Fluid Statistics and Dynamics

Fluid Statistics:

Generally matter exists in three states. They are,

i) Solid
ii) Liquid &
iii) Gas

Although different in many aspects, liquids and gases have a common characteristic in which they differ from solids. The liquid and as together called by the common term "fluids".

A fluid is a substance which deforms continuously under the action of shear stress, in addition it has the following properties :

i) It is unable to retain any unsupported shape.
ii) It flows under its own weight and takes the shape of any solid body with which it contained.
iii) A fluid in equilibrium cannot sustain any shear.
iv) It cannot regain its original shape on the removal of the shear force.
v) Shear stresses occur in fluids only when they are in motion.
vi) Rate of strain is directly proportional to the applied stress.

Liquid and Gases :

Liquid

It is a fluid which possesses a definite volume. The volume may be varying slightly with change in temperature and pressure. Liquid can be compressed to a small extent. But for all practical purposes, it is regarded as incompressible,

Gas ;

It is fluid which has a tendency to expand and fill the container in which they are kept. they do not have any free surface.

It is compressible fluids. Even a slight change in temperature, it has a significant effect on its volume and pressure.

Some of the examples for fluids are water, air, hydrogen gas, honey, oil, paint, glycerin, blood etc.

Fluid mechanics is the branch of science which deals with the behavior of a fluid at rest as well as in motion.

The behavior of a fluid when it is at rest is called Fluid statistics.

The behavior of a fluid when it is in motion without considering pressure force is called as Fluid Kinematics.

The behavior of a fluid when it is in motion with considering pressure force is called Fluid dynamics.

Classification of fluids :

1. Ideal fluids & real or practical fluids.
2. Newtonian fluids and Non –Newtonian fluids.

Ideal Fluids ;

- It is incompressible
- It has zero viscosity
- Shear force is zero when the fluids is in motion (i.e.) No resistance is offered to the motion of any fluid particles.

Real or Practical Fluids :

- It is incompressible

- They are viscous in nature.
- Some resistance is always offered by the fluid when it is in motion.
- Shear stress always exists in such fluids.

Newtonian fluids. ;

In Newtonian fluids, a linear relationship exists between the magnitudes of shear stress τ and the resulting rate of deformation (du/dy) i.e. the constant of proportionalists μ does not change with the rate of deformation.

$$\tau = \mu \frac{du}{dy}$$

Ex : Water, Kerosene.

The viscosity at any given temperature and pressure is constant for a Newtonian fluid and is independent of the rate of deformation.

Non-Newtonian fluids.

In Non-Newtonian fluids, there is a non-linear relation b/w the magnitude of the applied shear stress and the rate of deformation. The viscosity will vary with variation in rate of deformation. They do not obey Newton's law of viscosity. These fluids can be further classified into 5 groups.

1. Simple non-newtonain
2. Ideal Plastic
3. Shear thinning
4. Shear thickening
5. Real Plastic

In plastics, there is no flowup to a certain value of shear stress. After this limit it has a constant viscosity at any given tempearature.

In shear thinning materials, viscoslty will increase with rate of deformation (du/dy)

In shear thickening materials viscosity will decrease with rate of deformation.

Example : Paint, toothpaste and printer's ink.

Fluid properties :

Mass density (p)

Mass density (p) is defined as the mass per unit volume (i.e). mass of the fluid contained in 1 m^3 volume.

Density, p = $\frac{Mass}{Volume} = \frac{m}{V}$ kg/m^3

It's unit is kg/m^3. Density decreases with increase in temperature and it increases with increase in pressure. The characteristic equation is used to estimate the density from the measurement of pressure, temperature and volume.

The characteristic equation is pV = mRT.

Density of water is 1000 kg/m^3 at a standard condition.

Specific Volume (V) :

It is defined as volume of fluid occupied by unit mass.

Specific Volume, v = $\frac{Volume}{Mass} = \frac{v}{m}$ = m^3/kg

The unit used is m^3/kg. It is the reciprocal of density.

Specific weight (W) :

It is defined as the weight possesses per unit volume. It is denoted by W. It varies from place to place because of acceleration due to gravity varies from place to place.

Specific weight, w = $\frac{Weight}{Volume} = \frac{W}{V}$ N/m^3

It decrease with increase in temperature and increases with increase in pressure. Mathematically

w = ρg

$\because$ w = $\frac{w}{v} = \frac{mg}{v}$ = ρg

It is also known as weight density.

Specific gravity (S) :

It is the ratio of specific weight of any fluid to the specific weight of the standard fluid. It can also be defined as the ratio of mass density of a fluid to the mass density of the standard fluid.

Specific gravity, S = $\frac{Specific\ weight\ of\ a\ given\ flu}{Specific\ weight\ of\ the\ standard\ f}$

or

S = $\frac{Mass\ density\ of\ the\ given\ fluid}{Mass\ density\ of\ the\ standard\ fluid}$

For liquids, the standard fluid chosen for comparison is pure water at 4°C. Specific gravity of water at 4°C is taken as 1.0.

For gases, hydrogen or air is chosen.

Specific weight of given liquid.

= Specific gravity of liquid x Specific weight of water

= S x 9.81 N/m^3

Density of the given liquid

= Specific gravity of liquid x Density of water

= S x 1000 kg/m^3

Surface Tension :

Due to molecular attraction, liquids have properties of Cohesion and adhesion.

Cohesion is due to the force of attraction between molecules of same liquid. Otherwise, the intermolecular attraction holds the liquid molecules together are known as cohesion. This force is very small. It enables the liquid to withstand a small tensile stress. Surface tension is due to cohesion between particles at the free surface.

Adhesion is defined as the force of attraction between the molecules of two different liquids or between the molecules of the liquid and molecules of the liquid and molecules of the solid boundary surface. This property enables a liquid to stick to over another body.

Surface tension is due to the force of cohesion between liquid particles at the free surface- liquid molecules at the interior of the liquid are generally free to move within the liquid and they move at random, because these molecules are attracted equally in all direction by the other surrounding molecules and they are in equilibrium. When they reach free surface, there are no molecules above the surface to balance the force of the molecules below it.

Surface tension is defined as the tensile force required to keep unit length of the surface film in equilibrium. It may also be defined as the tensile force acting on the surface of the liquid when in contact with a gas or surface between different immiscible liquids. The surface tension is same everywhere on the surface irrespective of its curvature and acts in the plane of the surface.

Some important real life examples are :

i) Formation of water bubbles.

ii) Formation of rain droplets

iii) Collection of dust particles on water surface.

iv) A small needle can gently placed on the liquid surface without sinking.

v) Break up of liquid jets.

vi) capillary rise and capillary siphoning.

Surface tension depends directly upon the intermolecular cohesion and hence the cohesion decreases with temperature rise, the surface tension also decreases with rise in temperature. It also depends upon the following factors.

i) Nature of the liquid.

ii) Nature of the surrounding liquid.

iii) Kinetic energy of the liquid.

1. Surface tension in liquid droplet.

p = $\frac{4\sigma}{d}$

where p – pressure inside the droplet above outside pressure.

s – surface tension of the liquid

d – Diameter of the droplet.

2. Surface tension in a soap bubble.

p = $\frac{8\sigma}{d}$

3. Surface tension on a liquid jet.

p = $\frac{2\sigma}{d}$

Capillarity :

Capillarity is a phenomenon of rise or fall of liquid surface relative to the adjacent general level of liquid. This phenomenon is due to the combined effect of cohesion and adhesion of liquid particle. The rise of liquid level is known as capillary rise whereas the fall of liquid surface is known as capillary depression.

It is expressed in terms of cm or mm of liquid.

The magnitude of capillarity is dependent upon

i) Diameter of tube

ii) Specific weight of liquid

iii) Surface tension of liquid.

Viscosity :

Viscosity is the property of a fluid which determines the amount of resistance to a shearing stress. A real fluid has no viscosity but it is non – existent.

Viscosity can also be defined as the property of a fluid due to which it offers resistance to the movement of one layer of fluid over another adjacent layer.

Viscosity increases with increase in temperature in case of gases whereas it decreases in case liquid.

Newton's Law of Viscosity ;

It states that the shear stress τ on fluid element layer is directly proportional to the rate of shear strain.

The constant of proportionally is called coefficient of viscosity.

$$\tau = \mu.\frac{du}{dy}$$

The fluids which follow this law is known as Newtonian fluids otherwise, it is known as Non-Newtonian fluids.

Dynamic Viscosity

The dynamic viscosity (μ) is defined as the shear stress required causing unit rate of shear deformation.

$$\mu = \frac{\tau}{\left(\frac{du}{dy}\right)}$$

Units of Viscosity :

In metric system, $\frac{dyne - sec}{cm^2}$ or 'poise'

1 poise = 1 gm/cm-sec.

Centipoise = $\frac{1}{100}$ poise

In SI units,

$\frac{N-s}{ms^2}$ or $\frac{kg}{m-s}$

1 poise = 0.1 $\frac{N-s}{m^2}$

1 $\frac{N-s}{m^2}$ = 10 poise

1 $\frac{kgf-s}{m^2}$ = 98.1 poise

Kinematic viscosity (v) :

It is defined as the ratio of dynamic viscosity to mass density.

v = $\frac{\mu}{p}$ m^2/s

Units :

In SI unit, m^2/sec

It is often measured in stokes.

1 stokes = $\frac{cm^2}{s}$ = 10-4 m^2/sec

1 Centistoke = $\frac{1}{100}$ stoke

In case of liquids, kinematic viscosity decreases with increase in temperature. In case of gases it increases with increase in temperature.

Relative or specific viscosity = $\frac{Dymanic\ \ viscosity\ \ of\ given\ fluid\ .}{Dynamic\ \ viscosity\ \ of\ water}$

Since water has a viscosity of 1, it is taken as standard substance for relative viscosity.

Problems :

1. Calculate the specific weight, mass density specific gravity and specific volume of oil having a volume of 4.5m^3 and weight of 40kN.

Solution :

Given :

Volume of oil = 4.5m^3

weight of oil = 40 kN = 40 x10^3 N

Specific weight

W = $\frac{Weig\,ht\ of\ oil}{Volume\ \ of\ oil}$

= $\frac{4 \text{ x } 10^3}{4.5}$

= 8.889 x 10^3 N/m^3

Mass density of oil :

p = $\frac{Specific\ \ weig\,ht\ of\ oil}{Acceleration\ \ due\ to\ gravity}$

p = $\frac{w}{g}$

p = $\frac{8.889\ x\ 10^3}{9.81}$

p = 906.1 kg/m^3

Specific gravity of oil

S = $\frac{Specific\ \ weig\,ht\ of\ oil}{Specific\ \ weig\,ht\ of\ water}$

= $\frac{8.889\ x\ 10^3}{9.81\ x\ 10^3}$

= 0.906

Specific volume of oil

V = $\frac{1}{p}$ = $\frac{1}{906.1}$

V = 1.1 x 10^{-3} m^3/kg

2. If a liquid has a viscosity of 0.051 poise and kinematic viscosity 0.14 stokes, calculate its specific gravity :

Solution :

Given :

Viscosity μ = 0.051 poise = 0.0051 Ns/m^2

Kinematic viscosity, γ = 0.14 stokes

= 0.14 x 10^{-4} m^2/sec

Kinematic viscosity :

$\gamma = \frac{\mu}{\rho}$

$\gamma = \frac{\mu}{\gamma} = \frac{0.0051}{0.14\ x\ 10^{-4}}$

p = 364.28 kg/m^3

Specific gravity :

S = $\frac{Density\ \ of\ liquid}{Density\ \ of\ water}$

= $\frac{364.28}{1000}$

S = 0.364

3. If a certain oil has density 1370 kg/m^3, shear stress of a point in oil of 0.354 N/m^2 and velocity gradient at that point is 0.23 per second. Calculate the kinematic viscosity.

Solution :

Given :

Density p = 1370 kg/m^3

Shear stress, τ = 0.354 N/m^2

Velocity gradient, $\frac{du}{dy}$= 0.23 s^{-1}

Shear stress, $\tau = \mu \frac{du}{dy}$

0.354 = μ x 0.23

μ = 1.539 x Ns/m^2

Kinematic viscosity :

$\gamma = \frac{\mu}{p} = \frac{1.539}{1370}$

$\gamma = 1.12 \; x \; 10^{-3} m^2 / \; sec.$

= 11.2 stokes.

4. Fstimate pressure inside a water droplet of 0.5 mm diameter. Assume σ = 0.073 N/m.

Pressure inside a water droplet.

$p = \frac{4\sigma}{d} = \frac{4 \; x \; 0.073}{0.5 \; x \; 10^{-3}}$

p = 584 N/m^2

5. A soap bubble of 60 mm diameter has a gauge pressure 2N/m^2. Estimate the surface tension of the soap bubble.

Solution.

Diameter of soap bubble, d = 60 mm = 0.06 m

Gauge pressure, p = 2N/m^2

For soap bubble, we know that

$p = \frac{8\sigma}{d}$

$2 = \frac{8\sigma}{0.06}$

σ = 0.015 N/m

Fluid Pressure :

Pressure may be defined as the force exerted on a unit area. It may be called as intensity of pressure. If F is the total force exerted over an area A. the pressure at any point is given mathematically as

$p = \frac{F}{A}$

Unit of pressure is SI unit is N/m^2 or Pascal.

Atmospheric pressure (Patm) :

It is the pressure exerted by the air on the atmosphere.

Its value taken at mean sea level is 1.01325 bar.

Atmospheric pressure = 1.01325 bar

= 101.325 kN/mm^2

= 101325 N/mm^2

= 760 mm of Hg

= 10.34 m of water

Gause pressure (p_s) :

It is the pressure recorded by the pressure gause when the pressure gauses reads 'zero' pressure at atmospheric level. Hence, they actually measure the difference between fluid and atmospheric pressure.

Vacum pressure (P_{vac}) :

The pressure below the atmospheric pressure is called as vacuum pressure. It is also called as negative pressure. The pressure gauge which is used to measure vacuum pressure is called vacuum gauge.

Absolute pressure (P_{abs}) :

The pressure measured from the absolute zero pressure is called absolute pressure.

$P_{abs} = P_{atm} + P_g$

$P_{abs} = P_{atm} + P_{vac}$

Pressure head :

The vertical height of the free surface above any point in a liquid at rest is known as pressure head.

$p = \frac{Force}{Unit\ area}$

$p = \frac{whA}{A} = wh$

where w = Specific weight of the liquid

h = Height of the liquid in the cylinder

pressure head $h = \frac{p}{w}$

1. Find the pressure exerted on a bottom of a container if the container is filled by water of height 3m.

solution :

Height of the water, h = 3m

pressure, p = wh = 9.81 x 3 = 29.43 kN/m^2

2. A mild steel plate is immersed in an oil of specific gravity 0.77 upto a depth of 1.75m. Determine the intensity of pressure on the plate due to oil.

Specific gravity = 0.77

Height of oil, h = 1.75m

Specific weight of the oil = Specific gravity of oil x specific weight of pure water

= 0.77 x 9.81 – 7.55 kN/m^3

Intensity of pressure.

p = w x h

p = 7.55 x 1.75

= 13.21 kN/m^2 or kPa

Fluid velocity and Acceleration :

Fluid kinematics is a science which deals with the geometry of motion in terms of displacement, velocity and acceleration and their distribution in space without considering any force or energy involved. Thus kinematics involves only the description of the motion of fluids in terms of space-time relationship.

How ever, it is possible to compute the pressure distribution from velocity distribution and then estimate the forces acting on the fluid.

There are two methods by which the motion of a fluid may be described. There are

1. Largrangian method
2. Eulerian method

Types of fluid flow :

1. Steady flow and unsteady flow
2. Uniform and non – uniform flow
3. One-dimensional, two-dimensional flow and three dimensional flow
4. Rotational and irrotational flows
5. Laminar flow and Turbulent flow
6. Compressible and Incompressible flows.

In steady flow, various characteristics of flowing fluids such as velocity, pressure, density, temperature etc. at a point do not change with time.

Example:

Flow of water in a pipeline due to a centriful pump run at uniform speed. In unsteady flow, various characteristics of flowing fluid such as velocity, pressure density etc. at a point change with respect to time.

Example:

•Liquid falling under gravity out of an opening in the bottom of a vessel.

•Wave movements in a sea.

Uniform flow is a fluid flow in which the velocity of any given instant does not change both in magnitude and direction with respect to space.

Example:

- Flow between parallel plates.
- Open channel flow.

In non-uniform flow, the velocity of flow of fluid changes from one point to another point at any instant.

Example:

- Flow in converging or diverging pipes.
- Vortex flow.

One dimensional flow is the type of flow in which the flow characteristics such as velocity, pressure, density, temperature etc. are function of time and one space coordinate only.

Example:

- Flow in a pipe where average flow parameters are considered for analysis.

•Two dimensional flow is the type of flow in which the flow characteristics are the function of time and two rectangular space co-ordinates.

Example:

- Flow b/w parallel plates of infinite-extent.
- Flow in mainstream of a wide river.

Three-dimensional flow is a type of flow in which the flow characteristics are the function of time and three mutually perpendicular directions.

Example:

- Flow in a converging or diverging pipe or channel.
- Flow in an open channel in which the width and the water depth are of the same order of magnitude

Rotational and Irrotational flow:

A rotational flow exists when the fluid particles rotate about their mass centres while moving along a streamline.

Examples:

- Liquid in a rotating tank where the velocity varies directly with distance from the centre.
- Flow near the solid boundaries.

An irrotational flow exists when the fluid particles do not rotate about their mass centers while moving along a streamline.

True irrotational flow exists only in case of flow of an ideal for which no tangential or shear stresses occur. But the flow may be assumed as irrotational if the velocity of fluid has little significance.

Example:

- A vortex or whirlpool, which develops above a drain in the bottom of a stationary tank.
- Flow above a drain hole of a washbasin.

Laminar and Turbulent flow:

A Laminar flow is one in which the fluid particles move in layers (or lamina) with one layer of fluid sliding smoothly over an adjacent layer fluid particles move in well-defitnited paths and they retain the same relative position at successive cross section of the flow passage. It is also called streamline flow or viscous flow. For development of lamina flow, the viscosity plays an important role. This type of flow occurs generally in smooth pipes when the velocity of flow is low and also, in liquids having high viscosity.

A turbulent flow is one in which the fluid particles move in an entirely haphazard or erratic manner. Fluid particles move in an unpredictable path that results in a rapid and continuous mixing of the fluid leading to momentum transfer as flow occurs.

Compressible and Incompressible flow:

Compressible flow:

A flow is said to be compressible if the density changes from point to point due to pressure and temperature.

Mathematically, $\rho \neq$ constant. The gases are readily compressible fluids where as the ideal fluids are incompressible.

Incompressible flow:

A flow is said to be incompressible it the density is constant in flow field. For all practical purposes, liquids can be regarded as incompressible, because the pressure and temperature changes have little effect on their volume.

Stream lines:

A streamline is an imaginary line drawn through a flowing fluid in such a way that the tangent at any point on it indicates the velocity at that point. The pattern of flow of fluid may be represented by a series of streamlines, since a fluid is composed of fluid particles.

Stream-tube:

A stream-tube is a tube imagined to be formed by a group of neighbouring streamlines passing through a small closed curve, which may or may not be circular.

The stream-tube has finite dimensions. Since the stream-tube is bounded on all sides by streamlines, these can be no flow across the bounding surface of a stream tube.

As there is no flow perpendicular to streamlines, there is no flow across the surface of the stream-tube. The shape of the stream-tube changes from one instant to another because of change in the position of streamlines.

Example:

Pipes and nozzles.

Streak line:

The streak line is a line that is traced by a fluid particle passing through a fixed point in a flow field. It gives an instantaneous picture of the position of the fluid particle.-that have passed through a fixed point in a flow field.

Example:

• The path traced by a smoke coming out of a man when smoking.

• The path of the smoke coming out of Chimney.

In steady flow, the streak line is same as streamline and path line of a particle since there is no change in the flow pattern i.e. in steady flow a streak line, a stream line and a path line are identical. For an unsteady flow, the streamline, streak line and path lines are all different.

Path line:

A path line is a line that is traced by a single fluid particle as it moves over a period of time. Path line shows the direction of velocity of the same fluid particle at successive Instants of time.

Reynold's Number:

The velocity at which the flow changes from the laminar to turbulent for the case of given fluid at a given temperature and given pipe is known as critical velocity. Inertia force

Reynolds number. Re = $\frac{\text{inertia force}}{\text{Viscous force}}$

It is dimensionless.

Continuity Equation:

$$\boxed{\rho_1 A_1 V_1 = \rho_2 A_2 V_2}$$

A - Area of cross section

V - Velocity of fluid

ρ - Density of fluid

Potential Function (ϕ):

The potential function or velocity potential (ϕ)(phi) is defined as a scalar function of space and time such that its negative derivative with respect to any direction gives the fluid velocity in that direction. Mathematically, for steady flow $\phi = f(x, y, z)$

$u = -\frac{\partial \phi}{\partial x}; v = -\frac{\partial \phi}{\partial y}; w = -\frac{\partial \phi}{\partial z}$

where u, v and w are the components of velocity in x, y and z directions respectively.

Stream Function (ψ):

The stream function ψ(psi) is defined as a scalar function of space and time, such that its partial derivative with respect to any direction gives the velocity component at right angles to this direction. Its differentiation with respect to x gives the velocity in y-direction (generally taken as -ve) and its differentiation with respect to y gives the velocity in x-direction.

Properties:

- If stream function (ψ) exists, it is a possibe case of fluid flow.
- If stream function (ψ) satisfies Laplace equation, it is a possible case of an irrotational flow.

Relation between stream function (y) and potential function (ϕ):

$$\frac{\partial \phi}{\partial x} = \frac{\partial \psi}{\partial y}$$

$$-\frac{\partial \phi}{\partial y} = \frac{\partial \psi}{\partial x}$$

These equations are known as Cauchy-Rieman equation.

FLOW DYNAMICS:

The science which deals with the geometry of motion of fluids without reference to the forces causing the motion is known as hydrokinematics or simply kinematics. The science deals with the action of the forces in producing or changing motion of fluids is known as hydrokinetics or simply kinetics. If the science deals both the kinematics and kinetics, it is known as fluid dynamics.

In this, the dynamic equation of fluid motion is obtained by applying Newton's law of motion to a fluid element considered as a free body. In this study, the fluid is assumed as incompressible and non-viscous.

Euler's Equation:

$$\frac{dp}{\rho} + vdu + g.dz = 0$$

Bernoulli's Equation from Euler's Equation:

$$\frac{P_1}{w} + \frac{v_1^2}{2g} + z_1 + \frac{v_2^2}{2g} + z_2$$

Bernoulli's equation relates velocity, pressure and elevation changes of a fluid in motion.

Statement: In an ideal, incompressible fluid when the flow is steady and continuous, the sum of pressure energy, kinetic energy and potential energy is constant along a streamline.

Mathematically,

$$\frac{P}{w} + \frac{v^2}{2g} + z = \text{constant}$$

where

$\frac{P}{w} \Rightarrow$ Pressure energy

$\frac{v^2}{2g} \Rightarrow$ Kinetic energy

$z \Rightarrow$ Datum energy

Pressure Losses along the flow:

Pressure loss has to be considered in the application of Bernoulli's equation for real fluids.

Applications of Bernauli's equation are orifice meter, venturimeter and pitot tube.

∴The Bernauli's equation for real fluids. vi

$$\frac{v_1^2}{2g} + \frac{P_1}{w} + z_1 = \frac{v_2^2}{2g} + \frac{P_2}{w} + z_2 + h_L$$

where h_L = loss energy for real fluids.

When a fluid flowing through a pipe, certain resistance is offered to the flowing fluid, which results in causing a loss of energy. The loss of energy is classified as

1. Major losses
2. Minor losses

Major Losses:

The major loss of energy is caused by friction in pipe. It may be computed by Darcy - Weisbach equation.

Head loss due to friction,

$h_f = \frac{4fLV^2}{2gD}$

where f = friction factor

$f = \frac{16}{Re}$ for Re<2000

Re = Reynolds number

L = Length of the pipe

V = Velocity of flow

D = Diameter of pipe

The major loss of energy may also be computed by Chezy's formula.

Chezy's formula is given as

$V = C_{\sqrt{mi}}$

Where V = Velocity of flow

C = Chezy's coefficient

$m = \frac{\text{Area of the pipe}}{\text{Wetted Perimeter}}$

$= \frac{A}{P} = \frac{\frac{\pi}{4}D^2}{\pi D} = \frac{D}{4}$

i = loss of head per unit length of pipe $= \frac{hf}{L}$

Minor Losses in pipe Flow:

1. Loss of energy due to sudden enlargement.
2. Loss of head due to sudden contraction.
3. Loss of energy at the entrance to the pipe.
4. Loss of energy at the exist from the pipe.
5. Loss of energy due to gradual contraction or enlargement.
6. Loss of energy due to an obstruction in a pipe.
7. Loss of energy in bends.
8. Loss of energy in various pipe fittings.

Flow through circular pipes - Poisseule's Equation

$p_1 - p_2 = \frac{32\mu vL}{D^2} = \frac{128\mu QL}{\pi D^4}$

Darcy's equation for loss of head due to friction in pipe:

$hf = \frac{4fLV^2}{2gD}$

where f - Darcy coefficient of friction.