Laminar and Turbulent flow

A laminar flow is one in which paths taken by the individual particles do not cross one another and moves along well defined paths. It is also called stream line flow or viscous flow. eg Flow through capillary tube, flow of blood in veins and arteries and ground water flow.

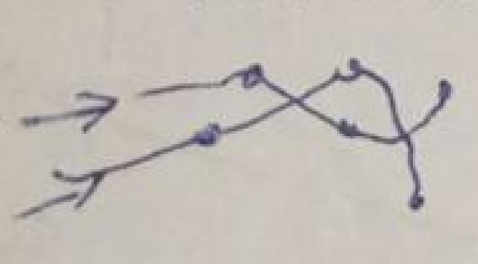
Turbulent flow is ~~one in wh~~ that flow in which fluid particles move in a zig-zag way. e.g high velocity flow in a conduit of large size. Nearly all fluid flow problems encountered in engineering practice have a turbulent characteristics.

Laminar and Turbulent flow are characterized on the basis of Reynolds number (Re)

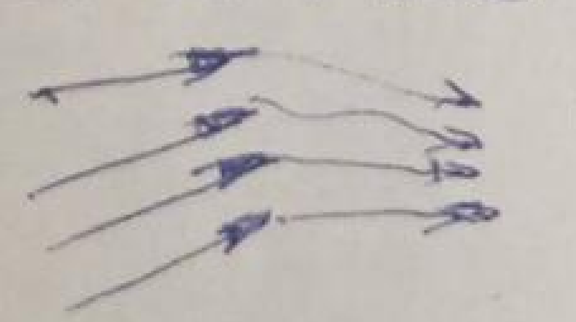
For Reynolds Number (Re) < 2000 flow in pipes is laminar
For Reynolds number (Re) > 4000 Flow in pipe is turbulent
For Reynolds number (Re) between 2000 and 4000 flow in ~~the~~ ~~pipe~~ Pipe could be laminar or turbulent.

Types of flow lines

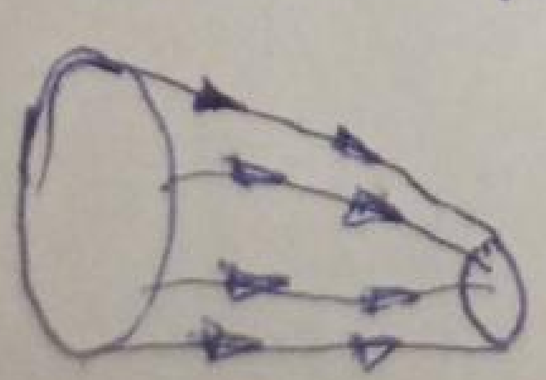
Path line: A path line is the path followed by a fluid particle in motion. It shows the direction of a particular particle as it moves ahead.



Stream line: May be define as an imaginary line within the flow so that the tangent at any point on it indicates the velocity at that point.



Stream tube: is a fluid mass bounded by a group of streamlines. The ~~content~~ contents of a stream tube is known as "current filament"



Streak line is a curve which gives an Instantaneous Picture of The location of the fluid particles, which have passed through a given point.

TYPES OF HEADS (OR ENERGIES) OF A LIQUID IN MOTION

There are 3 types of heads (energies) of flowing liquid

1. Potential head or Potential energy is the potential energy per unit weight of fluid with respect to an arbitrary datum of the fluid. It is denoted by Z is in J/N or m

2. Pressure head - This is due to ~~velocity~~ pressure of flowing liquid and is measure as P/w where P is ~~velocity~~ pressure of flow and w is ~~acceleration due to gravity~~ weight density of liquid. It is the pressure energy per unit weight of fluid. It represents the work done in pushing a body of fluid by fluid pressure P = J/N or m

3. Velocity head or Kinetic energy - This is due to the ~~Pressure~~ velocity of flowing liquid and is measure as $V^2/2g$ where V = velocity of flowing and g is acceleration due gravity is in J/N or m.

Total head or Total energy - Total head of a liquid particle in motion is the sum of its potential head, Kinetic head and Pressure head, Mathematically

$$\text{Total head } H = Z + \frac{V^2}{2g} + \frac{P}{w} \text{ m of liquid}$$

$$\text{Total energy} = Z + \frac{V^2}{2g} + \frac{P}{w} \text{ Nm/Kg of liquid}$$

QUESTION - In a pipe of 90mm diameter water is flowing with a mean velocity of 2m/s and at a gauge pressure of 350 KN/m². Determine the total head, if the pipe is 8 metres above the datum line neglecting friction.

Solution

Diameter of Pipe = 90mm

Pressure, $P = 350\ kN/m^2$

velocity of water, $V_1 = 2m/s$

Datum head $Z = 8m$

Specific weight of water $W = 9.81\ kN/m^3$

$$\text{Total head } (H) = Z + \frac{V^2}{2g} + \frac{P}{W}$$

$$= 8 + \frac{2^2}{2 \times 9.81} + \frac{350}{9.81}$$

$$\underline{H = 43.88m}$$

QUESTION

Water flows in a circular pipe. At one section the diameter is 0.3m, The static pressure is 260 kPa gauge, the velocity is 3m/s and the elevation is 10m above ground level. The elevation at a section down stream is 0m, and the pipe diameter is 0.15m. Find the gauge pressure at the downstream section. [Density of water = 999kg/m³]

Solution

$D_1 = 0.3m$

$D_2 = 0.15m$

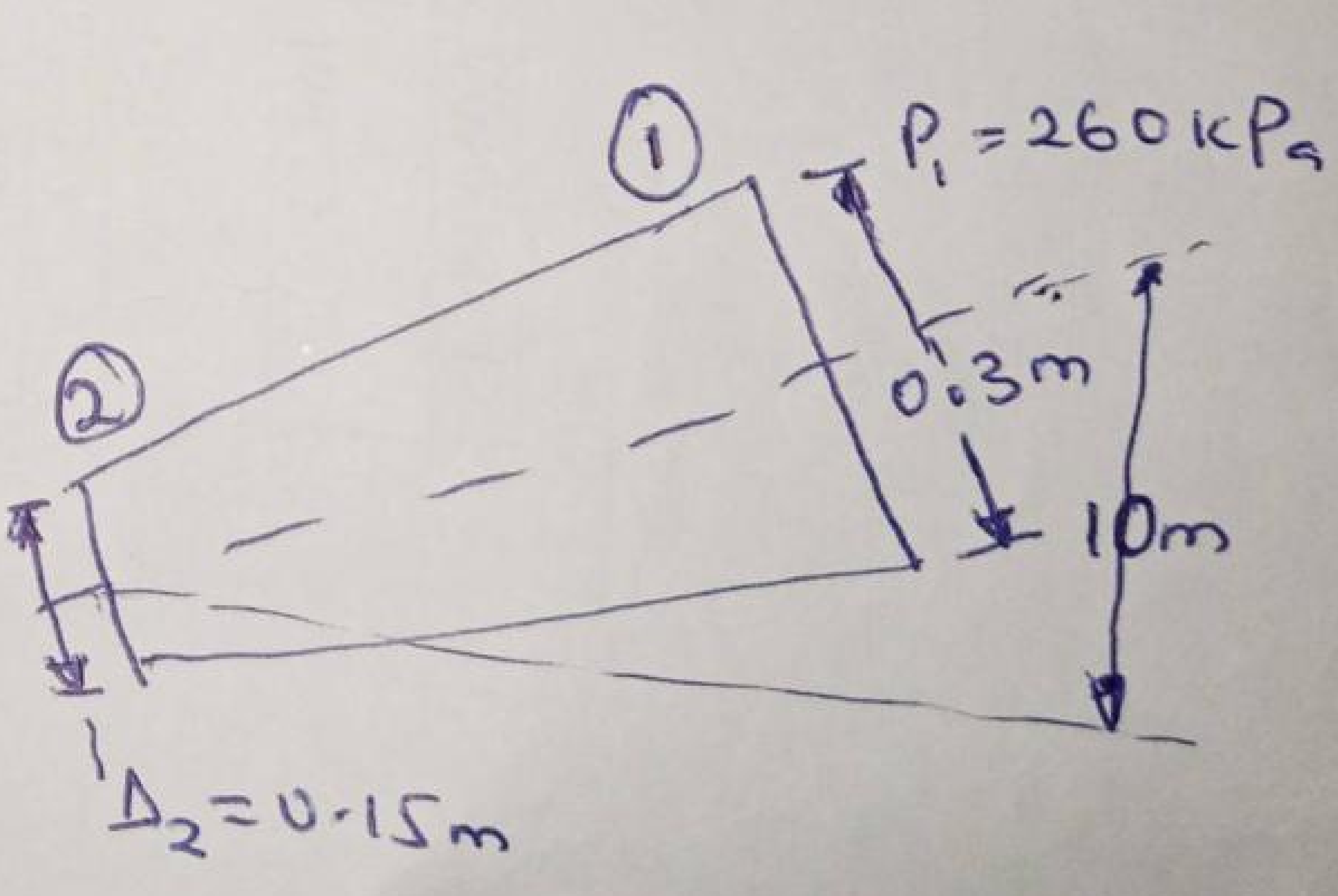
$Z_1 = 0$

$Z_2 = 10m$

$P_1 = 260\ kPa$

$V_1 = 3m/s$

$P = 999\ kg/m^3$



From continuity equation, $A_1 V_1 = A_2 V_2$

$$\therefore V_2 = \frac{A_1 V_1}{A_2} = \left(\frac{\frac{\pi}{4} D_1^2}{\frac{\pi}{4} D_2^2}\right) V_1$$

$$= \left(\frac{D_1}{D_2}\right)^2 \times V_1 = \left(\frac{0.3}{0.15}\right)^2 \times 3$$

$$= 12 \text{ m/s}$$

Weight density of water, $w = \rho g = 999 \times 9.81$

$$= 9800.19 \text{ N/m}^3$$

From Bernoullis equation between 1 and 2 section (neglecting friction effects as given) we have

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2$$

$$= \cancel{\frac{260 \times 1000}{9800.19} + \frac{(3)^2}{2 \times 9.81} + 10}$$

$$\frac{260 \times 1000}{9800.19} + \frac{(3)^2}{2.9.81} + 10 = \frac{P_2}{9800.19} + \frac{(12)^2}{2 \times 9.81} + 0$$

$$26.53 + 0.439 + 10 = \frac{P_2}{9800.19} + 7.34$$

$$\therefore P_2 = 290566 \text{ N/m}^2 = 290.56 \text{ kPa}$$

BERNOULLI'S EQUATION FOR REAL FLUID

The earlier equation was based on the assumption that fluid is non-viscous and therefore frictionless. Practically all fluids are real and not Ideal. and hence are viscous and therefore there are always some losses in fluid flows. The losses have to be taken into consideration in the application of Bernoulli's equation

For real fluid

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2 + h_L$$

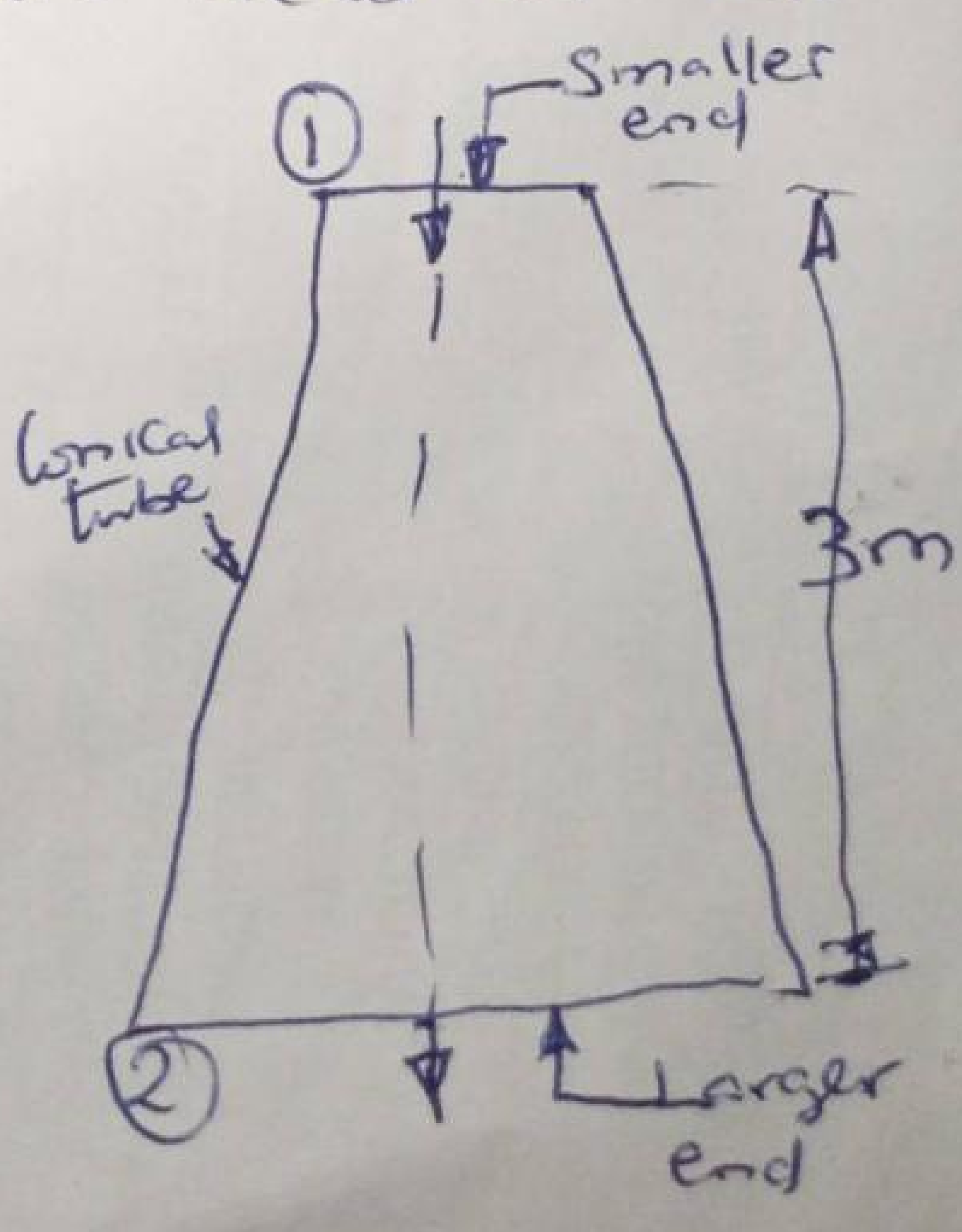
h_L = Loss of energy between section 1 and 2

QUESTIONS

The follow data relates to a conical tube of length 3.0m fixed vertically with its smaller end upwards and carrying fluid in the downward direction; The velocity of flow at the small end is 10m/s while at large end is 4m/s

$$\text{The loss of head in the tube} = \frac{0.4(V_1 - V_2)^2}{2g}$$

where V_1 and V_2 are velocities at the smaller and larger ends respectively. Pressure head at the ~~small end~~ small end is 4m of liquid. Determine the pressure head at the larger end.



Solution

Length of tube $l = 3.0m$

Velocity, $V_1 = 10m/s$

Pressure head, $\frac{P_1}{w} = 4m$ of liquid

Velocity, $V_2 = 4m/s$

$$\text{Loss of head } h_L = \frac{0.4(V_1 - V_2)^2}{2g} = \frac{0.4(10-4)^2}{2 \times 9.81}$$

$$= 0.73m$$

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Pressure head at The larger end, $\frac{P_2}{w}$

Applying Bernoulli's equation at sections (1) and (2)

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2 + h_L$$

Let the datum line passes through section 2

$\therefore Z_2 = 0, \quad Z_1 = 3.0 \text{ m}$

$$\therefore 4 + \frac{10^2}{2g} + 3 = \frac{P_2}{2} + \frac{4^2}{2g} + 0 + 0.73$$

$$= 4 + 5.09 + 3 = \frac{P_2}{w} + 0.815 + 0.73$$

$$= 12.09 = \frac{P_2}{w} + 1.54$$

$$= 12.09 - 1.54 = \frac{P_2}{w}$$

$$\therefore 10.55 = \frac{P_2}{w}$$

$$\therefore \frac{P_2}{w} = 10.55 \text{ m of liquid}$$