a hole of diameter 70mm at the centre of packing material and rectangular GI sheet so that water can flow out from main tank to the bell mouth and transparent pipe. We have kept the packing material on the main tank surface so the centre of hole of both, tank and packing material, comes in a line. Then, we placed the bell mouth tube on packing so that the holes of packing and bell mouth are aligned on the same line. At the middle of rectangular sheet we made a hole of diameter 70mm (i. e. same as inlet of bell mouth). Now, we kept it on the bell mouth so that proper fitting takes place. Packing material and GI sheet is fixed by tightening nut and volt on the main tank. To avoid leakage we pasted the M seal on the outer joint of tank and GI and also joined the joint of bell mouth and GI rectangular sheet. In this way, bell mouth is connected to transparent pipe with leakage proof setting. 3. STAND Purpose: - Main tank is mounted on the stand for proper holding of it and for steadily holding the transparent pipe in which the flow is seen. Materials required: - Angular strips, rectangular strips Tools and machines used: -Electric hacksaw, arc welding machine, scale Dimensions: - Height of stand: 80 cm, total length: 130 cm. Procedure: - We cut 4 angular strips of length 80 cm having a known cross- section, 4 angular strips of length 22. 5 cm having known cross-section, 4 flat strips of length 22. 5 cm having known cross- section using an electric hacksaw by proper clamping it to the hacksaw. Firstly to the four 80 cm legs, the 4 angular strips are welded to the upper end of the legs, thus forming a square. Similarly, 20 cm above the bottom end, the flat strips are welded forming a square. These welding are done using an electric arc welding. Then two rectangular strips 105 cm long are cut and welded to the initially made stand and to the other end of these rectangular strip two more angular legs of 80 cm height are welded. Now on these rectangular strips, 3 rectangular strips are welded of length 22. 5 cm and at equal intervals. On these vertical rods are welded to a height of bell mouth which form the support for the angular rod on which the transparent pipe is laid. Thus the complete stand for the apparatus is made. 4. COLLECTING TANK Purpose: - For collecting water and dye coming from the transparent pipe and the discharge, velocity and finding Reynolds number. measuring Dimensions: - 25 cm* 25 cm* 40 cm Tools required: - spanner, scale Materials required: - wood, elbow, M-seal, feviquick, metering scale Procedure:-We have a tank of dimension 25*25*. 40 cm3; in which the water is collected from the transparent pipe in which flow is seen. To the adjacent wall outside surface the scale is fixed using a feviquick; to measure the head. The lower end of the scale is just above a hole, which is at one base corner. We have an iron elbow; having outer threading at one end; and a nut. Using a spanner the iron elbow and nut are tightened with the tank, having the iron elbow at the outer surface. To prevent leakage, these parts are completely sealed using M- seal. Glass pipe is fixed to the elbow with the help of a cork. As the water is collected in the tank the level of water rises and can be seen in the glass tube attached outside. From this we can note the time taken for say a 5cm rise of height and thus the volume of water and discharge can be calculated. From this we can find the flow velocity and thus Reynolds number. 5. DYE TANK: Purpose:-Dye tank is used for storing dye that will help in the detection of laminar and turbulent flow. Size specification: cylindrical in shape with a base diameter of 7cm and height of 17 cm. Tools required: Hammer, edge folding machine. Material specification: G. I Sheet. Procedure: -We have taken a strip of G. I sheet of 24 cm length and 19 cm breadth. Then this strip is folded in circular form to form a cylindrical structure whose two ends are made to form a grove joint. Then the top edge is also folded so that top surface does not have a sharp edge. With the help of riveting and folding the bottom surface is attached to the cylinder and the dye tank becomes ready. Then it is stationed on top on the main tank and the point of injection of the needle is then injector is inserted in the bottom of the dye tank and this point it is then sealed with M- seal to prevent leakage of dye. In this way, we made the dye tank. 6. Connection of the main tank to the suction port The main tank is connected to the suction port using PVC pipe, in which a controlling valve is attached to control the flow rate to the main tank. Firstly, the cover of the inlet port is cut using a hacksaw. Then, the solvent cement is applied upto some length to outer surface of PVC pipe and the inner surface of the socket to fix them in the inlet port. The PVC pipe, socket and the controlling valve, all are of 25 mm diameter. The control valve is fixed to the PVC pipe at a height of 85 cm from the inlet port; using a solvent cement . At a height of 170 cm, the elbow is fixed to the PVC pipe using the solvent cement and a 10 cm pipe is horizontally fixed to the elbow. At the other end of that pipe, another elbow is fixed using the solvent cement. In that elbow, a PVC pipe is attached to the main tank. Thus, we get the connection of the main tank from the inlet port. 7. Transparent PVC pipe connection A transparent PVC pipe is used to check whether the flow is laminar, transition or turbulent. The pipe has diameter 3/4 inch and length 1 meter. This pipe has one end connection to the Bellmouth using the M-seal to prevent the leakage at that point. Another end is connected to a socket (coupler) which is connected to the outlet (tap). Since, the straightness of the pipe is very much important, therefore it is supported on an angular strip welded to the stand. The angular stand keeps the PVC pipe straight. Thus, we get the connection of the transparent PVC pipe from the main tank to the tap. 8. Needle Injector Needle injector is used to inject dye in to the transparent PVC pipe. For the flow of the dye through the injector, we have to keep dye tank at some height that we are giving by keeping it at the top of main tank. We are keeping the dye tank at constant height for constant dye flow. We have connected the needle injector to the bell-mouth tube. The dye flow pipe is of 3 mm diameter and 110 cm length. 9. Final Assembly For this experiment, we made separately the component such as dye tank, collecting tank, main tank, stand, bell mouth tube. After that, we joined the component in an appropriate way to prepare the whole apparatus for this experiment. First of all, we connect the inlet pipe to the inlet supply line with the help of solvent cement and inlet pipe consist of valve that will help to control the water supply and maintain constant water head during the experiment. From inlet pipe supply, we will get water in the main collecting tank. At the base of the dye tank, we made a hole of appropriate diameter, through which we connect a dye flow pipe. Dye flow pipe also have flow regulator, which will help to regulate the flow of dye. Dye flow pipe is connected to the dye flow injector which will inject the dye in to the tube. At the end of the one side of the tank, we made one square hole, at which we connect bell mouth tube, with the help of packing material. Bell mouth tube will help to prevent eddy current formation, which reduces the head during the experiment. On the other side of the bell mouth tube, we connected a transparent PVC pipe with the help of adhesive and M-seal. We made stand in such a way that will keep the pipe horizontal and linear. At the other end of the PVC pipe, we connected the pipe to the joiner, which is connected to the tap with the help of socket. From the tap, we collected the water at the collecting tank. Results and Analysis The experiment has been conducted on the Reynolds Experiment Set up after its fabrication. Each time the flow velocity is increased by controlling the outlet valve and the different parameters, like the Reynolds Number, the Discharge, the Velocity, the observed type of flow and the theoretical type of flow are noted down. And, the results are tabulated. The sample calculation used is as shown. OBSERVATION TABLE: Sl no. Volume Vâ‚€(ml) Time t(sec) Discharge Q (m3/sec) (X10) Velocity V (m/sec) (X10) Reynolds Number (Re) Observed Type of Flow Calculated Type of Flow 1. 2. 3. 4. 5. 6. 7. 8. 9. 210 200 210 240 220 350 370 400 430 21 18 14 15 13 15 13 13 12 10 11. 12 15 16 16. 92 23. 34 28. 46 30. 80 35. 83 3. 52 3. 92 5. 29 5. 64 5. 96 8. 23 10. 03 10. 86 12.

63 836 931 1256 1340 1415 1955 2382 2580 3000 laminar laminar laminar laminar transition transition laminar laminar laminar laminar laminar laminar turbulence transition turbulence transition turbulence transition 10. 450 12 37. 5 13. 22 3140 turbulence transition SAMPLE CALCULATION Volume, VO = 220ml Time, t= 13 sec (For set no. 5) Discharge= (volume/time) = (220ml/13 sec) = 16. 92*10-6 m3/sec Diameter of the pipe = 19 mm Cross-sectional area of the pipe, A= (Ï€/4) *D2= (Ï€/4)*(19*10-3)2 = 2. 835*10-4 m2 Velocity= (discharge/area) = (16. 92*10-6)/ (2. 835*10-6)= 5. 96cm/sec At 20 , At 30 , Ï�= 997kg/m3 Ï�= 995kg/m3 , , µ= 0. 799 10 µ= 1. 002 10 Ns /m2 Ns /m2 At Room Temperature= 26 , Î½ = (µ / Ï�) = 0. 8*10-6 Reynolds number= (Ï� v D/µ) = (VD/Î½) = (5. 96*10-2*19*10-3)/ (0. 8*10-6) = 1415 Here, Re= 1415 (Re is less than 2100). Hence, the calculated flow is LAMINAR and observed flow is also LAMINAR. So, the observed type of flow and the theoretical type of flow are the same in this case. Inference The observed Reynolds Number for the type of flow is not exactly coincident with the theoretical value of Reynolds Number, i. e. For the laminar flow because it should be < 2000 and it should be > 2000 for the turbulent flow. But, we are getting turbulent flow at the Reynolds Number which is less than 2000. The reason behind it may be followings……… 1. Surface Roughness Factor:- Here, we are using the PVC transparent pipe for the fluid flow whereas in the actual apparatus the glass pipe is used. Since, the PVC pipe is rough in comparison with the glass pipe, so the observed result may be deviated. 2. Constant overhead Factor: - For the constant overhead in the actual Reynolds Apparatus, the skim pipe is used. But, here we are not using the skim pipe. Instead, we are maintaining the constant overhead by maintaining the constant overhead by maintaining the flow velocity of the inlet and the

outlet to be same. This is causing some turbulence in the flow. This may be one of the reasons for the deviation in the observed type of flow from the theoretical flow. 3. Constriction in the flow at the inlet and outlet:- The connection at the Bell-mouth tube and the PVC transparent pipe, the coupler (joiner) used is of slightly lesser inner diameter than the diameter of the transparent PVC pipe. Similarly, at the outlet connection also, the connection is not purely perfect as per the original Reynolds Experiment Apparatus. So, the flow is not uniform. This may be another reason for the deviated type of flow than the theoretical type of flow. Difficulties in the Fabrication 1. For the dye flow pipe initially we were using the glass pipe. But, it had many difficulties like, (a) We could not find such a small diameter glass pipe. (b) The glass pipe could be easily broken and in fact it broke away. (c) It was difficult to fit the glass pipe because fitting required so much carefulness for preventing it from breakage. 2. For the dye tank, we used firstly the cuboid tank and then the cylindrical tank. But, it could not be made leak proof . So; we used finally the plastic bottle. 3. In making the Bell- mouth tube, we faced difficulty to give it the proper shape. It took so much time and also we had to make it again. 4. In making stand, we had to change the connections several times for keeping the PVC transparent pipe straight. Appendix A MANUAL FOR EXPERIMENT ON REYNOLDS NUMBER OBJECTIVE: to study the different type of flow. AIM: To determine the range of Reynolds number for different type of flow. THEORY: In Reynolds experiments the ratio of viscous force to inertia force was observed to be dimensionless and related to the viscosity, average pipeline velocity and geometrically similar boundary conditions. For a homogeneous Newtonian fluid, this dimensionless ratio is Re is expressed as: Re= Where: Ï�= Density of fluid (in kg/m3) V= average velocity of fluid flow in pipe (in m/sec) D= diameter of transparent glass tube (in m) µ= viscosity of fluid flow (Ns /m2) For laminar flow: Re4000 In transition state: 21004000 When the dye filament waves in Reynolds experiment, it indicates critical state of flow, and corresponding Reynolds number is called critical Reynolds number. And velocity of fluid flow in pipe corresponding to this critical condition is critical velocity. Re = 2100 is critical Reynolds number beyond which flow is transition and then becomes turbulent. Depending upon the relative magnitude of viscous forces, flow can occur in two different manners. A stream line flow is defined as a line, which lies in the direction of flow a every point a given instant. laminar flow is defined a flow in which stream line needs not be straight as the flow steady as long this criterion satisfied. This type of motion is also called stream line or viscous flow. If the Reynolds number is less than 2100, the motion is generally found not to be laminar throughout the channel. Eddies generated in the initial zone of instability spread rapidly throughout the fluid, thereby producing a disturbance of the entire flow pattern the result is flow becomes turbulence after some length of flow. Superimposed upon the primary motion of transition, producing what is called turbulence flow. APPARATUS DESCRIPTION: The apparatus consists of a transparent pvc pipe with one end having bell mouth entrance connected to water tank. At the other end of transparent pipe a tap is provided to vary the rate of flow. Flow rate of water can be measured with the help of a measuring beaker and stop watch supplied with the setup. A capillary tube is introduced centrally in the bell mouth, at the end of this a needle injector is attached. To this tube dye is fed from a small container, placed at the top of a constant head tank. UTILITIES REQUIRED: a) Water supply b) required chemical: dye (KMnOâ,„) c) collecting beaker (one litter) EXPERIMENTAL PROCEDURE: Clean the apparatus and make all tanks free from dust. Close the flow control tap given at the end of test section (i. e. transparent pipe). Fill the main tank with fresh water and ensure that no foreign particles are there. Prepare a dye solution (KMnOâ‚„) in clean water in a separate vessel. Close the control valve for dye, given on the capillary tube. Put this solution in dye vessel often ensuring that there are no foreign particles in solution. e) Regulate minimum flow of water through test section with the help of given valve attach at the end of transparent test pipe. Then adjust the flow of dye through capillary tube attach so that a fine color thread is observed indicating laminar flow. Increase the flow through test tube and observe the color thread, if it is still straight the flow still remains to be in laminar region and if waviness starts it is the indication that the flow is not laminar. f) Opening of valve at the end of test pipe is increase the, color thread is start breaking this is the condition of transition flow. a) b) c) d) g) If opening increase more dye completely mix with water this is turbulent flow. h) Measure the flow rate using measuring cylinder and stop watch. SPECIFICATION: Tube: material pvc, transparent, diameter ¾ inch, length= 1m Dye vessel: material galvanized iron sheet, capacity = 1 lire Water tank (main tank): capacity= 32 litre, height = 80cm Flow measurement: collecting beaker (1 litre), collecting tank (25 litre) Dye injector: capillary pipe with needle at the end. Supply: 25 mm diameter PVC hard pipe with connected valve at the middle, and net attach at the other end to distribute flow large area. FORMULAE: a) Discharge: â‚€ Q= Vâ‚€= volume collected in time t (in milliliter) t = time for collecting water (in second) Q= discharge through test pipe (in m3/sec) b) Average velocity of fluid in test pipe: V= A= cross-sectional area of test pipe (in m2) V= velocity (in m / sec.) c) Reynolds number: Re= Ï�= Density of fluid (in kg/m3) at room temperature V= average velocity of fluid flow in pipe (in m/sec) D= diameter of transparent test tube (in m) µ= viscosity of fluid flow (Ns /m2) at room temperature d) Kinematic viscosity of fluid: Î½= , Re = OBSERVATION TABLE: Sl no. Volume Vâ‚€(ml) Time t(sec) Discharge Q (m3/sec) (X10) Velocity V (m/sec) (X10) Reynolds Number (Re) Observed Type of Flow Calculated Type of Flow 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. Appendix B Properties of pure water at atmospheric pressure Here, Ï�= Density µ = Viscosity Î½ = Kinematic viscosity T (0 10 20 30 40 50) (Ï� kg/m3 1000 1000 997 995 992 988 µ (Ns /m2) 1. 787 E -3 1. 307 E -3 1. 002 E -3 0. 799 E -3 0. 653 E -3 0. 548 E -3 Î½ (m2/s) 1. 787 E-6 1. 307 E -6 1. 005 E -6 0. 802 E -6 0. 658 E -6 0. 555 E -6)