R.M.K COLLEGE OF ENGINEERING AND TECHNOLOGY

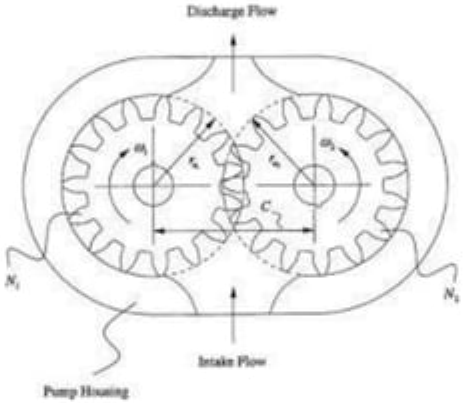
RSM NAGAR, PUDUVOYAL-601206

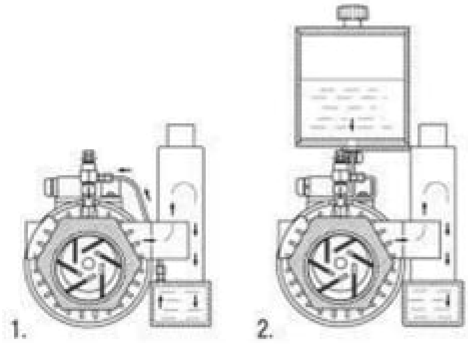
DEPARTMENT OF MECHANICAL ENGINEERING

CE6451 – FLUID MECHANICS & MACHINERY

III SEM MECHANICAL ENGINEERING

REGULATION 2013





ANNA UNIVERSITY

2 MARKS QUESTIONS & ANSWERS

PREPARED BY

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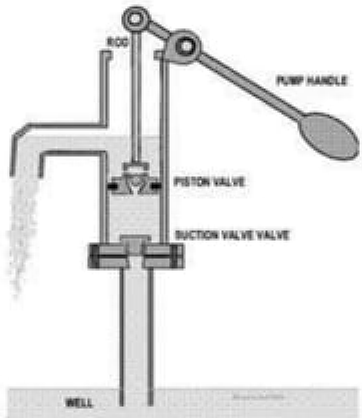


UNIT - I - FLUID PROPERTIES AND FLOW CHARACTERISTICS

1.1) Define fluid. Give examples. *[AU, Nov / Dec - 2010]*

A fluid is a substance which is capable of flowing. It has no definite shape.

1.2) How fluids are classified? *[AU, Nov / Dec - 2008, May / June - 2012]*

- Ideal and Real fluids
- Newtonian and Non – Newtonian fluids.

1.3) Distinguish between solid and fluid. *[AU, May / June - 2006]*

Solid	Fluid
❖ Solids have their own shape ❖ Solids are compressible ❖ They offer resistance to change in shape	❖ Fluids not have their own shape ❖ Fluids are incompressible ❖ They do not offer resistance to change in shape

1.4) Differentiate between solids and liquids. *[AU, May / June - 2007]*

Solid	Liquid
❖ Solids have their own shape ❖ Solids are compressible ❖ They offer resistance to change in shape	❖ Fluids not have their own shape ❖ Fluids are incompressible ❖ They do not offer resistance to change in shape

1.5) Discuss the importance of ideal fluid. *[AU, April / May - 2011]*

- Ideal fluid: a fluid with no friction
- Also referred to as an inviscid (zero viscosity) fluid
- Internal forces at any section within are normal (pressure forces)
- Practical applications: many flows approximate frictionless flow away from solid boundaries.
- Do not confuse ideal fluid with a perfect (ideal) gas.

1.6) Write the properties of ideal fluid *[AU, Nov / Dec - 2016]*

- Ideal fluid have no viscosity and surface tension
- Ideal fluid are incompressible
- Ideal fluid do not offer any resistance to deformation under shear stress

1.7) What is a real fluid? *[AU, April / May - 2003]*

- The fluid which posses viscosity is known as real fluid

1.8) Define Newtonian and Non – Newtonian fluids. *[AU, Nov / Dec - 2008]*

A real fluid, in which the shear stress is directly proportional to the rate of shear strain (or velocity), is known as **Newtonian fluid**

A real fluid, in which the shear stress is not proportional to the rate of shear strain (or velocity gradient), is known as **Non – Newtonian fluid**

1.9) What are Non – Newtonian fluids? Give example. *[AU, Nov / Dec - 2009]*

A real fluid, in which the shear stress is not proportional to the rate of shear strain (or velocity gradient), is known as **Non – Newtonian fluid**

Examples – Paint, Toothpaste and Printer's Ink

1.10) Differentiate between Newtonian and Non – Newtonian fluids.

[AU, Nov / Dec - 2007]

Newtonian fluid	Non – Newtonian fluid
❖ A real fluid, in which the shear stress is directly proportional to the rate of shear strain (or velocity gradient) ❖ Examples – Water & Kerosene	❖ A real fluid, in which the shear stress is not proportional to the rate of shear strain (or velocity gradient) ❖ Examples – Paint, Toothpaste and Printer's Ink

1.11) What is Thyxotrphic fluid? *[AU, Nov / Dec - 2003]*

The fluid which possess a definite yield stress but then the relationship between shear stress and angular deformation is non – linear are called as thixotrophic fluid. Example printer ink and lipstick

1.12) Define - Incompressible fluid. *[AU, Nov / Dec - 2014]*

A liquid is considered to be incompressible only when there is a change in volume of a liquid that occurs under smaller pressure variation.

1.13) Define Pascal's law. *[AU, Nov / Dec – 2005, 2008]*

The normal stress acting at a point in a fluid id independent of the orientation of the surface on which it acts.

1.14) Define mass density and weight density. *[AU, Nov / Dec - 2007]*

Mass density of the fluid is defined as the ratio of the mass of a fluid to its volume.

Weight density of a fluid is the ratio between the weight of a fluid to its volume

1.15) Distinguish between the mass density and weight density.

[AU, May / June - 2009]

Mass Density	Weight Density
❖ Mass density of the fluid is defined as the ratio of the mass of a fluid to its volume. ❖ The unit of mass density kg/m^3	❖ Weight density of a fluid is the ratio between the weight of a fluid to its volume ❖ The unit of mass density N/m^3

1.16) Define the term specific volume and express its units.

[AU, April / May - 2011]

Specific volume is defined as the volume of a fluid occupied by a unit mass or volume per unit mass of the fluid. The unit of specific volume is m^3/kg.

1.17) Define specific weight and density. *[AU, May / June - 2012]*

Density of the fluid is defined as the ratio of the mass of a fluid to its volume.

Specific Weight of a fluid is the ratio between the weight of a fluid to its volume

1.18) Define density and specific gravity of a fluid. *[AU, Nov / Dec - 2012]*

Density of the fluid is defined as the ratio of the mass of a fluid to its volume.

Specific gravity is defined as the ratio of the weight density of a fluid to the weight density of the standard fluid.

1.19) What is specific weight and specific gravity of a fluid?

[AU, April / May - 2010]

Specific Weight of a fluid is the ratio between the weight of a fluid to its volume

Specific gravity is defined as the ratio of the weight density of a fluid to the weight density of the standard fluid.

1.20) What is specific gravity? How is it related to density?

[AU, April / May - 2008]

Specific gravity is defined as the ratio of the weight density of a fluid to the weight density of the standard fluid.

The density of a liquid = Specific gravity of the liquid * weight density of water

1.21) Define specific gravity of fluid. *[AU, Nov / Dec - 2016]*

Specific gravity is defined as the ratio of the weight density of a fluid to the weight density of the standard fluid.

1.22) What is viscosity? What is the cause of it in liquids and in gases?

[AU, Nov / Dec - 2005]

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

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

1.23) Define viscosity and what is the effect due to temperature on liquid and gases.

[AU, April / May - 2017]

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

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

1.24) Define Viscosity and give its unit. *[AU, Nov / Dec 2003]*

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid. Unit for viscosity is $\frac{NS}{m^2}$

1.25) Define Newton's law of viscosity. *[AU, Nov / Dec - 2012]*

The shear force acting between two layers of fluid is proportional to the difference in their velocities and the area is inversely proportional to the distance between two plates.

1.26) State the Newton's law of viscosity.

[AU, April / May, Nov / Dec - 2005, May / June - 2007]

The shear force acting between two layers of fluid is proportional to the difference in their velocities and the area is inversely proportional to the distance between two plates.

1.27) Define Newton's law of viscosity and write the relationship between shear stress and velocity gradient? *[AU, Nov / Dec - 2006]*

The shear force acting between two layers of fluid is proportional to the difference in their velocities and the area is inversely proportional to the distance between two plates.

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

1.28) What is viscosity and give its units? *[AU, April / May - 2011]*

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid. Unit for viscosity is $\frac{NS}{m^2}$

1.29) Define coefficient of viscosity. *[AU, April / May - 2005]*

The Newton's law of viscosity states theta the shear stress on a fluid element layer is directly proportional to the rate of the shear strain. The constant of proportionality is called the coefficient of viscosity

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

1.30) Define coefficient of volume of expansion. *[AU, Nov / Dec - 2012]*

Coefficient of volume of expansion is defined as the amount of expansion (or contraction) per unit length of a material resulting from one degree change in temperature

1.31) Define relative or specific viscosity. *[AU, May / June - 2013]*

It is the ratio of dynamic viscosity of fluid to dynamic viscosity of water at 20° C.

1.32) Define kinematic viscosity. ***[AU, Nov / Dec - 2009]***

The kinematic viscosity is defined ratio between the dynamic viscosity and density of the fluid.

1.33) Define kinematic and dynamic viscosity. ***[AU, May / June - 2006]***

The **Kinematic Viscosity** is defined ratio between the dynamic viscosity and density of the fluid.

The **Dynamic Viscosity** is defined as the shear stress required to produce unit rate of shear deformation.

1.34) Define dynamic viscosity. ***[AU, Nov / Dec - 2008, May / June - 2012]***

The **Dynamic Viscosity** is defined as the shear stress required to produce unit rate of shear deformation.

1.35) What is kinematic viscosity? State its units? ***[AU, May / June - 2014]***

The **Kinematic Viscosity** is defined ratio between the dynamic viscosity and density of the fluid. The unit of kinematic viscosity is m^2/sec and also known as stoke.

1.36) Define the terms kinematic viscosity and give its dimensions.

[AU, May / June - 2009]

The **Kinematic Viscosity** is defined ratio between the dynamic viscosity and density of the fluid. The unit of kinematic viscosity is m^2/sec and also known as stoke.

1.37) Differentiate between kinematic viscosity of liquids and gases with respect to pressure. ***[AU, Nov / Dec - 2013]***

For liquids, the kinematic viscosity is practically independent of pressure. For gases, the kinematic viscosity is inversely proportional to density and thus pressure since the density of a gas is proportional to its pressure.

1.38) What is the importance of kinematic viscosity? ***[AU, Nov / Dec - 2014]***

Kinematic viscosity is the only fluid property will relate density and absolute viscosity. As the Gases are compressible, viscosity of gases should be specified through kinematic viscosity rather than Absolute viscosity. Also the kinematic viscosity value of any fluid will be for a standard temperature & pressure (STP) not like absolute viscosity. Hence Kinematic viscosity is an important property of any fluid

1.39) Write the units and dimensions for kinematic and dynamic viscosity.

[AU, Nov / Dec - 2005]

The unit of kinematic viscosity is **m^2/sec** and also known as **stoke**.

The Unit for dynamic viscosity is $\frac{NS}{m^2}$

1.40) What are the units and dimensions for kinematic and dynamic viscosity of a fluid? *[AU, Nov / Dec - 2006, 2012]*

The unit of kinematic viscosity is **m^2/sec** and also known as **stoke**.

The Unit for dynamic viscosity is $\frac{NS}{m^2}$

1.41) Differentiate between kinematic and dynamic viscosity.

[AU, May / June - 2007, Nov / Dec – 2008, 2011]

Kinematic Viscosity	Dynamic viscosity
❖ The **Kinematic Viscosity** is defined ratio between the dynamic viscosity and density of the fluid. ❖ The unit of kinematic viscosity is **m^2/sec** and also known as **stoke**. ❖ It is concerned with length and time only	❖ The **Dynamic Viscosity** is defined as the shear stress required to produce unit rate of shear deformation. ❖ The Unit for dynamic viscosity is $\frac{NS}{m^2}$ ❖ It is not concerned with length and time only

1.42) How does the dynamic viscosity of liquids and gases vary with temperature?

[AU, Nov / Dec - 2007, April / May - 2008]

Dynamic Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

Dynamic Viscosity increases with increase in temperature in case of gases whereas it decrease in case of liquid

1.43) What are the variations of viscosity with temperature for fluids?

[AU, Nov / Dec - 2009]

Viscosity decrease when there is increase in temperature of a fluid.

1.44) Why is it necessary in winter to use lighter oil for automobiles than in summer? To what property does the term lighter refer? ***[AU, Nov / Dec - 2010]***

Oil will congeal in the winter by making the engine and transmission system stiff during winter. This will lead to consume more power from battery. It will be difficult to start the car with less battery power. The use of lighter will remain more fluid than heavy oil during winter. The term lighter refers to specific gravity of oil which indirectly relates with density. The lighter oil has specific gravity less than unity.

1.45) Explain the variation of viscosity with temperature. ***[AU, Nov / Dec - 2015]***

The viscosity of liquid decreases when the temperature increases, while the viscosity of gases increases with the increase in temperature. This is due to the viscous forces, cohesive forces and molecular momentum transfer.

In liquids the cohesive forces more important than the molecular momentum transfer, due to closely molecules and with the increases in temperature, the cohesive forces decreases with the result of decreasing viscosity.

For Liquids:

$$\mu = \mu_0 \left(\frac{1}{1 + At + Bt^2}\right)$$

Where μ – Viscosity of liquids at t°C, in poise

μ_0 – Viscosity of liquids at 0°C, in poise

A & B – Constants of liquid

1.46) Brief on the effect of temperature on viscosity in gases.

[AU, May / June - 2016]

The gas viscosity will increase with temperature. According to the kinetic theory of gases, viscosity should be proportional to the square root of the absolute temperature, in practice, it increases more rapidly.

1.47) Write down the effect of temperature of viscosity of liquids and gases.

[AU, Nov / Dec - 2016]

The viscosity of liquid decreases when the temperature increases, while the viscosity of gases increases with the increase in temperature. This is due to the viscous forces, cohesive forces and molecular momentum transfer.

In liquids the cohesive forces more important than the molecular momentum transfer, due to closely molecules and with the increases in temperature, the cohesive forces decreases with the result of decreasing viscosity.

But in gases, molecular transfer is more important than the cohesive forces. Molecular momentum transfer increases with the increases in temperature and hence viscosity of the gases increases

For Liquids:

$$\mu = \mu_0 \left(\frac{1}{1 + At + Bt^2}\right)$$

Where μ – Viscosity of liquids at t°C, in poise

μ_0 – Viscosity of liquids at 0°C, in poise

A & B – Constants of liquid

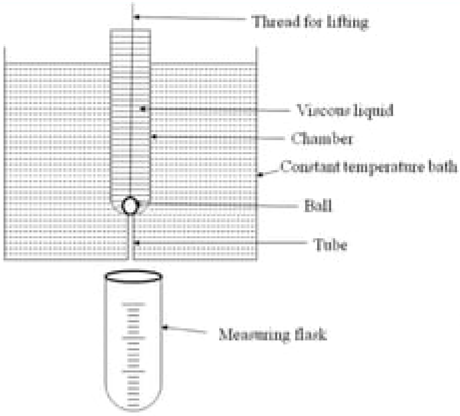
For Gases:

$$\mu = \mu_0 + \alpha t - \beta t^2$$

Where α & β – Constants of gas

1.48) How does Redwood viscometer work? ***[AU, May / June - 2016]***

A Redwood viscometer works on principle of vertical gravity flow of a viscous liquid through a capillary tube. It has a vertical cylindrical chamber filled with liquid whose viscosity is to be measured. It is surrounded by a constant temperature bath and a capillary tube (length 12mm and diameter 1.75mm) is attached vertically at the bottom of the chamber. For measurement of viscosity, the orifice at the bottom of the tube is opened and time for 50ml of liquid to flow is noted. The value of viscosity of the liquid may be obtained by comparison with value of time for the liquid of known viscosity.



1.49) Define the term pressure. What are its units? ***[AU, Nov / Dec - 2005]***

Pressure is an expression of force exerted on a surface per unit area. The standard unit of pressure is the Pascal.

1.50) Define eddy viscosity. How it differs from molecular viscosity? ***[AU, Nov / Dec - 2010]***

Eddy viscosity is defined as the turbulent transfer of momentum by eddies giving rise to an internal fluid friction with respect to the action of molecular viscosity in laminar flow much large scale.

But molecular viscosity is transfer of mass motion momentum alone by random motion of individual molecules.

1.51) Define surface tension. ***[AU, May / June - 2006]***

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.

1.52) Define surface tension and expression its unit. ***[AU, April / May - 2011]***

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension. The unit is N/m.

1.53) Define capillarity. ***[AU, Nov / Dec - 2005, May / June - 2006]***

Capillarity is defined as phenomenon of rise or fall of a liquid surface in the small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid.

1.54) Define capillarity and surface tension. *[AU, Nov / Dec - 2015]*

Capillarity is defined as phenomenon of rise or fall of a liquid surface in the small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid.

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.

1.55) What is meant by vapour pressure of a fluid? *[AU, April / May - 2010]*

The vapour molecules get accumulated in the space between the free liquid surface and top of the vessel. These accumulated vapour exerts a pressure on the liquid surface. This pressure is known as vapour pressure.

1.56) Brief on the significance of vapour pressure. *[AU, Nov / Dec - 2014]*

Vapour pressure is the only property of a liquid responsible for cavitation phenomena. For any temperature there should be a vapour pressure, so, during the fluid motion at ambient temperature, if any obstructions are there results to sudden increase in pressure. This leads to achieve the vapour pressure and convert the portion of liquid into high intensity gas bubbles causes to cavitation.

1.57) What do you mean by capillarity? *[AU, Nov / Dec - 2009]*

Capillarity is phenomenon of rise or fall of a liquid surface in the small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid.

1.58) Define compressibility of the fluid.

[AU, Nov / Dec – 2008, May / June - 2009]

Compressibility is the property by virtue of fluid undergoes a change in volume under the action of external pressure. It is the reciprocal of bulk modulus.

1.59) Define compressibility and viscosity of a fluid. *[AU, April / May - 2005]*

Compressibility is the property by virtue of fluid undergoes a change in volume under the action of external pressure. It is the reciprocal of bulk modulus.

Viscosity is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.

1.60) Define coefficient of compressibility. *[AU, Nov / Dec - 2010]*

Coefficient of compressibility is defined the decrease in volume per unit volume of a substance resulting from a unit increase in pressure

1.61) List the components of total head in a steady, in compressible irrotational flow. *[AU, Nov / Dec - 2009]*

- Pressure Head (Dynamic Head)
- Kinetic Head
- Potential Head

1.62) Define the bulk modulus of fluid. *[AU, Nov / Dec - 2008]*

Bulk modulus is defined as ratio of change in pressure to rate of change in volume due do change in pressure.

1.63) Define - compressibility and bulk modulus. *[AU, Nov / Dec – 2011]*

Compressibility is the property by virtue of fluid undergoes a change in volume under the action of external pressure. It is the reciprocal of bulk modulus.

Bulk modulus is defined as ratio of change in pressure to rate of change in volume due do change in pressure.

1.64) Differentiate between the steady and unsteady flow.

[AU, May / June - 2006]

Steady flow	Unsteady flow
❖ Steady flow is defined as that type of flow which the fluid characteristics like velocity, pressure, density at a point do not change with time	❖ Unsteady flow is defined as that type of flow which the fluid characteristics like velocity, pressure, density at a point changes with respect to time

1.65) When is the flow regarded as unsteady? Give an example for unsteady flow.

[AU, April / May - 2003]

Unsteady flow is defined as that type of flow which the fluid characteristics like velocity, pressure, density at a point changes with respect to time. Water flowing from dam.

1.66) State the conditions under which uniform and non-uniform flows are produced. ***[AU, May / June - 2016]***

Uniform flow is type of flow which velocity at any given time does not change with respect to space.

$$\left(\frac{\partial V}{\partial s}\right)_{t=constant} = 0$$

Non – uniform flow is type of flow which velocity at any given time changes with respect to space.

$$\left(\frac{\partial V}{\partial s}\right)_{t=constant} \neq 0$$

1.67) Differentiate between steady flow and uniform flow. ***[AU, Nov / Dec - 2007]***

Steady flow	Uniform flow
❖ Steady flow is defined as that type of flow which the fluid characteristics like velocity, pressure, density at a point do not change with time.	❖ Uniform flow is defined as that type of flow which velocity at any given time does not change with respect to space.

1.68) Differentiate between laminar and turbulent flow.

[AU, Nov / Dec – 2005, 2008, April / May - 2015]

Laminar flow	Turbulent flow
❖ Laminar flow is defined as that type of flow in which the fluid particles move along well – denied path or stream line. ❖ The stream lines are straight and parallel to each other	❖ Turbulent flow is defines as that type of flow in which the fluid particles move in a zig – zag way. ❖ The stream lines are not straight to each other

1.69) Distinguish between Laminar and Turbulent flow. ***[AU, April / May - 2010]***

Laminar flow	Turbulent flow
❖ Laminar flow is defined as that type of flow in which the fluid particles move along well – denied path or stream line. ❖ The stream lines are straight and parallel to each other	❖ Turbulent flow is defines as that type of flow in which the fluid particles move in a zig – zag way. ❖ The stream lines are not straight to each other

1.70) State the criteria for laminar flow. ***[AU, Nov / Dec - 2008]***

Laminar flow is defined as that type of flow in which the fluid particles move along well – denied path or stream line. The stream lines are straight and parallel to each other.

1.71) State the characteristics of laminar flow. ***[AU, April / May - 2010]***

Laminar flow is defined as that type of flow in which the fluid particles move along well – denied path or stream line. The stream lines are straight and parallel to each other. The particles move smoothly over the adjacent layer.

1.72) What are the characteristics of laminar flow? ***[AU, May / June - 2014]***

Laminar flow is defined as that type of flow in which the fluid particles move along well – denied path or stream line. The stream lines are straight and parallel to each other. The particles move smoothly over the adjacent layer.

1.73) Mention the general characteristics of laminar flow.

[AU, May / June – 2013, Nov / Dec - 2016]

Laminar flow is defined as that type of flow in which the fluid particles move along well – denied path or stream line. The stream lines are straight and parallel to each other. The particles move smoothly over the adjacent layer.

1.74) Define stream line. ***[AU, Nov / Dec - 2007]***

In Euler's approach, the velocity vector is defines as a function of time and space coordinates. If for a fixed instance time a space curve is drawn so that it is tangent everywhere to the velocity vector, then the curve is called as stream line.

1.75) Define streamline and path line in fluid flow. *[AU, Nov / Dec - 2005]*

In Euler's approach, the velocity vector is defines as a function of time and space coordinates. If for a fixed instance time a space curve is drawn so that it is tangent everywhere to the velocity vector, then the curve is called as **stream line**.

Path line are the outcome of the Lagrange method in describing fluid flow and show the paths of different fluid particles as a function of time.

1.76) What is stream line and path line in fluid flow? *[AU, April / May - 2010]*

In Euler's approach, the velocity vector is defines as a function of time and space coordinates. If for a fixed instance time a space curve is drawn so that it is tangent everywhere to the velocity vector, then the curve is called as **stream line**.

Path line are the outcome of the Lagrange method in describing fluid flow and show the paths of different fluid particles as a function of time.

1.77) What is a streamline? *[AU, Nov / Dec - 2010]*

In Euler's approach, the velocity vector is defines as a function of time and space coordinates. If for a fixed instance time a space curve is drawn so that it is tangent everywhere to the velocity vector, then the curve is called as stream line.

1.78) Define streak line. *[AU, April / May - 2008]*

A streak line at any instant of time is the locus of the temporary location of all particles that have passed through a fixed point in the flow field.

1.79) Define stream function. *[AU, April / May – 2010, May / June - 2012]*

Stream function is defined as the scalar function of space and time, such that its partial derivative with respect to any direction gives the velocity component at right angles to that direction

1.80) Define control volume. *[AU, April / May - 2015]*

The region in which the mass crosses the system boundary is called control volume. A control volume is a mathematical abstraction employed in the process of creating mathematical models of physical processes.

1.81) What is the use of control volume? *[AU, April / May - 2015]*

When the fluid is in motion, it is convenient to consider a certain control volume and study the quantity of the fluid entering and leaving the control volume in a definite period of time. It is an imaginary volume bounded by the control surface.

1.82) Distinguish between a control and differential control volume.

[AU, April / May - 2011]

The region in which the mass crosses the system boundary is called control volume. A control volume is a mathematical abstraction employed in the process of creating mathematical models of physical processes.

The control volume in which the conservation of mass equation is applied is called a differential control volume.

1.83) What is meant by continuum? *[AU, Nov / Dec - 2008, April / May - 2017]*

A continuous distribution of matter with no void or empty spaces is called as continuum. For mechanical analysis, a fluid is consider to be continuum. Example water flowing in a pipe.

1.84) Write down the equation of continuity. *[AU, Nov / Dec –2008, 2009, 2012]*

$$\frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w) = 0$$

1.85) State the continuity equation in one dimensional form?

[AU, May / June - 2012]

$$\frac{\partial}{\partial x}(\rho u) = 0$$

1.86) State the general continuity equation for a 3 - D incompressible fluid flow.

[AU, May / June - 2007, Nov / Dec - 2012]

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

1.87) State the continuity equation for the case of a general 3-D flow.

[AU, Nov / Dec - 2007]

$$\frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w) = 0$$

1.88) State the equation of continuity in 3dimensional incompressible flow.

[AU, Nov / Dec - 2005]

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

1.89) State the assumptions made in deriving continuity equation.

[AU, Nov / Dec - 2011]

- The liquid is ideal and incompressible
- The flow is steady and continuous
- The velocity is uniform over the cross section and equal to mean velocity
- The force only acting on the fluids are the gravity force and the pressure force
- All the frictional losses are negligible

1.90) Write the Euler's equation. *[AU, April / May - 2011]*

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

1.91) What is Euler's equation of motion? *[AU, Nov / Dec - 2008]*

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

1.92) State the empirical pressure density relation for a liquid.

[AU, Nov / Dec - 2014]

The relationship between the pressure and density is given by

$$PV^k = \frac{p}{\rho^k}$$

Where $k = \frac{C_p}{C_v}$

1.93) Write the Bernoulli's equation in terms of head. Explain each term.

[AU, Nov / Dec - 2007]

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

$$\frac{p}{w} = Pressure\ Energy$$

$$\frac{v^2}{2g} = Kinetic\ Energy$$

$$z = Datum\ Energy$$

1.94) What are the basic assumptions made is deriving Bernoulli's theorem?

[AU, Nov / Dec – 2005, 2012]

- The liquid is ideal and incompressible
- The flow is steady and continuous

- The velocity is uniform over the cross section and equal to mean velocity
- The force only acting on the fluids are the gravity force and the pressure force
- All the frictional losses are negligible

1.95) List the assumptions which are made while deriving Bernoulli's equation. ***[AU, May / June – 2009, 2012]***

- The liquid is ideal and incompressible
- The flow is steady and continuous
- The velocity is uniform over the cross section and equal to mean velocity
- The force only acting on the fluids are the gravity force and the pressure force
- All the frictional losses are negligible

1.96) State the assumptions used in the derivation of the Bernoulli's equation. ***[AU, Nov / Dec - 2014]***

- The liquid is ideal and incompressible
- The flow is steady and continuous
- The velocity is uniform over the cross section and equal to mean velocity
- The force only acting on the fluids are the gravity force and the pressure force
- All the frictional losses are negligible

1.97) What are the applications of Bernoulli's theorem? ***[AU, April / May - 2010]***

- Venturimeter
- Orifice meter
- Pitot tube

1.98) List the types of flow measuring devices fitted in a pipe flow, which uses the principle of Bernoulli's equation. ***[AU, May / June - 2012]***

- Venturimeter
- Orifice meter
- Pitot tube

1.99) Mention the uses of manometer. ***[AU, Nov / Dec - 2009]***

- It used to measure pressure of the fluid

1.100) State the use of venturimeter. *[AU, May / June - 2006]*

Venturimeter is a device used to measure the rate of flow fluid through the pipelines.

1.101) What is an impulse – momentum equation? *[AU, May / June - 2016]*

Impulse momentum equation states that the impulse of force acting on the fluid mass in a short interval of time is equal to the change in momentum in the direction of the force.

$$F = \frac{d}{dt}(mv)$$

1.102) Write the impulse momentum equation. *[AU, May / June - 2007]*

F = ma

Where $a = dv/dt$

Let m be constant

$$F = m\frac{dv}{dt}$$

$$F = \frac{d}{dt}(mv)$$

1.103) What do you understand by impulse momentum equation?

[AU, May / June - 2013]

Impulse momentum equation states that the impulse of force acting on the fluid mass in a short interval of time is equal to the change in momentum in the direction of the force.

$$F = \frac{d}{dt}(mv)$$

1.104) State the momentum equation. When can it applied.*[AU, May / June - 2009]*

It states that "The force F acting on a fluid of mass 'm' in a short interval of time 'dt' is equal to change in momentum d(mv) in the direction of force.

F = ma

Where $a = dv/dt$

Let m be constant

$$F = m\frac{dv}{dt}$$

$$F = \frac{d}{dt}(mv)$$

1.105) State the usefulness of momentum equation as applicable to fluid flow phenomenon. ***[AU, May / June– 2007, Nov / Dec - 2012]***

The momentum equation is used to determine the resultant force exerted on the force boundary of the flow passage by a stream of flowing fluid as the flow changes its direction.

The practical applications are

- Flow through bend pipes
- Jet propulsions and propellers
- Hydraulic jump in open channels
- Fluid flow through stationary and moving plates
- Non uniform flow through sudden enlarged pipes

1.106) What is the moment of momentum equation? ***[AU, May / June - 2014]***

Moment of momentum equation is derived from moment of momentum principle which states that the resulting torque acting on a rotating fluid is equal to rate of change of moment of momentum.

Moment of moment equation

$$T = \rho Q\,(V_2 r_2 - V_1 r_1)$$

V_1 & V_2 = Velocity of fluid at section 1 & 2

r_1 & r_2 = Radius of curvature of fluid at section 1 & 2

ρ = Density of fluid

Q = Flow rate of the fluid

1.107) Give the dimensions of the following: (a) Torque (b) Momentum.

[AU, Nov / Dec - 2015]

Torque - N – m

Momentum - N – s

1.108) Calculate the density of one litre petrol of specific gravity 0.7?

[AU, April / May - 2011]

Given:

Volume of petrol = 1 litre = 1 *$10^{-3}m^3$

Specific gravity S = 0.7

Solution:

$$Specific\ gravity\ S = \frac{Density\ of\ petrol}{Density\ of\ water}$$

$$\rho_p = S * \rho_w$$

$$= 0.7 * 1000$$

$$\boldsymbol{\rho_p = 700\ kg/m^3}$$

1.109) Calculate the specific weight and specific gravity of 1 litre of a liquid with a density of 713.5 kg/m³ and which weighs 7N. *[AU, Nov / Dec - 2015]*

Given:

Volume V = 1 litre = 1 *$10^{-3}m^3$

Density ρ = 713.5 kg/m³

Weight W = 7 N

Solution:

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

$$Specific\ gravity\ S = \frac{713.5}{1000}$$

S = 0.7135

Specific Weight w = ρ * g

= 713.5 * 9.81

w = 6999.43 N/m³

1.110) If a liquid has a viscosity of 0.051 poise and kinematic viscosity of 0.14 stokes, calculate its specific gravity. *[AU, April / May - 2015]*

Given:

Viscosity $\mu = 0.051\ poise = \frac{0.051}{10}$

$= 0.0051 \frac{kg}{sm}$

Kinematic viscosity $= 0.7$ stokes

$= 0.7 * 10^{-4}\ m^2/s$

Solution:

$$kinematic\ viscosity = \frac{viscosity}{Density}$$

$$0.7 * 10^{-4} = \frac{0.0051}{Density}$$

$$\rho = 728.57\ kg/m^3$$

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

$$S = \frac{728.57}{1000}$$

$$\boldsymbol{S = 0.72857}$$

1.111) Calculate the mass density and specific volume of one litre of a liquid which weighs 7 N. ***[AU, April / May - 2015]***

Given:

Mass m = 7N $= \frac{7}{9.81} = 0.7135$ kg

Volume V = 1 litre = $1*10^{-3}\ m^3$

Solution:

$$Mass\ density = \frac{Mass\ of\ fluid}{Volume\ of\ fluid}$$

$$mass\ density = \frac{0.7135}{1 * 10^{-3}}$$

$$\boldsymbol{\rho = 713.557\ {}^{kg}/_{m^3}}$$

$$Specific\ Volume = \frac{1}{Mass\ density}$$

$$Specific\ Volume = \frac{1}{713.557}$$

$$Specific\ Volume = 1.40 * 10^{-3}\ m^3/_{kg}$$

1.112) A quantity of helium (molecular weight = 4) when confined to a volume of 100 litres at -20°C weight 25N. Find the pressure exerted by the gas.

[AU, April / May - 2017]

Given:

Mass	m	=	25N	$= \frac{25}{9.81}$	= 2.548 kg
Volume	V	=	1 litre	$= 1*10^{-3}\ m^3$	
Temperature	T	=	-20°C	= 253K	
	R	=	8.314 J/mol. K		
Molecular Weight		=	4		

Solution:

$$PV = mRT$$

$$P * 1 * 10^{-3} = 2.548 * \frac{8.314}{4} * 253$$

$$\mathbf{P = 1.34*10^6\ N/m^2}$$

1.113) A soap bubble is formed when the inside pressure is 5 N/m²above the atmospheric pressure. If surface tension in the soap bubble is 0.0125 N/m, find the diameter of the bubble formed. ***[AU, April / May - 2010]***

Given:

$p = 5\ N/m^2$ $\sigma = 0.0125\ N/m$

Solution:

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

$$5 = \frac{8 * 0.0125}{d}$$

d = 0.02m

1.114) The converging pipe with inlet and outlet diameters of 200 mm and 150 mm carries the oil whose specific gravity is 0.8. The velocity of oil at the entry is 2.5 m/s, find the velocity at the exit of the pipe and oil flow rate.

[AU, April / May - 2010]

Given:

$D_1 = 200$ mm $D_2 = 150$mm $S = 0.8$ $V_1 = 2.5$m/s

Solution:

Discharge Q = A_1V_1

$$Q = \frac{\pi}{4} * 0.2^2 * 2.5$$

$$Q = 0.0785\ m^3/sec$$

According to continuity equation

$$A_1V_1 = A_2V_2$$

$$\frac{\pi}{4} * 0.2^2 * 2.5 = \frac{\pi}{4} * 0.15^2 * V_2$$

$$V_2 = 4.44 m/s$$

1.115) Calculate the height of capillary rise for water in a glass tube of diameter 1mm and surface tension as 0.072N/m.

[AU, May / June - 2012, April / May - 2017]

Given:

$d = 1 * 10^{-3}$m $\sigma = 0.072$N/m

Solution:

$$capillary\ (h) = \frac{4\sigma}{\rho g d}$$

$$= \frac{4 * .072}{1000 * 9.81 * 1 * 10^{-3}}$$

h = 0.0293m

1.116) Find the height through which the water rises by the capillary action in a 2mm bore if the surface tension at the prevailing temperature is0.075 g/cm.

[AU, April / May - 2003]

Given:

$d = 0.2$cm $\sigma = 0.75*10^{-3}$ kg/cm

Solution:

$$capillary\ rise\ (h) = \frac{4\sigma}{wd}$$

$$w = \rho g$$

$= 1000 * 9.81$

$= 9810\ kg/m^3$

$= 0.00981 kg/cm^3$

$$h = \frac{4\sigma}{wd}$$

$$h = \frac{4 * 0.75 * 10^{-3}}{0.00981 * 0.2}$$

h = 1.52cm

1.117) Calculate the capillarity rise in glass tube of 2.5mm diameter when immersed vertically in (a) water and (b) mercury. Take the surface tension σ = 0.0725 N/m for water and σ = 0.52 N/m for mercury in contact with air. The specific gravity for mercury is given as 13.6 and angle of contact = 130°

[AU, Nov / Dec - 2016]

Given:

$d = 2.5*10^{-3} m$ $\sigma_w = 0.725\ N/m$ $\sigma_m = 0.52\ N/m$

$\theta_m = 130$

Solution:

$$capillary\ (h_w) = \frac{4\sigma_w}{\rho g d}$$

$$capillary\ (h_w) = \frac{4 * .725}{1000 * 9.81 * 2.5 * 10^{-3}}$$

$$\boldsymbol{capillary\ (h_w) = 0.1182\ m}\ \textbf{(Rise)}$$

$$capillary\ (h_m) = \frac{4\sigma_m cos\theta_m}{\rho g d}$$

$$capillary\ (h_m) = \frac{4 * .52 * cos130}{13.6 * 1000 * 9.81 * 2.5 * 10^{-3}}$$

$$\boldsymbol{capillary\ (h_m) = -0.0040m\ (Depression)}$$

1.118) Find the height of a mountain where the atmospheric pressure is 730mm of Hg at normal conditions. ***[AU, Nov / Dec - 2009]***

Given:

h = 730mm of Hg = 0.73m

Solution:

$$\text{Specific weight } (w) = \rho g$$

$$w = 13.6 * 9.81$$

$$= 133.416\ kg/m^3$$

$$\text{Height of the mountain } = \frac{P_{atm}}{\rho_w * g}$$

$$H = \frac{133.416 * 0.73}{1000 * 9.81}$$

$$\mathbf{H = 9.93m}$$

1.119) Suppose the small air bubbles in a glass of tap water may be on the order of 50 μ m in diameter with surface tension 0.0125 N/m. What is the pressure inside these bubbles? ***[AU, Nov / Dec - 2010]***

Given:

$d = 50 * 10^{-3}m$ $\sigma = 0.0125\ N/m$

Solution:

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

$$p = \frac{8 * 0.0125}{50 * 10^{-3}}$$

$$\mathbf{p = 2.05\ N/m^2}$$

1.120) An open tank contains water up to depth of 2.85m and above it an oil of specific gravity 0.92 for the depth of 2.1m. Calculate the pressures at the interface of two liquids and at the bottom of the tank. ***[AU, April / May - 2011]***

Given:

Height of water	$Z_1 = 2.85m$
Height of oil	$Z_2 = 2.1m$
Specific gravity of oil	$S_0 = 0.92$
Density of water	$\rho_1 = 100\ kg/m^3$
Density of oil	$\rho_2 = 0.92 * 1000 = 920\ kg/m^3$

Solution:

Pressure intensity at interface of liquid:

$$p = \rho * g * z$$

$$p = \rho_2 * g * z_2$$

$$= 920 * 9.81 * 2.1$$

$$\mathbf{p = 18952.92\ N/m^2}$$

Pressure intensity at bottom of the tank

$$p = \rho_1 * g_1 * z_1 + \rho_2 * g_2 * z_2$$

$$= 1000 * 9.81 * 2.85 + 920 * 9.81 * 2.1$$

$$\mathbf{p = 46911.42\ N/m^2}$$

1.121) Two horizontal plates are placed 12.5mm apart, the space between them is being filled with oil of viscosity 14 poise. Calculate the shear stress in the oil if the upper plate is moved with the velocity of 2.5m/s. ***[AU, May / June - 2012]***

Given:

dy = 0.0125 m μ = 14 poise = 1.4 Ns/m^2 u = 2.5m/s

Solution:

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

du = change in velocity between plates = u – 0 = 2.5m/sec

$$\tau = 1.4 * \frac{2.5.}{0.125}$$

$$\boldsymbol{\tau = 280\ N/m^2}$$

UNIT - II - FLOW THROUGH CIRCULAR CONDUCTS

2.1) How are fluid flows classified? *[AU, May / June - 2012]*

- Steady and Unsteady flow
- Uniform and Non – uniform flow
- Laminar and Turbulent
- Compressible flow and Incompressible flow
- Rotational and Irrotational flow
- One, Two and Three dimensional flow

2.2) Distinguish between Laminar and Turbulent flow. *[AU, Nov / Dec - 2006]*

Laminar flow	Turbulent flow
❖ Laminar flow is defined as that type of flow in which the fluid particles move along well – denied path or stream line. ❖ The stream lines are straight and parallel to each other	❖ Turbulent flow is defines as that type of flow in which the fluid particles move in a zig – zag way. ❖ The stream lines are not straight to each other

2.3) Write down Hagen Poiseuille's equation for laminar flow.

[AU, April / May - 2005, Nov / Dec - 2012]

$$\frac{p_1 - p_2}{\rho g} = \frac{32\mu u L}{\rho g D^2}$$

Where p_1 and p_2 pressure at inlet and outlet of the pipe

μ = Dynamic viscosity

u = Velocity of the fluid

L = Length of the pipe

D = Diameter of the pipe

2.4) Write the Hagen – Poiseuille's Equation and enumerate its importance.

[AU, April / May - 2011]

$$\frac{p_1 - p_2}{\rho g} = \frac{32\mu u L}{\rho g D^2}$$

Where p_1 and p_2 pressure at inlet and outlet of the pipe μ Dynamic viscosity

u Velocity of the fluid

L Length of the pipe

D Diameter of the pipe

2.5) State Hagen – Poiseuille's formula for flow through circular tubes.

[AU, May / June - 2012]

$$\frac{p_1 - p_2}{\rho g} = \frac{32\mu uL}{\rho g D^2}$$

Where p_1 and p_2 pressure at inlet and outlet of the pipe

μ Dynamic viscosity

u Velocity of the fluid

L Length of the pipe

D Diameter of the pipe

2.6) Write down the Darcy - Weisbach's equation for friction loss through a pipe

[AU, Nov / Dec - 2009, April / May - 2011]

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

f = coefficient of friction

L = length of the pipe

V =velocity of the fluid

D = diameter of the pipe

g = acceleration due to gravity

2.7) Brief on Darcy-Weisbach equation. *[AU, May / June - 2016]*

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

f = coefficient of friction

L = length of the pipe

V =velocity of the fluid

D = diameter of the pipe

g = acceleration due to gravity

2.8) What is Darcy's equation? Identify various terms in the equation.

[AU, April / May - 2011]

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

f = coefficient of friction

L = length of the pipe

V =velocity of the fluid

D = diameter of the pipe

g = acceleration due to gravity

2.9) How does the roughness of channel affect the Chezy's constant?

[AU, May / June - 2016]

Dracy' Equation

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

Chezy' Equation

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

Where $m = \frac{d}{4}$ *and* $i = \frac{h_f}{L}$

Substituting the values of m and i in Chezy's Equation we get

$$h_f = \frac{4V^2L}{C^2d}$$

Therefore

$$h_f = \frac{4fLV^2}{2gd} = \frac{4V^2L}{C^2d}$$

$$f = \frac{8g}{C^2}$$

2.10) State the equation of discharge of water through an open channel.

[AU, May / June - 2016]

$$Q = A * V$$

$$Q = A * C\sqrt{mi}$$

2.11) What is the relationship between Darcy Friction factor, Fanning Friction Factor and Friction coefficient? *[AU, Nov / Dec – 2010, May / June - 2012]*

Darcy Friction factor	Fanning Friction Factor	Friction coefficient
Dimensionless number used in fluid flow calculations. Darcy-Weisbach equation relates losses hl to length of pipe L, diameter D, and velocity V by a dimensionless friction factor1 f $h_l = f\frac{L}{D}\frac{V^2}{2g}$	Dimensionless number used in fluid flow calculations. It is related to the shear stress at the wall as: $\tau = \frac{f\rho v^2}{2}$	Friction factor is the factor equating the proportionality for the above two head loss friction equation. Darcy-Weisbach friction factor, is four times the size of the Fanning friction factor, also called f.

2.12) Mention the types of minor losses. *[AU, April / May - 2010]*

The losses due to disturbance in the flow pattern is called as minor losses.

- Loss due to sudden enlargement
- Loss due to sudden contraction
- Loss due to entrance
- Loss due to exit
- Loss due to bends or pipe fittings
- Head loss due to an obstacle in a pipe

2.13) List the minor losses in flow through pipe.

[AU, April / May - 2005, May / June - 2007]

The losses due to disturbance in the flow pattern is called as minor losses.

- Loss due to sudden enlargement
- Loss due to sudden contraction
- Loss due to entrance
- Loss due to exit
- Loss due to bends or pipe fittings
- Head loss due to an obstacle in a pipe

2.14) What are minor losses? Under what circumstances will they be negligible?

[AU, May / June - 2012]

The losses due to disturbance in the flow pattern is called as minor losses. In case of long pipe, it does not makes any serious effect.

2.15) What are the minor losses in pipes? *[AU, Nov / Dec - 2015]*

The losses due to disturbance in the flow pattern is called as minor losses.

- Loss due to sudden enlargement
- Loss due to sudden contraction
- Loss due to entrance
- Loss due to exit
- Loss due to bends or pipe fittings
- Head loss due to an obstacle in a pipe

2.16) Distinguish between the major loss and minor losses with reference to flow through pipes. *[AU, May / June - 2009]*

Major loss	Minor loss
❖ The major loss of energy is due to friction ❖ It depends on roughness of pipe, length, velocity and diameter of pipe ❖ Dracy formula is used as major formula ❖ Major losses cannot be neglected	❖ The losses due to disturbance in the flow pattern is called as major loss ❖ It occurs due to sudden expansion or contraction, valves, fittings, bends and at entrance and exit of pipe ❖ Dracy formula is not used for minor losses ❖ Minor losses is neglected in case of large pipe

2.17) List the causes of minor energy losses in flow through pipes.

[AU, Nov / Dec - 2009]

- Loss due to sudden enlargement
- Loss due to sudden contraction

- Loss due to entrance
- Loss due to exit
- Loss due to bends or pipe fittings
- Head loss due to an obstacle in a pipe

2.18) What do you understand by minor energy losses in pipes?

[AU, Nov / Dec - 2008]

The losses due to disturbance in the flow pattern is called as minor losses. It occurs due to sudden expansion or contraction, valves, fittings, bends and at entrance and exit of pipe

2.19) What are 'major' and 'minor losses' of flow through pipes?

[AU, May / June 2007, Nov / Dec - 2007, 2012, April / May - 2010]

The major loss of energy is due to friction. It depends on roughness of pipe, length, velocity and diameter of pipe.

The minor loss due to disturbance in the flow pattern is called as minor losses. It occurs due to sudden expansion or contraction, valves, fittings, bends and at entrance and exit of pipe

2.20) List the minor and major losses during the flow of liquid through a pipe.

[AU, April / May - 2008]

The major loss of energy is due to friction. It depends on roughness of pipe, length, velocity and diameter of pipe.

The minor loss due to disturbance in the flow pattern is called as minor losses. It occurs due to sudden expansion or contraction, valves, fittings, bends and at entrance and exit of pipe

2.21) Enlist the various minor losses involved in a pipe flow system.

[AU, Nov / Dec - 2008]

- Loss due to sudden enlargement
- Loss due to sudden contraction
- Loss due to entrance
- Loss due to exit
- Loss due to bends or pipe fittings
- Head loss due to an obstacle in a pipe

2.22) Explain what is meant by a smooth pipe? ***[AU, Nov / Dec - 2015]***

Hydraulically smooth means that the roughness on the wall of the pipe is less the thickness of the laminar sub layer of the turbulent flow. A hydraulically smooth pipe has excellent hydraulic properties that allow fluids to be flow with a minimum head loss.

2.23) Write the expression for calculating the loss due to sudden expansion of the pipe. ***[AU, April / May - 2015]***

$$h_e = \frac{(V_1 - V_2)^2}{2g}$$

V_1 = Velocity at inlet

V_2 = Velocity at outlet

g = Acceleration due to gravity

2.24) What are the factors influencing the frictional loss in pipe flow? ***[AU, Nov / Dec - 2016]***

- In laminar flow, losses are proportional to fluid velocity, *V*; that velocity varies smoothly between the bulk of the fluid and the pipe surface, where it is zero. The roughness of the pipe surface influences neither the fluid flow nor the friction loss.
- In turbulent flow, losses are proportional to the square of the fluid velocity, V^2; here, a layer of chaotic eddies and vortices near the pipe surface, called the viscous sub-layer, forms the transition to the bulk flow. In this domain, the effects of the roughness of the pipe surface must be considered. It is useful to characterize that roughness as the ratio of the roughness height ε to the pipe diameter *D*, the "relative roughness". Three sub-domains pertain to turbulent flow:
  - In the smooth pipe domain, friction loss is relatively insensitive to roughness.
  - In the rough pipe domain, friction loss is dominated by the relative roughness and is insensitive to Reynolds number.
  - In the transition domain, friction loss is sensitive to both.

2.25) What factors account in energy loss in laminar flow.

[AU, May / June - 2012]

- ❖ Due to friction between the inner circumference of a pipe and fluid flow
- ❖ Due to viscosity of a fluid (friction between the internal molecules of a fluid)

2.26) What is meant by laminar flow instability? *[AU, Nov / Dec - 2014]*

Stability of laminar flow is disturbed by infinitesimal particles (Small change in pressure, Temperature, viscosity, density & other fluid and flow properties) are leads to converting the laminar flow into turbulent flow, even though the Reynold's no is with in laminar flow range. The above phenomena is called laminar flow instability.

2.27) Differentiate between pipes in series and pipes in parallel.

[AU, Nov / Dec - 2006]

Pipe in series	Pipe in parallel
❖ When the pipe of different length and diameters are connected to each other to form a pipe line the such a pipeline is called as pipe in series ❖ Discharge in each pipe will be same $Q = Q_1 = Q_2$	When a pipeline divides into two or more parallel pipes which again join together at downstream then that pipe is said to parallel ❖ Discharge in the main pipe is equal to sum of discharge in each of the parallel pipes $Q = Q_1 + Q_2$

2.28) What is equivalent pipe? Mention the equation used for it.

[AU, April / May - 2017]

Equivalent pipe is defined as, a pipe of uniform diameter having the same loss of head and discharge as that of the compound pipe line.

$$\frac{L}{d^5} = \frac{L_1}{{d_1}^5} + \frac{L_1}{{d_2}^5} + \frac{L_1}{{d_3}^5}$$

2.29) When is the pipe termed to be hydraulically rough? *[AU, Nov / Dec - 2009]*

- ❖ The pipe which has poor internal surface finish.
- ❖ The pipe should have very high friction factor
- ❖ The pipe should have rough surface.

2.30) What is the physical significance of Reynold's number?

[AU, May / June, Nov / Dec - 2007]

- Motion of air planes
- Flow is incompressible fluid in close pipes
- Motion of submarines
- Flow around structures and other bodies immersed fully in moving fluids

2.31) Define Reynolds Number. ***[AU, Nov / Dec - 2012]***

It is defined as the ratio of inertia force of a flowing fluid and viscous force of the fluid.

2.32) What are the uses of Moody's diagram?

[AU, Nov / Dec - 2008, 2012, April / May - 2017]

- It is used for determining friction factor for any turbulent flow problem
- It can be used for non-circular conduits and also for open channels.

2.33) Mention the use of Moody diagram. ***[AU, April / May - 2015]***

- It is used for determining friction factor for any turbulent flow problem
- It can be used for non-circular conduits and also for open channels.

2.34) State the importance of Moody's chart. ***[AU, Nov / Dec - 2014]***

The Moody's chart is a graph plotted to find Darcy – Weisbach friction factor for commercial pipe. The diagram is plotted in the form of frictional factor verses Reynold's number for various values of relative roughness (R/k). The curve is plotted using the following equation

$$\frac{1}{\sqrt{f}} - 2\,log_{10}\left(\frac{R}{k}\right) = 1.74 - 2\,log_{10}\left(1 + 18.71\,\frac{R/k}{R_e\sqrt{f}}\right)$$

- It is used for determining friction factor for any turbulent flow problem
- It can be used for non-circular conduits and also for open channels.

2.35) How does surface roughness affect the pressure drop in a pipe if the flow is turbulent? ***[AU, Nov / Dec - 2013]***

In turbulent flow, the tubes with rough surface have much higher friction factors than the tubes with smooth surface, and thus much larger pressure drop.

2.36) A piping system involves two pipes of different diameters (but of identical length, material, and roughness) connected in parallel. How would you compare the flow rates and pressure drops in these two pipes? ***[AU, Nov / Dec - 2013]***

For a piping system that involves two different pipes of different diameters connected in parallel. The flow rate through the larger diameter pipe is larger and the pressure drop through both pipes is the same.

2.37) What do you mean by flow through parallel pipes? ***[AU, May / June – 2013***

When the pipe divides into two or more branches and again join together downstream to form a single pipe then it is called as pipes in parallel. The governing equations are:

$$Q = Q_1 + Q_2$$

$$h_{f1} = h_{f2}$$

2.38) Give the expression for power transmission through pipes? ***[AU, Nov / Dec - 2008]***

Power available at the outlet of the pipe

$$P = wQh$$

$$P = w * \frac{\pi}{4} * D^2 * v * \left(H - \frac{4fLV^2}{2gD}\right)$$

Maximum power transmission

$$h_f = \frac{H}{3}$$

The power transmitted through the pipe is maximum when head lost due to friction in the pipe is equal to 1/3 of the total head supplied.

2.39) What is the condition for maximum power transmission w.r.t. head available? ***[AU, May / June - 2016]***

Maximum power transmission

$$h_f = \frac{H}{3}$$

The power transmitted through the pipe is maximum when head lost due to friction in the pipe is equal to 1/3 of the total head supplied.

2.40) Define boundary layer and boundary layer thickness.

[AU, Nov / Dec – 2007, 2008, 2012]

The variation of velocity from zero to free stream velocity in the direction normal to the boundary takes place in a narrow region in the vicinity of solid boundary. This narrow region of the fluid is called as **boundary layer**.

Boundary layer thickness as the distance from the boundary of the solid body measured in y – direction to the point, where the velocity of the fluid is approximately equal to 0.99 times the free stream velocity of the fluid.

2.41) Define boundary layer. *[AU, April / May - 2017]*

The variation of velocity from zero to free stream velocity in the direction normal to the boundary takes place in a narrow region in the vicinity of solid boundary. This narrow region of the fluid is called as **boundary layer**.

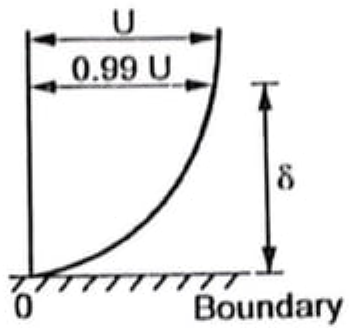
2.42) Define boundary layer thickness.

[AU, May / June - 2006, Nov / Dec – 2009, 2015]

Boundary layer thickness as the distance from the boundary of the solid body measured in y – direction to the point, where the velocity of the fluid is approximately equal to 0.99 times the free stream velocity of the fluid.

2.43) State boundary layer thickness with a neat sketch. *[AU, April / May - 2017]*

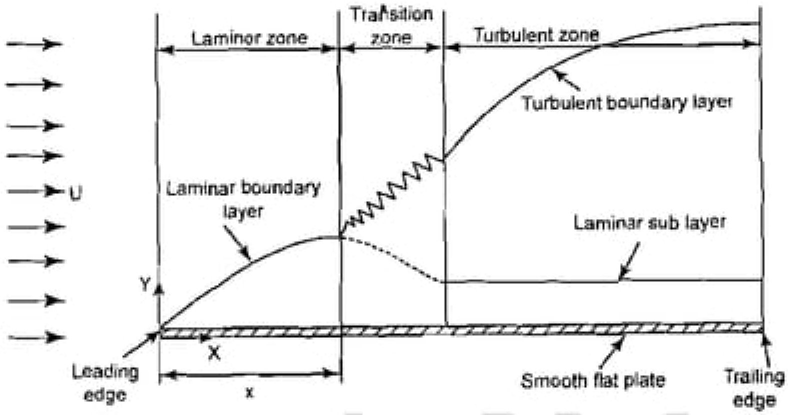
Boundary layer thickness as the distance from the boundary of the solid body measured in y – direction to the point, where the velocity of the fluid is approximately equal to 0.99 times the free stream velocity of the fluid.



Boundary layer thickness

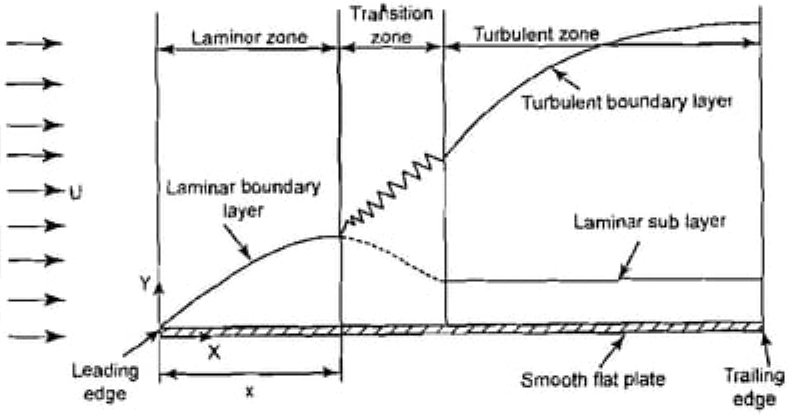
2.44) What is boundary layer? Give its sketch of a boundary layer region over a flat plate. *[AU, April / May – 2003, 2010]*

The variation of velocity from zero to free stream velocity in the direction normal to the boundary takes place in a narrow region in the vicinity of solid boundary. This narrow region of the fluid is called as **boundary layer**.



2.45) What is boundary layer? Why is it significant? *[AU, Nov / Dec - 2009]*

The variation of velocity from zero to free stream velocity in the direction normal to the boundary takes place in a narrow region in the vicinity of solid boundary. This narrow region of the fluid is called as **boundary layer**.



2.46) Give the classification of boundary layer flow based on the Reynolds number. *[AU, April / May - 2015]*

- Laminar boundary layer
- Transition boundary layer
- Turbulent boundary layer

2.47) What is boundary layer and write its types of thickness?

[AU, Nov / Dec – 2005, 2006]

The variation of velocity from zero to free stream velocity in the direction normal to the boundary takes place in a narrow region in the vicinity of solid boundary. This narrow region of the fluid is called as **boundary layer**.

Types of boundary layer

- Displacement thickness
- Momentum thickness
- Energy thickness

2.48) What do you understand by the term boundary layer?

[AU, Nov / Dec - 2008]

The variation of velocity from zero to free stream velocity in the direction normal to the boundary takes place in a narrow region in the vicinity of solid boundary. This narrow region of the fluid is called as **boundary layer**.

2.49) What is a laminar sub layer? *[AU, Nov / Dec - 2010]*

Within a turbulent boundary layer zone, if the boundary is smooth, a thin layer adjacent to the plate surface over which the flow is assumed to be laminar is called laminar sub – layer. The velocity distribution in the laminar sub – layer is assumed to be linear.

2.50) Define momentum thickness and energy thickness.

[AU, May / June – 2007, 2012]

Momentum thickness is defined as the distance measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for the reduction in momentum of the flowing fluid on account of boundary layer formation.

Energy thickness is defined as the distance measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for the reduction in kinetic energy of the flowing fluid on account of boundary layer formation.

2.51) Define the term boundary layer. *[AU, May / June - 2009]*

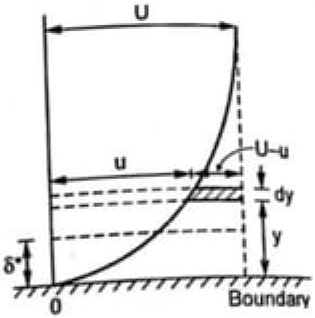
The variation of velocity from zero to free stream velocity in the direction normal to the boundary takes place in a narrow region in the vicinity of solid boundary. This narrow region of the fluid is called as **boundary layer**.

2.52) What is boundary layer separation? *[AU, Nov / Dec - 2012]*

The boundary layer is formed on the flat plate when it is held immersed in a flowing liquid. If the immersed plate or body is curved or angular one, the boundary layer does not stick to the whole surface and gets separated from it. This phenomenon is known as boundary layer separation.

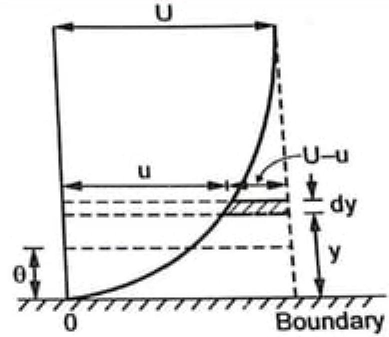
2.53) What do you mean by displacement thickness and momentum thickness? *[AU, Nov / Dec - 2008]*

Displacement thickness is defined as the distance, measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for reduction in flow rate on account of boundary layer formation.



Displacement Thickness

Momentum thickness is defined as the distance measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for the reduction in momentum of the flowing fluid on account of boundary layer formation.



Momentum thickness

2.54) What do you understand by hydraulic diameter? ***[AU, Nov / Dec - 2011]***

Hydraulic diameter is the effective diameter of wetted surface when the flow takes through the system. It is the ratio of wetted area to the wetted perimeter.

2.55) What is hydraulic gradient line? ***[AU, May / June - 2009]***

Hydraulic gradient line is defined as the line which gives the sum of pressure head and datum head of the flowing fluid in a pipe with respect to some reference line or it is the line which is obtained by joining top of all vertical ordinates, showing the pressure head of a flowing fluid in a pipe from the center pipe.

2.56) Define hydraulic gradient and energy gradient. ***[AU, Nov / Dec - 2011]***

Hydraulic gradient is the piezometric head which is the sum of potential head and datum head.

Energy gradient is the sum of hydraulic gradient and kinetic head.

2.57) Brief on HGL. ***[AU, April / May - 2011]***

Hydraulic **G**radient **L**ine is defined as the line which gives the sum of pressure head and datum head of the flowing fluid in a pipe with respect to some reference line or it is the line which is obtained by joining top of all vertical ordinates, showing the pressure head of a flowing fluid in a pipe from the center pipe.

2.58) Differentiate between Hydraulic gradient line and total energy line.

[AU, Nov / Dec - 2003, 2015, April / May - 2005, 2010, May / June–2007, 2009]

Hydraulic Gradient Line	Total Energy Line
❖ It is the sum of pressure head and datum head with respect to datum line.	❖ Total energy line is the sum of velocity head, pressure head and datum head.

❖ Hydraulic grade line less below total energy line by $\frac{V^2}{2g}$	❖ Total energy line has above hydraulic grade line by $\frac{V^2}{2g}$

2.59) Differentiate hydraulic gradient line and energy gradient line.

[AU, May / June - 2014]

Hydraulic Gradient Line	Energy Gradient Line
❖ Pressure Energy alone plotted along the flow to some specified scale gives the energy line. ❖ The plot of $\frac{P}{\gamma} + z$ along the flow is called the hydraulic gradient line. ❖ The hydraulic gradient line provides useful information about pressure variations (static head) in a flow.	❖ The total energy plotted along the flow to some specified scale gives the energy line. ❖ Energy line is the plot of $\frac{P}{\gamma} + z + \frac{V^2}{2g}$ along the flow. It is constant along the flow when losses are negligible ❖ The hydraulic gradient line provides useful information about total head variations in a flow.

2.60) Differentiate between hydraulic grade line and energy grade line.

[AU, Nov / Dec - 2014]

Hydraulic Grade Line	Energy Grade Line
❖ Pressure Energy alone plotted along the flow to some specified scale gives the energy line. ❖ The plot of $\frac{P}{\gamma} + z$ along the flow is called the hydraulic gradient line.	❖ The total energy plotted along the flow to some specified scale gives the energy line. ❖ Energy line is the plot of $\frac{P}{\gamma} + z + \frac{V^2}{2g}$ along the flow. It is

❖ The hydraulic gradient line provides useful information about pressure variations (static head) in a flow.	constant along the flow when losses are negligible ❖ The hydraulic gradient line provides useful information about total head variations in a flow.

2.61) What is T.E.L? *[AU, Nov / Dec - 2009]*

Total **E**nergy **L**ine is defined as the line which gives the sum of pressure head, datum head and kinetic head of a flowing fluid in a pipe with respect to reference line. It is also defined as the line which is obtained by joining the tops of all vertical ordinates showing the sum of pressure head and kinetic head from the center of the pipe.

2.62) Distinguish between hydraulic and energy gradients. *[AU, Nov / Dec - 2011]*

Hydraulic gradient is the piezometric head which is the sum of potential head and datum head.

Energy gradient is the sum of hydraulic gradient and kinetic head.

2.63) What are stream lines, streak lines and path lines in fluid flow?

[AU, Nov / Dec –2006, 2009]

In Euler's approach, the velocity vector is defines as a function of time and space coordinates. If for a fixed instance time a space curve is drawn so that it is tangent everywhere to the velocity vector, then the curve is called as **stream line**.

Path line are the outcome of the Lagrange method in describing fluid flow and show the paths of different fluid particles as a function of time.

A **streak line** at any instant of time is the locus of the temporary location of all particles that have passed through a fixed point in the flow field.

2.64) Define flow net. *[AU, Nov / Dec - 2008]*

A grid obtained by drawing a series of equipment lines and steam lines is called a flow net. The flow net is an important tool is analysis two dimensional irrotational flow problems.

2.65) What is flow net and state its use? *[AU, April / May - 2011]*

A grid obtained by drawing a series of equipment lines and steam lines is called a flow net. The flow net is an important tool is analysis two dimensional irrotational flow problems.

2.66) Define lift. *[AU, Nov / Dec - 2005]*

The component of total force in the direction perpendicular to the direction of flow is known as lift.

2.67) Define the terms: drag and lift. *[AU, Nov / Dec – 2007, May / June - 2009]*

The component of total force in the direction of flow of fluid is known as **drag**.

The component of total force in the direction perpendicular to the direction of flow is known as **lift**.

2.68) Give the expression for Drag coefficient and Lift coefficient.

[AU, April / May - 2011]

Drag coefficient C_d is defined by

$$F_D = \frac{1}{2}\,\rho\,V^2 C_d A$$

F_D = The drag force, which is by definition the force component in the direction of the flow velocity

ρ = The mass density of the fluid

V = The velocity of the object relative to the fluid

A = The reference area

C_d = the drag coefficient – a dimensionless coefficient related to the object's geometry and taking into account both skin friction and form drag

The lift coefficient C_L is defined by

$$C_L = \frac{L}{qS}$$

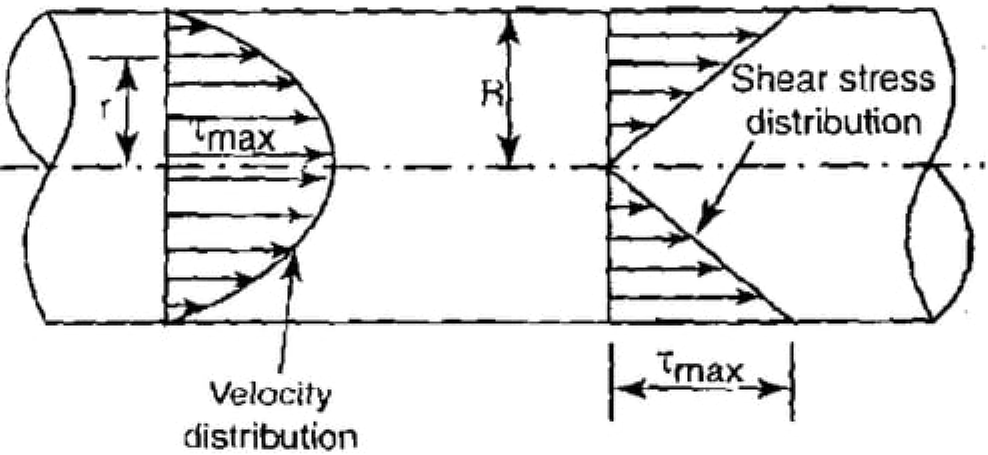
Where

L = The lift force

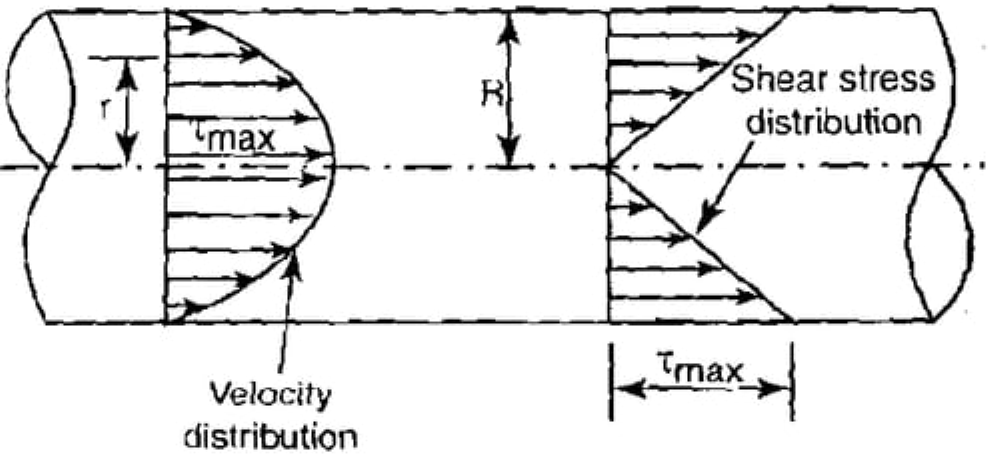
S = Plan form area and

q = The fluid dynamic pressure.

2.69) Considering laminar flow through a circular pipe, draw the shear stress and velocity distribution across the pipe section. *[AU, Nov / Dec - 2010]*



2.70) Draw the velocity distribution and the shear stress distribution for the flow of circular pipes. *[AU, Nov / Dec - 2016]*



2.71) Considering laminar flow through a circular pipe, obtain an expression for the velocity distribution. *[AU, Nov / Dec - 2012]*

$$u = -\frac{1}{2\mu}\frac{\partial p}{\partial x}(ty - y^2)$$

In the above equation μ, ∂p/∂x and t are constant.

2.72) A circular and a square pipe are of equal sectional area. For the same flow rate, determine which section will lead to a higher value of Reynolds number. *[AU, Nov / Dec - 2011]*

Area of square section A_S = Area of circular section A_C

$$L^2 = \frac{\pi}{4} D^2$$

Where L is the side of a square and D be the diameter of a circular section.

$$L = 0.886\ D$$

Reynold's number for circular section

$$R_{e\ circular} = \frac{\rho v D}{\mu}$$

Reynold's number for square section

$$R_{e\ square} = \frac{\rho v L}{\mu}$$

$$R_{e\ square} = 0.886\ R_{e\ circular}$$

2.73) A 20cm diameter pipe 30km long transport oil from a tanker to the shore at 0.01m^3/s. Find the Reynolds number to classify the flow. Take the viscosity μ = 0.1 Nm/s^2 and density ρ = 900 kg/m^3 for oil. ***[AU, April / May - 2003]***

Given:

D = 0.2m L = 30 * 10^{3}m Q = 0.01m^3/s μ = 0.1 Nm/s^2

ρ = 900 kg/m^3

Solution:

Cross sectional area:

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

$$A = \frac{\pi}{4} * 0.2^2$$

$$A = 0.03141 m^2$$

Velocity of the flow

$$v = \frac{Q}{A}$$

$$v = \frac{0.01}{0.03141}$$

$$v = 0.318\ m/s$$

$$R_e = \frac{\rho v D}{\mu}$$

$$R_e = \frac{900 * 0.318 * 0.2}{0.1}$$

$$\boldsymbol{R_e = 572.95 < 2000}$$

The flow is **laminar**

2.74) Find the loss of head when a pipe of diameter 200 mm is suddenly enlarged to a diameter 0f 400 mm. Rate of flow of water through the pipe is 250 litres/s.

[AU, April / May - 2010]

Given:

$D_1 = 200mm$ $D_2 = 400mm$ $Q = 0.250 m^3/s$

Solution:

From continuity equation:

$$Q = A_1 V_1$$

$$.250 = \frac{\pi}{4} * 0.2^2 * V_1$$

$$V_1 = 7.95\ m/s$$

From continuity equation:

$$Q = A_2 V_2$$

$$.250 = \frac{\pi}{4} * 0.4^2 * V_2$$

$$V_2 = 1.98\ m/s$$

Head loss due to enlargement

$$h_e = \frac{(V_1 - V_2)^2}{2g}$$

$$h_e = \frac{(7.95 - 1.98)^2}{2 * 9.81}$$

$$\boldsymbol{h_e = 1.81m}$$

2.75) Find the displacement thickness for the velocity distribution in the boundary layer given by $\frac{u}{U} = 2\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^2$ *[AU, Nov / Dec - 2016]*

Given:

$$\frac{u}{U} = 2\frac{y}{\delta} - \left(\frac{y}{\delta}\right)^2$$

Solution:

$$\boldsymbol{\delta^* = \int_0^\delta \left(1 - \frac{u}{U}\right) dy}$$

$$\delta^* = \int_0^\delta \left(1 - \left(2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2\right)\right) dy$$

$$\delta^* = \left[y - \frac{2y^2}{2\delta} + \frac{y^3}{3\delta^2}\right]_0^\delta$$

$$\boldsymbol{\delta^* = \frac{\delta}{3}}$$

UNIT - III - DIMENSIONAL ANALYSIS

3.1) What do you understand by fundamental units and derived units?

[AU, April / May - 2010]

The physical parameters are independent of each other called fundamental or primary quantities / parameters. Example: Mass, length and time

The parameters which are expressed in terms of primary quantities are called secondary or derived quantities. Example: velocity, force and power.

3.2) Differentiate between fundamental units and derived units. Give examples.

[AU, Nov / Dec - 2011]

Fundamental Units	Derived Units
❖ The physical parameters are independent of each other called fundamental or primary quantities / parameters. ❖ Example: Mass, length and time	❖ The parameters which are expressed in terms of primary quantities are called secondary or derived quantities. ❖ Example: velocity, force and power.

3.3) What do you mean by dimensional analysis? *[AU, Nov / Dec - 2009]*

Dimensional analysis is a mathematical technique which deals with the dimensions of the physical quantities involved in the phenomenon. Some complex problems in nature and very difficult to solve. This type of problem can be simplified by using dimensional analysis.

3.4) State the methods of dimensional analysis. *[AU, Nov / Dec - 2016]*

The methods of dimensional analysis are

- ❖ Rayleigh's method
- ❖ Buckingham π theorem
- ❖ Bridge man's method
- ❖ Matrix tensor method

3.5) What are the limitations of dimensional analysis? *[AU, Nov / Dec - 2016]*

The limitations of dimensional analysis are

- Dimensional analysis tells us nothing about the dimensionless constant of an equation
- This method cannot be used with exponential and trigonometric functions.
- The method cannot be used if the physical quantity contains more than one term in one side of the equation
- It does not have any specific rule, regarding the selection of variables

3.6) Brief on dimensional variables with examples. ***[AU, Nov / Dec - 2014]***

Dimensional variables are the quantities that actually vary during a given case and would be plotted against each other to show the data.

$$S = S_0 + V_0 t + \frac{1}{2} g t^2$$

In the above equation dimensional variables are S and t

$$\frac{p}{\rho} + \frac{1}{2}V^2 + gz = \text{const}$$

In the above equation dimensional variables are p, V, and z.

3.7) Brief on Intuitive method. Give some examples. ***[AU, Nov / Dec - 2014]***

Most Dimensional analysis methods are called as Intuitive method, with the help of units and dimensions they are able to form a physical relationship among several variables. Examples Buckingham π Theorem & Rayleigh's method of dimensional analysis

3.8) What is dimensional homogeneity and write any one sample equation? ***[AU, Nov / Dec - 2006]***

Dimensional analysis is based on the principle that the variables in a physical phenomenon is arranged properly to give an equation which is dimensionally homogenous.

To check the dimensional homogeneity of the Dracy's Equation.

$$h_f = \frac{flV^2}{2gd}$$

Dimension of L.H.S = h_f = L

Dimension of R.H.S $= \frac{flV^2}{2gd} = \frac{1*L*(L/T)^2}{2*\left(\frac{L}{T^2}\right)*L} = \mathrm{L}$

Where f constant is taken as 1 and number 2 is neglected

Dimension of L.H.S = Dimension of R.H.S

3.9) Define dimensional homogeneity. *[AU, Nov / Dec - 2015]*

Dimensional analysis is based on the principle that the variables in a physical phenomenon is arranged properly to give an equation which is dimensionally homogenous.

To check the dimensional homogeneity of the Dracy's Equation.

$$h_f = \frac{flV^2}{2gd}$$

Dimension of L.H.S = h_f = L

Dimension of R.H.S $= \frac{flV^2}{2gd} = \frac{1*L*(L/T)^2}{2*\left(\frac{L}{T^2}\right)*L} = \mathrm{L}$

Where f constant is taken as 1 and number 2 is neglected

Dimension of L.H.S = Dimension of R.H.S

3.10) Explain the term dimensional homogeneity. *[AU, Nov / Dec - 2011]*

The law of Fourier principle of dimensional homogeneity states "an equation which expresses a physical phenomenon of fluid flow should be algebraically correct and dimensionally homogenous"

Dimensional analysis is based on the principle that the variables in a physical phenomenon is arranged properly to give an equation which is dimensionally homogenous.

To check the dimensional homogeneity of the Dracy's Equation.

$$h_f = \frac{flV^2}{2gd}$$

Dimension of L.H.S = h_f = L

Dimension of R.H.S $= \frac{flV^2}{2gd} = \frac{1*L*(L/T)^2}{2*\left(\frac{L}{T^2}\right)*L} = \mathrm{L}$

Where f constant is taken as 1 and number 2 is neglected

Dimension of L.H.S = Dimension of R.H.S

3.11) State a few applications, usefulness of 'dimensional analysis'.

[AU, May / June - 2007]

- It is used to change the theoretical equation into a simple dimensionless form.
- By dimensional analysis, any complex fluid flow phenomenon can be easily solved.
- It helps to convert the units of quantities from one system to another system.

3.12) Give the applications of dimensional analysis. *[AU, Nov / Dec - 2015]*

- It is used to change the theoretical equation into a simple dimensionless form.
- By dimensional analysis, any complex fluid flow phenomenon can be easily solved.
- It helps to convert the units of quantities from one system to another system.

3.13) State the application of dimensional analysis. *[AU, May / June - 2016]*

- It is used to change the theoretical equation into a simple dimensionless form.
- By dimensional analysis, any complex fluid flow phenomenon can be easily solved.
- It helps to convert the units of quantities from one system to another system.

3.14) What is a dimensionally homogenous equation? Give example.

[AU, Nov / Dec - 2003]

Dimensional analysis is based on the principle that the variables in a physical phenomenon is arranged properly to give an equation which is dimensionally homogenous.

To check the dimensional homogeneity of the Dracy's Equation.

$$h_f = \frac{flV^2}{2gd}$$

Dimension of L.H.S = h_f = L

Dimension of R.H.S $= \frac{flV^2}{2gd} = \frac{1*L*(L/T)^2}{2*\left(\frac{L}{T^2}\right)*L} = L$

Where f constant is taken as 1 and number 2 is neglected

Dimension of L.H.S = Dimension of R.H.S

3.15) Cite examples for dimensionally homogeneous and non-homogeneous equations. ***[AU, Nov / Dec - 2010]***

Dimensionally homogeneous equation

- Head loss in flow through pipes
- Reynolds number
- Bernoulli's equation

Non – homogenous equation

- Equation of simple harmonic motion
- The second order linear equation of both free and forced damped oscillation

3.16) Check whether the following equation is dimensionally homogeneous.
Q =Cd .a √(2 gh) . ***[AU, April / May - 2011]***

$$Q = C_d * a\sqrt{2gh}$$

Dimension of each parameter

Q	=	Discharge	$= L^3T^{-1}$
C_d	=	Coefficient of discharge	= 1
a	=	Area	$= L^2$
g	=	Acceleration	$= LT^{-2}$
h	=	Height	= L

$$L^3T^{-1} = L^2 * (LT^{-2} * L)^{1/2}$$

$$L^3T^{-1} = L^2 * (L^2T^{-2})^{1/2}$$

$$L^3T^{-1} = L^3T^{-1}$$

Since both the sides are identical. The given equation is dimensionally homogenous

3.17) Write the dimensions of surface tension and vapour pressure in MLT system. *[AU, April / May - 2015]*

Surface tension = MT^{-2}

Vapour pressure = $ML^{-1}T^{-2}$

3.18) Give the Rayleigh method to determine dimensionless groups.

[AU, Nov / Dec - 2011]

- First the functional relationship is written with the given data. Consider X as a variable which depends on $X_1, X_2, X_3 \ldots X_n$. So, the functional equation is written as $X = f(X_1, X_2, X_3 \ldots X_n)$
- Then the equation is expressed in the terms of a constant with exponents like powers of a, b, c … Therefore the equation is again written as $X = \Phi(X_1^a, X_2^b, X_3^c \ldots X_n^z)$. Here Φ = constant. a ,b, c…z are arbitrary constants.
- The values of a, b, c … z are determined with the help of dimensional homogeneity. It means, the powers of the fundamental dimensions on both sides are compared to obtain the values of exponents.
- Finally, the exponent's power values are substituted in the functional equation and simplified to obtain the suitable form.

3.19) State any two choices of selecting repeating variables in Buckingham π theorem. *[AU, April / May - 2011]*

- No repeating variable should be dimensionless
- The selected two repeating variables should not have the same dimensions.
- The selected repeating variables should be independent as far as possible.

3.20) State Buckingham's π theorem.

[AU, Nov / Dec – 2008, 2012, April / May – 2015, 2017]

It states that if there are 'n' variables in a dimensionally homogenous equation and if these variables contain 'm' fundamental dimensions (M, L, T) then they are grouped into (n – m), dimensionless independent π – terms.

3.21) State Buckingham's π theorem. Why this method is considered superior to Rayleigh's method? *[AU, Nov / Dec - 2016]*

It states that if there are 'n' variables in a dimensionally homogenous equation and if these variables contain 'm' fundamental dimensions (M, L, T) then they are grouped into (n – m), dimensionless independent π – terms.

The Rayleigh's method has a limitations if the number of parameters or variables are more than four. If the variables are more than four it is difficult to find the expression for dependent variable. Where more variables can be solved using Buckingham's π theorem.

3.22) The excess pressure Δp inside a bubble is known to be a function of the surface tension and the radius. By dimensional reasoning determine how the excess pressure. Will vary if we double the surface tension and the radius.

[AU, Nov / Dec - 2013]

$$\Delta p = f(a\,, r) = \;(constant)a^a r^b$$

$$\left(\frac{F}{L^2}\right) = \left(\frac{F}{L}\right)^a (L)^b$$

F: a =1 L: -a+b = -2

b = -1

$$\Delta p = \frac{\sigma}{r}$$

If σ is doubled Δp is doubled

If r is doubled Δp is half

3.23) Distinguish between Rayleigh's method and Buckingham's π- theorem.

[AU, April / May - 2011]

Rayleigh's method	Buckingham's π- theorem
❖ The expression is determined for a variable depending upon maximum three or four variables only	❖ It is easy for the number of independent variables being more than three or four
❖ This method is difficult for more than four variables	❖ In this method 'n' variables can be used without any difficulties

3.24) Define similitude. *[AU, April / May - 2017]*

It is defined as the similarity between the model and its prototype in every aspect. It means, the model and prototype have similar properties or model and prototype are completely similar.

3.25) What are the similitudes that should exist between the model and its prototype? *[AU, April / May - 2015]*

- ❖ Geometric similitude
- ❖ Kinematic similitude
- ❖ Dynamic similitude

3.26) What are the types of similarities? *[AU, Nov / Dec - 2012]*

- ❖ Geometric similarity
- ❖ Kinematic similarity
- ❖ Dynamic similarity

3.27) What is meant by dynamic similarity? *[AU, Nov / Dec - 2008]*

Dynamic similarity means the similarity of forces between the model and prototype. Thus the dynamic similarity is said to exist between the model and the prototype if the ratios of the corresponding forces acting at the corresponding points are equal.

Let $(F_i)_p$ = Inertia force at a point in prototype

$(F_v)_p$ = Viscous force at a point in prototype

$(F_g)_p$ = Gravity force at a point in prototype

$(F_i)_m$ = Inertia force at a point in model

$(F_v)_m$ = Viscous force at a point in model

$(F_g)_m$ = Gravity force at a point in model

F_r = Force ratio

$$\frac{(F_i)_p}{(F_i)_m} = \frac{(F_v)_p}{(F_v)_m} = \frac{(F_g)_p}{(F_g)_m} = F_r$$

3.28) What is dynamic similarity? *[AU, Nov / Dec - 2009]*

Dynamic similarity means the similarity of forces between the model and prototype. Thus the dynamic similarity is said to exist between the model and the prototype if the ratios of the corresponding forces acting at the corresponding points are equal.

Let $(F_i)_p$ = Inertia force at a point in prototype

$(F_v)_p$ = Viscous force at a point in prototype

$(F_g)_p$ = Gravity force at a point in prototype

$(F_i)_m$ = Inertia force at a point in model

$(F_v)_m$ = Viscous force at a point in model

$(F_g)_m$ = Gravity force at a point in model

F_r = Force ratio

$$\frac{(F_i)_p}{(F_i)_m} = \frac{(F_v)_p}{(F_v)_m} = \frac{(F_g)_p}{(F_g)_m} = F_r$$

3.29) What is meant by kinematic similarity? ***[AU, Nov / Dec - 2014]***

Kinematic similarity means similarity of motion between model and prototype. Thus the similarity is said to exist between the model and prototype if the ratios of the velocity and acceleration at the corresponding points in the model and the corresponding points in the prototype are the same.

Let V_{p1} = Velocity of fluid at a point 1 in prototype

V_{p2} = Velocity of fluid at a point 2 in prototype

a_{p1} = Acceleration of fluid at a point 1 in prototype

a_{p2} = Acceleration of fluid at a point 2 in prototype

V_{m1} = Velocity of fluid at a point 1 in model

V_{m2} = Velocity of fluid at a point 2 in model

a_{m1} = Acceleration of fluid at a point 1 in model

a_{m2} = Acceleration of fluid at a point 2 in model

$$\frac{V_{p1}}{V_{m2}} = \frac{V_{p2}}{V_{m2}} = V_r$$

$$\frac{a_{p1}}{a_{m2}} = \frac{a_{p2}}{a_{m2}} = a_r$$

3.30) What is similarity in model study? ***[AU, April / May - 2005]***

Similitude is defined as the similarity between the model and its prototype in every respect, which means that the model and prototype have similar properties or model and prototype are completely similar. There are three types of similarities exists between the model and prototype

- Geometric Similarity
- Kinematic Similarity
- Dynamic Similarity

3.31) Explain the types of similarities. *[AU, April / May - 2017]*

Geometric Similarity is the similarity of size and shape between the model and its prototype.

L_m = Length of model

b_m = Breadth of model

D_m = Diameter of model

L_p = Length of prototype

b_p = Breadth of prototype

D_p = Diameter of prototype

$$\frac{L_p}{L_m} = \frac{b_p}{b_m} = \frac{D_p}{D_m} = L_r$$

Kinematic similarity means similarity of motion between model and prototype. Thus the similarity is said to exist between the model and prototype if the ratios of the velocity and acceleration at the corresponding points in the model and the corresponding points in the prototype are the same.

Let V_{p1} = Velocity of fluid at a point 1 in prototype

V_{p2} = Velocity of fluid at a point 2 in prototype

a_{p1} = Acceleration of fluid at a point 1 in prototype

a_{p2} = Acceleration of fluid at a point 2 in prototype

V_{m1} = Velocity of fluid at a point 1 in model

V_{m2} = Velocity of fluid at a point 2 in model

a_{m1} = Acceleration of fluid at a point 1 in model

a_{m2} = Acceleration of fluid at a point 2 in model

$$\frac{V_{p1}}{V_{m2}} = \frac{V_{p2}}{V_{m2}} = V_r$$

$$\frac{a_{p1}}{a_{m2}} = \frac{a_{p2}}{a_{m2}} = a_r$$

Dynamic similarity means the similarity of forces between the model and prototype. Thus the dynamic similarity is said to exist between the model and the prototype if the ratios of the corresponding forces acting at the corresponding points are equal.

Let $(F_i)_p$ = Inertia force at a point in prototype

$(F_v)_p$ = Viscous force at a point in prototype

$(F_g)_p$ = Gravity force at a point in prototype

$(F_i)_m$ = Inertia force at a point in model

$(F_v)_m$ = Viscous force at a point in model

$(F_g)_m$ = Gravity force at a point in model

F_r = Force ratio

$$\frac{(F_i)_p}{(F_i)_m} = \frac{(F_v)_p}{(F_v)_m} = \frac{(F_g)_p}{(F_g)_m} = F_r$$

3.32) What is scale effect in physical model study?

[AU, Nov / Dec – 2005, 2006, May / June– 2012]

It is impossible to product the exact behavior of the prototype by model testing alone. The two models of same prototype behavior will be different. Scale ratios will not be same. So discrepancy between models and prototype will always occur. It is known as scale effect.

3.33) What is the effect of scale effect and distorted model in dimensional analysis?

[AU, May / June - 2016]

It is impossible to product the exact behavior of the prototype by model testing alone. The two models of same prototype behavior will be different. Scale ratios will not be same. So discrepancy between models and prototype will always occur. It is known as scale effect.

3.34) Mention the circumstances which necessitate the use of distorted models.

[AU, Nov / Dec - 2010]

- ❖ To maintain accuracy
- ❖ To maintain turbulent flow
- ❖ To accommodate available facilities
- ❖ To obtain suitable bed materials

- To obtain required roughness condition.

3.35) Write down the dimensionless number for pressure. ***[AU, Nov / Dec - 2011]***

Pressure P $= ML^{-1}T^{-2}$

3.36) Give the dimensions of power and specific weight. ***[AU, Nov / Dec - 2009]***

Power P $= ML^{2}T^{-2}$

Specific weight w $= ML^{-2}T^{-2}$

3.37) Give the dimensions of the following physical quantities: surface tension and dynamic viscosity. ***[AU, May / June - 2013]***

Surface tension σ $= MT^{-2}$

Dynamic viscosity μ $= ML^{-1}T^{-1}$

3.38) Define Reynold's number. What its significance? ***[AU, Nov / Dec - 2010]***

It is defined as the ratio of inertia force of a flowing fluid and viscous force of the fluid.

- Motion of air planes
- Flow is incompressible fluid in close pipes
- Motion of submarines
- Flow around structures and other bodies immersed fully in moving fluids

3.39) Define Reynold's number and state its significance? ***[AU, April / May - 2015]***

It is defined as the ratio of inertia force of a flowing fluid and viscous force of the fluid.

- Motion of air planes
- Flow is incompressible fluid in close pipes
- Motion of submarines
- Flow around structures and other bodies immersed fully in moving fluids

3.40) Derive the expression for Reynolds's Number. ***[AU, Nov / Dec - 2015]***

Reynold's number is defined as the ratio of inertia force of a flowing fluid and viscous force of the fluid.

$$R_e = \frac{Inertia\ Force}{Viscous\ force} = \frac{F_i}{F_v}$$

$$R_e = \frac{\rho A V^2}{\mu \frac{V}{L} A} = \frac{\rho V L}{\mu}$$

3.41) Define Reynold's number and Froude's numbers.

[AU, Nov / Dec – 2007, 2011]

Reynold's number is defined as the ratio of inertia force of a flowing fluid and viscous force of the fluid.

Froude's number is defined as the square root of the ratio of inertia force of a slowing fluid to the gravity force.

3.42) Define Froude's number.

[AU, Nov / Dec – 2005, 2009, 2008, April / May – 2010, May / June - 2012]

Froude's number is defined as the square root of the ratio of inertia force of a slowing fluid to the gravity force.

3.43) Define the Froude's dimensionless number. *[AU, May / June - 2014]*

Froude's number is defined as the square root of the ratio of inertia force of a slowing fluid to the gravity force.

3.44) State Froude's model law. *[AU, May / June - 2013]*

Froude model law is the law in which the models are based on Froude number which means for dynamic similarity between the model and prototype, the Froude number for both model and prototype must be equal. Froude model law is applicable when the gravity force is only predominant force which controls the flow in addition to the force of inertia.

3.45) Derive the scale ratio for velocity and pressure intensity using Froude model law. *[AU, Nov / Dec - 2016]*

Velocity Ratio

$$(F_e)_{model} = (F_e)_{prototype}$$

$$\frac{V_m}{\sqrt{g_m L_m}} = \frac{V_p}{\sqrt{g_p L_p}}$$

Since $g_m = g_p$

$$\frac{V_m}{\sqrt{L_m}} = \frac{V_p}{\sqrt{L_p}}$$

$$\frac{\sqrt{L_p}}{\sqrt{L_m}} = \frac{V_p}{V_m}$$

$$\sqrt{\boldsymbol{L_r}} = \boldsymbol{V_r}$$

Pressure Intensity

$$p = \frac{force}{area} = \frac{\rho L^2 V^2}{L^2} = \rho V^2$$

$$p_r = \frac{p_p}{p_m} = \frac{\rho_p {V^2}_p}{\rho_m {V^2}_m}$$

Since the fluid is same $\rho_p = \rho_m$

$$p_r = \frac{{V^2}_p}{{V^2}_m} = \left(\frac{V_p}{V_m}\right)^2 = \left(\sqrt{L_r}\right)^2$$

$$\boldsymbol{p_r = L_r}$$

3.46) Define Euler's number. *[AU, May / June - 2009]*

Euler's number is the ratio of the square root of inertia force and pressure force.

3.47) Define Euler number and Mach number. *[AU, May / June - 2007]*

Euler's number is the ratio of the square root of inertia force and pressure force.

Mach's number is defined as the square root of the ratio of the inertia force of a flowing fluid to the elastic force.

3.48) Brief on Euler number. *[AU, May / June - 2016]*

Euler's number is the ratio of the square root of inertia force and pressure force.

$$E_u = \sqrt{\frac{Inertia\ Force}{Pressure\ force}} = \sqrt{\frac{F_i}{F_p}}$$

$$E_u = \sqrt{\frac{\rho A V^2}{p * A}} = \frac{V}{\sqrt{p/\rho}}$$

3.49) Define Reynold's number and Mach number. *[AU, Nov / Dec - 2012]*

Reynold's number is defined as the ratio of inertia force of a flowing fluid and viscous force of the fluid.

Mach's number is defined as the square root of the ratio of the inertia force of a flowing fluid to the elastic force.

3.50) Define Mach number. *[AU, May / June - 2009]*

Mach's number is defined as the square root of the ratio of the inertia force of a flowing fluid to the elastic force.

3.51) Define -Mach number and state its application. *[AU, Nov / Dec - 2014]*

Mach's number is defined as the square root of the ratio of the inertia force of a flowing fluid to the elastic force. Its applications are

- Aerodynamic testing
- Under water testing of torpedoes
- Water – hammer problems

3.52) Write the expression for Mach number and state its applications.

[AU, April / May - 2017]

The expression for Mach number is

$$M = \frac{V}{\sqrt{K/\rho}} = \frac{V}{C}$$

Where C - Velocity of sound in the fluid

Its applications are

- Aerodynamic testing
- Under water testing of torpedoes
- Water – hammer problems

3.53) What is Mach number? Mention its field of use. *[AU, April / May - 2003]*

Mach's number is defined as the square root of the ratio of the inertia force of a flowing fluid to the elastic force. It is used in

- Aerodynamic testing
- Under water testing of torpedoes
- Water – hammer problems

UNIT – IV – PUMPS

4.1) Mention the main parts of the Centrifugal pump. ***[AU, Nov / Dec - 2012]***

- Impeller
- Casing
- Suction pipe
- Delivery pipe
- Strainer and foot valve
- Delivery valve

4.2) How centrifugal pumps are classified based on casing?

[AU, May / June - 2006]

- Volute pump or constant velocity pump
- Vortex pump or variable velocity pump
- Diffuser or turbine pump

4.3) List the commonly used casings in centrifugal pumps.

[AU, Nov / Dec - 2010]

- Volute casing
- Vortex casing
- Volute casing with guide blades

4.4) What is the role of a volute chamber of a centrifugal pump?

[AU, Nov / Dec - 2005]

- To guide water to and from the impeller
- To partially convert the kinetic energy into pressure energy

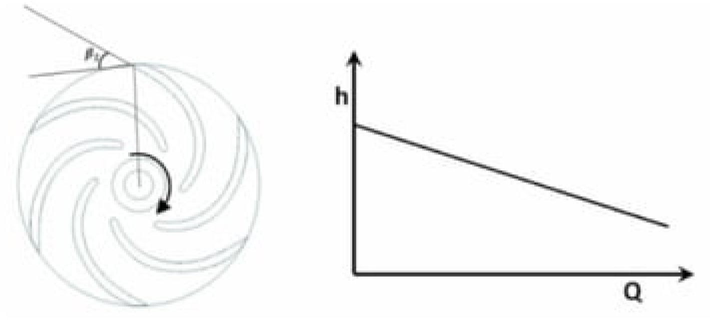
4.5) What is the function of volute casing? ***[AU, Nov / Dec - 2015]***

- To guide water to and from the impeller
- To partially convert the kinetic energy into pressure energy

4.6) Explain curved blades used in centrifugal pumps?

Backward Curved Blades

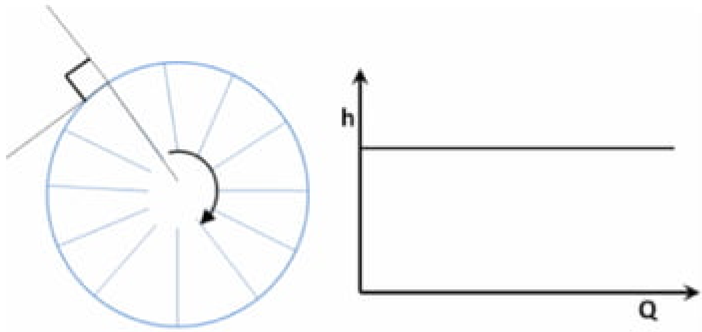
If beta is less than 90 degree. Since second term in LHS of head vs flow equation is positive in this case, pressure head decreases with increase in flow. These kinds of impellers are called backward curved.



Head vs Flow rate curve for a bacward curved blade impeller

Radial Blades

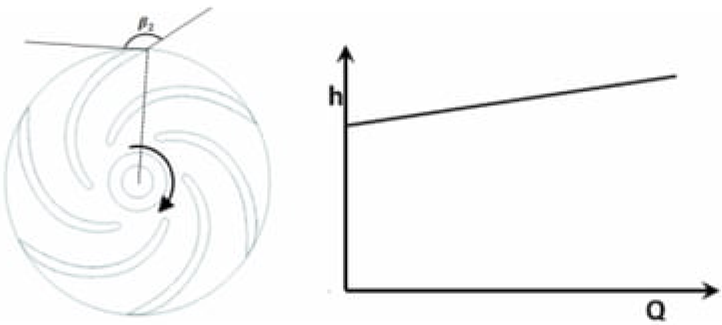
If beta is 90 degree, with flow rate there is no change in pressure rise. Because second term in LHS of head vs flow equation is zero here. They are called Radial type.



Head vs Flow rate curve for a radial blade impeller

Forward Curved Blades

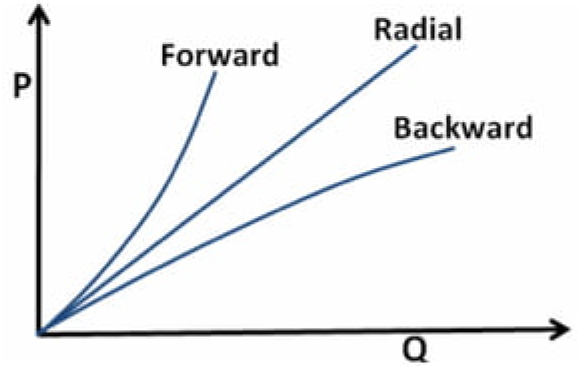
If beta is more than 90 degree, pressure increases with increase in flow rate. Such blades are called forward curved blades.



Head vs Flow rate curve for a forward curved blade impeller

Suited Blade for Industrial Use

For backward curved blades as energy head decreases with discharge power consumption stabilizes with flow. In radial blades since head does not have any connection with flow rate, power consumption increases linearly. In forward curved blades since energy head increases with flow power consumption increases exponentially. This will make the operation unstable and will eventually lead to burnout of motor.



Power consumption in different blade geometries

4.7) Why is forward curved blading rarely used in pumps?

[AU, May / June - 2016]

In forward curved blades since energy head increases with flow power consumption increases exponentially. This will make the operation unstable and will eventually lead to burnout of motor. For backward curved blades as energy head decreases with discharge power consumption stabilizes with flow. In radial blades since head does not have any connection with flow rate, power consumption increases linearly.

4.8) What precautions are to be taken while starting and closing the centrifugal pump? ***[AU, May / June - 2012]***

- While starting the pump. The delivery valve is closed. Priming of the pump is carried out.
- Before stopping the pump, it is necessary to close the delivery pipe otherwise the back flow of liquid may take place from the high head reservoir.

4.9) What is priming? *[AU, Nov / Dec - 2010]*

Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe up to the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped.

4.10) Why priming is necessary in a centrifugal pump?

[AU, May / June - 2007, April / May - 2010]

Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe up to the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped.

If the pump is started with air pockets inside the impeller may give rise to vortices and causes the discontinuity of flow. Under these conditions, the flow of fluid does no commence and the pump runs dry. It causes the rubbing and seizing of the wearing rings, increases noise level and vibrations and finally may cause series damage to pump.

4.11) What is meant by priming of pumps? *[AU, April / May - 2008]*

Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe up to the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped.

4.12) What is priming? Why is it necessary? *[AU, Nov / Dec - 2011]*

Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe up to the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped.

If the pump is started with air pockets inside the impeller may give rise to vortices and causes the discontinuity of flow. Under these conditions, the flow of fluid does no commence and the pump runs dry. It causes the rubbing and seizing of the wearing rings, increases noise level and vibrations and finally may cause series damage to pump.

4.13) What is meant by priming of a centrifugal pump? Why it is necessary?

[AU, Nov / Dec - 2016]

Priming of a centrifugal pump is defined as the operation in which the suction pipe, casing of the pump and a portion of the delivery pipe up to the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped.

If the pump is started with air pockets inside the impeller may give rise to vortices and causes the discontinuity of flow. Under these conditions, the flow of fluid does no commence and the pump runs dry. It causes the rubbing and seizing of the wearing rings, increases noise level and vibrations and finally may cause series damage to pump.

4.14) Define cavitation. ***[AU, Nov / Dec - 2008]***

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below the vapour pressure and the sudden collapsing on these vapour in a region of high pressure.

4.15) Define cavitation in a pump. ***[AU, May / June - 2007]***

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below the vapour pressure and the sudden collapsing on these vapour in a region of high pressure.

4.16) What is the effect of cavitation in pump? ***[AU, April / May - 2011]***

- ❖ The metallic surfaces are damaged and cavities are formed on the surfaces.
- ❖ Due to sudden collapse of vapour bubble, considerable noise and vibrations are produced.
- ❖ The efficiency of a pump decreases due to cavitation.
- ❖ Due to pitting action, the surface on the impeller becomes rough.

4.17) What are the effects of cavitation? Give necessary precautions against cavitation? *[AU, May / June - 2012]*

The effects of cavitation are

- ❖ The metallic surfaces are damaged and cavities are formed on the surfaces.
- ❖ Due to sudden collapse of vapour bubble, considerable noise and vibrations are produced.
- ❖ The efficiency of a pump decreases due to cavitation.
- ❖ Due to pitting action, the surface on the impeller becomes rough.

Precautions against cavitation

- ❖ The pressure of the flowing liquid in any part of the hydraulic system should not allowed to fall below its vapour pressure. If the flowing liquid is water, then the absolute pressure head should not be below 2.5m of water.
- ❖ The special materials or coatings such as aluminum – bronze and stainless steel, which are cavitation resistant materials, should be used.

4.18) What is cavitation? *[AU, Nov / Dec - 2013]*

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below the vapour pressure and the sudden collapsing on these vapour in a region of high pressure.

4.19) Explain the cavitation problem in Centrifugal pumps *[AU, Nov / Dec - 2015]*

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below the vapour pressure and the sudden collapsing on these vapour in a region of high pressure.

Effect of Cavitation:

- ❖ The metallic surfaces are damaged and cavities are formed on the surfaces.
- ❖ Due to sudden collapse of vapour bubble, considerable noise and vibrations are produced.
- ❖ The efficiency of a pump decreases due to cavitation.
- ❖ Due to pitting action, the surface on the impeller becomes rough

4.20) What is cavitation in pump? How it can be avoided? ***[AU, May / June - 2016]***

Cavitation is defined as the phenomenon of formation of vapour bubbles of a flowing liquid in a region where the pressure of the liquid falls below the vapour pressure and the sudden collapsing on these vapour in a region of high pressure.

Cavitation can be avoided by following some precautions

- ❖ The pressure of the flowing liquid in any part of the hydraulic system should not allowed to fall below its vapour pressure. If the flowing liquid is water, then the absolute pressure head should not be below 2.5m of water.
- ❖ The special materials or coatings such as aluminum – bronze and stainless steel, which are cavitation resistant materials, should be used.

4.21) List the losses in centrifugal pump. ***[AU, Nov / Dec - 2014]***

- ❖ **Mechanical friction losses** between the fixed and rotating parts in the bearings and gland and packing.
- ❖ **Disc friction loss** between the impeller surfaces and the fluid.
- ❖ **Leakage and recirculation losses.** The recirculation is along the clearance between the impeller and the casing due to the pressure difference between the hub and tip of the impeller

4.22) What are the advantages of centrifugal pump over reciprocating pumps? ***[AU, May / June - 2009]***

- ❖ Its discharge capacity is much higher
- ❖ It can also be used for highly viscous fluids like oils, muddy and sewage water, chemicals, paper pulp less
- ❖ Being high speed machine it can be directly coupled to the prime mover
- ❖ It is compact, smaller in size and has low weight for the same discharge capacity
- ❖ Maintenance cost is comparatively very low.

4.23) What is the maximum theoretical suction head possible for a centrifugal pump? ***[AU, April / May - 2008]***

$$h_s = H_a - H_v - \frac{{v_s}^2}{2g} - h_{fs}$$

h_s = = Height of inlet of pump from datum line

H_a = $p_a/\rho g$ = Atmospheric pressure head (meter of liquid)

H_v = $p_v/\rho g$ = Vapour pressure head (meter of liquid)

v_s = = Velocity of liquid through suction pipe

h_{fs} = = Loss of head in foot valve, strainer and suction pipe

4.24) Tabulate the causes and remedies for a centrifugal pump, when pump fails to pump the fluid. ***[AU, April / May - 2015]***

S.No	Fault	Other Symptoms	Cause	Remedies
1	No Output	❖ Suction and delivery gauges read zero	❖ Pump has lost its water due to air lock in suction pipe, air leaks in suction pipe, air leaks in stuffing boxes, or level of water dropped below strainers	❖ Stop and reprime. ❖ Remake pipe joints. ❖ Tighten glands or repack lengthen suction pipe to lower strainer
		❖ Suction gauge reads zero but delivery gauge normal	❖ Speed too low to overcome the total head, or choke in delivery pipe	❖ Increase speed. ❖ Clear choke in delivery pipe.
2	Poor Output : it should be note that unless a flow meter is provided, the pump	❖ Surging in delivery pressure gauge	❖ Air leak in suction pipe or stuffing boxes or air entering strainer	❖ Increase speed. ❖ Clear choke in delivery pipe.
		❖ Suction gauge shows high	❖ Chocked strainer, foot valve or suction pipe.	❖ Clean strainer, foot valve or suction pipe

	attendant has very little to inform him that the output of the pump is not normal	vacuum, vibration and noise	❖ Vibration and noise due to cavitation	
		❖ Suction gauge shows low vacuum	❖ Impeller partly chocked. ❖ Partial choke in delivery pipe	❖ Clean impeller. ❖ Clean choke in delivery pipe
		❖ Pump not running upto speed	❖ Motor defective ❖ Voltage low ❖ Belt slipping	❖ Replace or overhaul ❖ Check and rectify ❖ Tighten belt

4.25) Define suction head and manometric head of a centrifugal pump.

[AU, Nov / Dec - 2012]

Suction head (h_s) is the vertical height of the center line of the centrifugal pump above the water surface in the tank or pump from which water is lifted. This height is also called suction lift.

The Manometric head (H_m) is defines as the head against which a centrifugal pump has to work.

4.26) Define - manometric head and write its mathematical equation.

[AU, Nov / Dec - 2013]

The Manometric head (H_m) is defines as the head against which a centrifugal pump has to work.

H_m = Head imparted by the impeller to the water – loss of head in the pump

$$H_m = h_s + h_d + h_{fs} + h_{fd} + \frac{{V_d}^2}{2g}$$

h_s = Suction head

h_d = Delivery head

h_{fs} = Frictional head loss in suction pipe

h_{fd} = Frictional head loss in delivery pipe

V_d = Velocity of water in delivery pipe

4.27) What do you mean by 'Net Positive Suction Head' (NPSH)?

[AU, May / June - 2014]

The **N**egative **P**ositive **S**uction **H**ead (NPSH) is defined as the absolute pressure head at the inlet to pump, minus the vapour pressure head (in absolute units) plus the velocity head.

NPSH = Absolute pressure head at inlet of the pump – vapour pressure head (absolute units) + velocity head

4.28) Define 'Net Positive Suction Head' ***[AU, Nov / Dec - 2014]***

The **N**egative **P**ositive **S**uction **H**ead (NPSH) is defined as the absolute pressure head at the inlet to pump, minus the vapour pressure head (in absolute units) plus the velocity head.

NPSH = Absolute pressure head at inlet of the pump – vapour pressure head (absolute units) + velocity head

4.29) What is meant by NPSH? ***[AU, Nov / Dec - 2014]***

The **N**egative **P**ositive **S**uction **H**ead (NPSH) is defined as the absolute pressure head at the inlet to pump, minus the vapour pressure head (in absolute units) plus the velocity head.

NPSH = Absolute pressure head at inlet of the pump – vapour pressure head (absolute units) + velocity head

4.30) Write the equation for specific speed for pumps and also for turbine.

[AU, Nov / Dec - 2005]

Specific speed of pump

$$N_s = \frac{N\sqrt{Q}}{{H_m}^{3/4}}$$

N = Speed of the pump

Q = Discharge of the pump

H_m = Manometric head

Specific speed of turbine

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

N = Speed of the turbine

P = Power developed

H = Head

4.31) Define specific speed as applied to pumps. *[AU, May / June - 2009]*

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver one cubic meter of liquid per second against a head of one meter.

4.32) Define specific speed. *[AU, Nov / Dec - 2007]*

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver one cubic meter of liquid per second against a head of one meter.

4.33) What is specific speed of a pump? How are pumps classified based on this number? *[AU, Nov / Dec - 2009]*

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver one cubic meter of liquid per second against a head of one meter.

Pump	Speed N	Specific speed
Radial flow	Slow	10 – 30
	Medium	30 – 50
	High	50 – 80
Mixed flow	-	80 – 160
Axial flow	-	100 – 450

4.34) Define specific speed of a centrifugal pump, giving its importance.

[AU, Nov / Dec - 2015]

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver one cubic meter of liquid per second against a head of one meter.

- To know the basic geometry of impeller.
- To know the maximum obtainable efficiency

4.35) Define manometric efficiency and mechanical efficiency of a centrifugal pump. *[AU, April / May - 2015]*

Manometric efficiency is the ratio of the manometric head to the head imparted by the impeller to the water

$$\eta_{man} = \frac{Manometric\ head}{head\ imparted\ by\ impeller\ to\ water}$$

Mechanical efficiency is the ratio of the power available at the impeller to the power at the shaft of the centrifugal pump

$$\eta_{mech} = \frac{Power\ at\ the\ impeller}{Power\ at\ the\ shaft}$$

4.36) What do you mean by manometric efficiency and mechanical efficiency of a centrifugal pump? *[AU, Nov / Dec - 2007]*

Manometric efficiency is the ratio of the manometric head to the head imparted by the impeller to the water

$$\eta_{man} = \frac{Manometric\ head}{head\ imparted\ by\ impeller\ to\ water}$$

Mechanical efficiency is the ratio of the power available at the impeller to the power at the shaft of the centrifugal pump

$$\eta_{mech} = \frac{Power\ at\ the\ impeller}{Power\ at\ the\ shaft}$$

4.37) What are operating characteristics curves of centrifugal pump? *[AU, April / May - 2015]*

The curves which are plotted while the pump is running at a constant design speed. These curves show the relation between efficiency, brake power, head and discharge.

4.38) What is meant by pump? *[AU, Nov / Dec - 2009]*

The hydraulic machines which convert the mechanical energy into hydraulic energy are called as pump

4.39) Under what conditions would you suggest use of double-suction pump and a multistage pump? *[AU, Nov / Dec - 2010]*

- If the need of continuous delivery of fluid
- If uniform discharge of fluid is needed
- If the required discharge of the fluid is more

- If the space is limited to use single suction pump for the higher capacity.

4.40) What are roto dynamic pumps? Give examples. *[AU, Nov / Dec - 2009]*

The centrifugal pump is the common type roto dynamic pump in which the rotating impeller of a pump impresses a centrifugal head or pressure on the liquid which leaves the impeller at a high velocity. This pressure enables the liquid to raise to higher level.

4.41) Why the reciprocating pump is called a positive displacement pump?

[AU, April / May - 2011]

It discharges a definite quantity of a liquid during the displacement of its piston, therefore it is called as positive displacement pump.

4.42) How are reciprocating pumps classified? *[AU, Nov / Dec - 2011]*

According to fluid being contact with piston

- Single acting pump
- Double acting pump

According to number of cylinders

- Single cylinder pump
- Double cylinder pump
- Triple cylinder pump
- Duplex double acting pump
- Quantiplex pump

4.43) What are the materials used for manufacturing reciprocating pumps?

[AU, Nov / Dec - 2014]

- Stainless steel
- Aluminum
- Brass
- Bronze
- Nickel – alloy

4.44) When will you select a reciprocating pump? *[AU, Nov / Dec – 2005, 2015]*

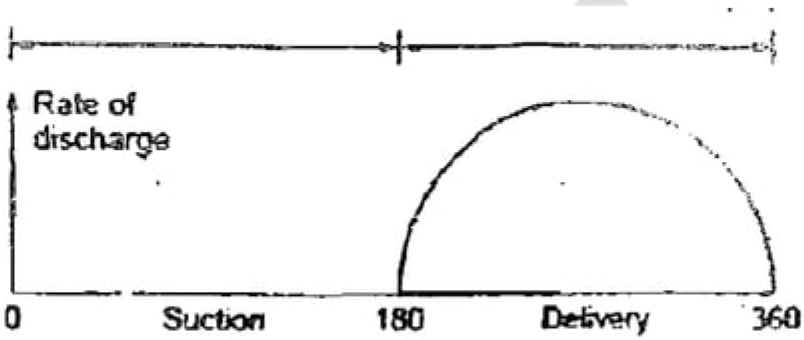
For obtaining high pressure or head and low discharge, a reciprocating pump is selected.

4.45) List the advantages of double acting reciprocating pump.

[AU, Nov / Dec - 2014]

- ❖ Both suction and delivery strikes takes place simultaneously
- ❖ Discharge is continuous and more uniform
- ❖ Rate of discharge is almost twice that of single acting pump

4.46) Draw the relationship between discharge and crank angle for a single acting pump. *[AU, Nov / Dec - 2013]*



4.47) What is the function of non – return valve in a reciprocating pump?

[AU, May / June - 2012]

The function of non – return valve in reciprocating pump to allow the water to flow only in one direction, the suction non return valve allows water from sump to cylinder and the delivery non – return valve allows water from cylinder to delivery pipe.

4.48) Distinguish between centrifugal pump and reciprocating pump.

[AU, Nov / Dec – 2005, 2012]

Centrifugal pump	Reciprocating pump
❖ The discharge is continuous and smooth.	❖ The discharge is fluctuating and pulsating.
❖ Starting torque is more	❖ Staring torque is less
❖ Action on fluid is dynamic	❖ Action on fluid by the pump is due to positive displacement.
❖ Used for lower heads and large discharge	❖ Used for high heads and low discharge

❖ Efficiency is high	❖ Efficiency is low
❖ It is compact	❖ It is comparatively large
❖ Smooth operation without noise	❖ Not smooth in operation and noisy
❖ Maintenance cost is low	❖ Maintenance cost is high
❖ Priming is necessary	❖ Priming is not necessary

4.49) Mention the significance of 'back leakage'. ***[AU, Nov / Dec - 2013]***

As the rotor of rotary positive displacement pump rotates the trapped oil is carried to the pressure side through the clearance which is known as back leakage. The maximum operating pressure is controlled by the back leakage

4.50) Define slip of reciprocating pump.

[AU, April / May - 2010, Nov / Dec – 2012, 2015]

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump.

4.51) When does negative slip occur?

[AU, Nov / Dec - 2008, May / June - 2016 April / May - 2017]

Negative slip occurs when the delivery pipe is short and suction pipe is long and the pump is running at high speed

4.52) What is negative slip in a reciprocating pump? What are the causes for it?

[AU, May / June - 2013]

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump. If actual discharge is more than the theoretical discharge the slip of the pump is negative. In that case the slip of the pump is known as negative slip.

Negative slip occurs when the delivery pipe is short and suction pipe is long and the pump is running at high speed

4.53) Define slip, negative slip in reciprocating pump. ***[AU, May / June - 2014]***

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump.

If actual discharge is more than the theoretical discharge the slip of the pump is negative. In that case the slip of the pump is known as negative slip.

4.54) Define slip of a pump. When does negative slip occur?

[AU, Nov / Dec - 2003]

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump.

Negative slip occurs when the delivery pipe is short and suction pipe is long and the pump is running at high speed.

4.55) Define slip. What conditions lead to a negative slip? ***[AU, Nov / Dec - 2015]***

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump. If actual discharge is more than the theoretical discharge the slip of the pump is negative. In that case the slip of the pump is known as negative slip.

Negative slip occurs when the delivery pipe is short and suction pipe is long and the pump is running at high speed

4.56) Define slip and percentage of slip of a reciprocating pump.

[AU, Nov / Dec – 2008, 2010]

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump.

The ratio between slip and theoretical discharge is called as percentage of slip.

$$Percentage\ of\ slip = \frac{Q_{th} - Q_{act}}{Q_{th}} * 100$$

4.57) Define slip and percentage slip. ***[AU, Nov / Dec - 2011]***

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump.

The ratio between slip and theoretical discharge is called as percentage of slip.

$$Percentage\ of\ slip = \frac{Q_{th} - Q_{act}}{Q_{th}} * 100$$

4.58) What is the % of slip in reciprocating pump?

[AU, Nov / Dec – 2006, May / June– 2012]

The ratio between slip and theoretical discharge is called as percentage of slip.

$$Percentage\ of\ slip = \frac{Q_{th} - Q_{act}}{Q_{th}} * 100$$

4.59) Discuss – slip. *[AU, April / May - 2011]*

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump. If actual discharge is more than the theoretical discharge the slip of the pump is negative. In that case the slip of the pump is known as negative slip.

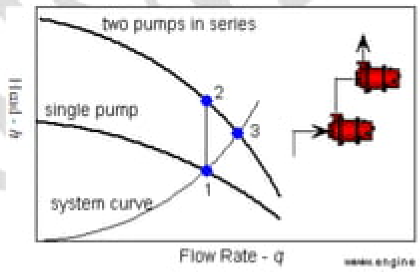
Negative slip occurs when the delivery pipe is short and suction pipe is long and the pump is running at high speed

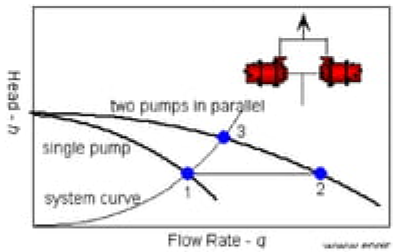
4.60) Define slip in reciprocating machines. *[AU, Nov / Dec - 2011]*

Slip is defined as the difference between the theoretical discharge and actual discharge of the pump.

4.61) Distinguish between pumps in series and pumps in parallel.

[AU, April / May - 2005]

<table>
<tr><th>Pumps In Series</th><th>Pumps In Parallel</th></tr>
<tr><td>❖ When two (or more) pumps are arranged in serial their resulting pump performance curve is obtained by adding their heads at the same flow rate as indicated in the figure below.


❖ Centrifugal pumps in parallel are used to overcome larger volume flows than one pump can handle alone.</td><td>❖ When two or more pumps are arranged in parallel their resulting performance curve is obtained by adding their flow rates at the same head as indicated in the figure below.


❖ Centrifugal pumps in parallel are used to overcome larger volume flows than one pump can handle alone.</td></tr>
</table>

4.62) Can actual discharge be greater than theoretical discharge in a reciprocating pump? *[AU, Nov / Dec - 2009]*

Sometimes the actual discharge of a reciprocating pump is more than the theoretical discharge. It happens when the delivery pipe is short and suction pipe is long and the pump is running at high speed. It cause the delivery valve to open even before the suction stroke is completed. It results into pushing some quantity of water into the delivery pipe before the commencement of delivery stroke. Thus the actual discharge become more than the theoretical discharge.

4.63) Which factors determine the maximum speed of reciprocating pump? *[AU, Nov / Dec - 2009]*

The maximum speed of the reciprocating pump is governed by the maximum allowable vacuum pressure or minimum absolute pressure so that the separation of flow does not takes place.

Maximum vacuum pressure of the head which occurs at $\theta = 0$

It also depends on atmospheric head, acceleration head, suction head and delivery head.

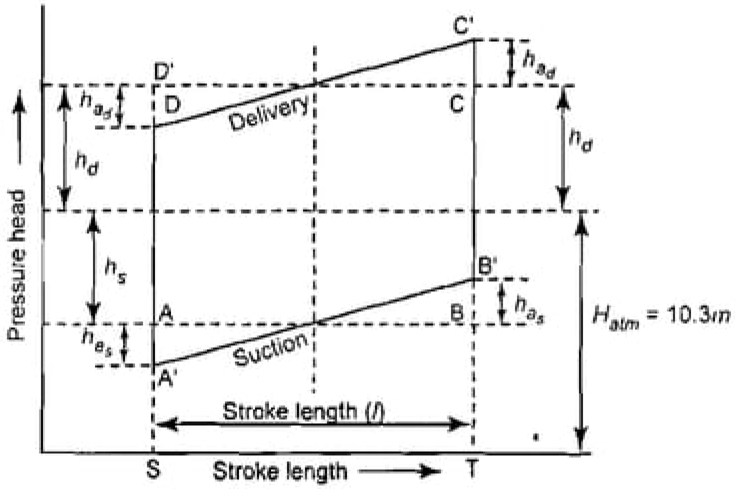
4.64) What factors govern the speed of reciprocating pump? *[AU, May / June - 2012]*

The maximum speed of the reciprocating pump is governed by the maximum allowable vacuum pressure or minimum absolute pressure so that the separation of flow does not takes place.

Maximum vacuum pressure of the head which occurs at $\theta = 0$

It also depends on atmospheric head, acceleration head, suction head and delivery head.

4.65) Brief on acceleration head. *[AU, Nov / Dec - 2011]*



When the piston moves outward at the beginning of the stroke, a negative pressure is created which is equal to the suction head *(h_s)*. In addition to this, the fluid or liquid will also be accelerated in the suction stroke. Due to acceleration head *(h_{as})*, the total negative pressure head at the beginning of the stroke is equal to $h_s + h_{as}$ denoted by the ordinate ***EA'*** shown in Figure. So, the absolute pressure at the ordinate ***A'*** is equal to ***A'S.*** At the same time, the absolute pressure should not fall below the vapour or vacuum pressure and the separation should not take place. At the beginning of delivery pipe, the liquid is accelerated but it is decelerated or retarded while at the end of delivery pipe. Here also, the absolute pressure should not fall below the vacuum pressure to avoid separation.

4.66) What are rotary pumps? Give examples *[AU, April / May - 2003]*

Rotary pumps resemble like a centrifugal pumps in appearance. But, the working method differs. Uniform discharge and positive displacement can be obtained by using these rotary pumps. So, we can clearly say, it has the combined advantages of both centrifugal and reciprocating pumps. The examples for rotary pumps are

- ❖ Gear pump
  - ✓ External gear pump.
  - ✓ Internal gear pump.
  - ✓ Lobe pump.

- Vane pump
  - ✓ Balanced vane pump
  - ✓ Unbalanced vane pump
- Piston pump
  - ✓ Radial piston pump
  - ✓ Axial piston pump

4.67) What is a rotary pump? Give its classification. ***[AU, April / May - 2011]***

Rotary pumps resemble like a centrifugal pumps in appearance. But, the working method differs. Uniform discharge and positive displacement can be obtained by using these rotary pumps. So, we can clearly say, it has the combined advantages of both centrifugal and reciprocating pumps. The various types of rotary pumps are

- Gear pump
  - ✓ External gear pump.
  - ✓ Internal gear pump.
  - ✓ Lobe pump.
- Vane pump
  - ✓ Balanced vane pump
  - ✓ Unbalanced vane pump
- Piston pump
  - ✓ Radial piston pump
  - ✓ Axial piston pump

4.68) Write the classification of positive displacement rotary pumps.

[AU, Nov / Dec - 2016]

- Gear pump
  - ✓ External gear pump.
  - ✓ Internal gear pump.
  - ✓ Lobe pump.
- Vane pump
  - ✓ Balanced vane pump
  - ✓ Unbalanced vane pump
- Piston pump

- ✓ Radial piston pump
- ✓ Axial piston pump

4.69) What is the function of air vessel?

[AU, Nov / Dec – 2008, May / June - 2009, April / May - 2010]

The main functions of air vessels are

- ❖ To obtain a continuous supply of liquid at a uniform rate
- ❖ To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- ❖ To run the pump at a high speed without separation

4.70) What is an air vessel in reciprocating pump? ***[AU, May / June - 2006]***

An air vessel is a closed chamber containing compressed air in the portion and liquid at the bottom of the chamber. At the base of the chamber there is an opening through which the liquid may flow into the vessel or out from the vessel. When the liquid enters the vessel the air gets compressed and when leaves the vessel the air will expand in the chamber.

4.71) Mention the working principle of an Air-vessel. ***[AU, April / May - 2010]***

An air vessel is a closed chamber containing compressed air in the portion and liquid at the bottom of the chamber. At the base of the chamber there is an opening through which the liquid may flow into the vessel or out from the vessel. When the liquid enters the vessel the air gets compressed and when leaves the vessel the air will expand in the chamber. Pump has two air vessel each fitted to suction pipe and delivery pipe

4.72) List importance of air vessels in reciprocating pump. ***[AU, May / June - 2016]***

- ❖ To obtain a continuous supply of liquid at a uniform rate
- ❖ To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- ❖ To run the pump at a high speed without separation

4.73) What is the function of air vessel in reciprocating pumps?

[AU, Nov / Dec - 2016]

The function of air vessel in reciprocating pumps are

- ❖ To obtain a continuous supply of liquid at a uniform rate

- ❖ To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- ❖ To run the pump at a high speed without separation

4.74) Explain the purpose of Air Vessel and in which pump it is used?

[AU, April / May - 2017]

The purpose of Air Vessel is

- ❖ To obtain a continuous supply of liquid at a uniform rate
- ❖ To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- ❖ To run the pump at a high speed without separation

The Air Vessels are used in Reciprocating pumps

4.75) What is an air vessel? List the objectives that would be fulfilled by the use of air vessels. ***[AU, Nov / Dec - 2010]***

An air vessel is a closed chamber containing compressed air in the portion and liquid at the bottom of the chamber. At the base of the chamber there is an opening through which the liquid may flow into the vessel or out from the vessel. When the liquid enters the vessel the air gets compressed and when leaves the vessel the air will expand in the chamber.

The main objectives of air vessels are

- ❖ To obtain a continuous supply of liquid at a uniform rate
- ❖ To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- ❖ To run the pump at a high speed without separation

4.76) What is an air vessel? What are its uses? ***[AU, May / June - 2012]***

An air vessel is a closed chamber containing compressed air in the portion and liquid at the bottom of the chamber. At the base of the chamber there is an opening through which the liquid may flow into the vessel or out from the vessel. When the liquid enters the vessel the air gets compressed and when leaves the vessel the air will expand in the chamber.

The uses of air vessels are

- ❖ To obtain a continuous supply of liquid at a uniform rate

- To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- To run the pump at a high speed without separation

4.77) What are the advantages of air vessel? *[AU, May / June - 2013]*

- To obtain a continuous supply of liquid at a uniform rate
- To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- To run the pump at a high speed without separation

4.78) State the advantages of fitting air vessels in reciprocating pumps. *[AU, May / June - 2009]*

- To obtain a continuous supply of liquid at a uniform rate
- To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- To run the pump at a high speed without separation

4.79) What are the uses of air vessels? *[AU, May / June – 2014, April / May - 2017]*

The uses of air vessels are

- To obtain a continuous supply of liquid at a uniform rate
- To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipe
- To run the pump at a high speed without separation

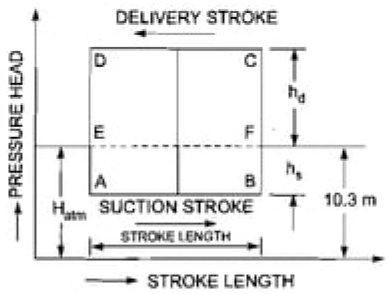
4.80) Define indicator diagram. *[AU, May / June, Nov / Dec - 2007]*

Indicator diagram is the graph between the pressure head in the cylinder and distance travelled by piston from inner dead center for one complete revolution of the crank.

4.81) What is indicator diagram? *[AU, May / June - 2009]*

Indicator diagram is the graph between the pressure head in the cylinder and distance travelled by piston from inner dead center for one complete revolution of the crank.

4.82) Draw the ideal indicator diagram. *[AU, April / May - 2010]*



4.83) A single acting reciprocating pump, running at 50rpm. The diameter of piston = 20cm and length = 40cm. Find the theoretical discharge of the pump. *[AU, April / May - 2011]*

Given:

N = 50 rpm D = 0.2m L = 0.4m

Solution:

$$Q_{th} = \frac{A * L * N}{60}$$

$$Q_{th} = \frac{\pi * D^2 * L * N}{4 * 60}$$

$$Q_{th} = \frac{\pi * 0.2^2 * 0.4 * 50}{4 * 60}$$

$$\boldsymbol{Q_{th} = 0.0104\, m^3/s}$$

4.84) A centrifugal pump delivers 20 litres/s of water against a manometric head of 850 mm at 900 rpm. Find the specific speed of pump. *[AU, April / May - 2010]*

Given:

$Q = 20*10^{-3}\ m^3/s$ $H_m = 0.850m$ N = 900rpm

Solution:

$$N_s = \frac{N\sqrt{Q}}{{H_m}^{3/4}}$$

$$N_s = \frac{900\sqrt{20 * 10^{-3}}}{0.850^{3/4}}$$

$$\boldsymbol{N_s = 143.778\, rpm}$$

4.85) The following data refer to a centrifugal pump which is designed to run at 1500 rpm. D_1 = 100 mm, D_2 = 300 mm, B_1 = 50 mm, B_2 = 20 mm, V_{f1}= 3 m/s. Find the velocity of flow at outlet. ***[AU, April / May - 2010]***

Given:

N = 1500 rpm $D_1 = 0.1m$ $D_2 = 0.3m$ $B_1 = 0.05m$

$B_2 = 0.02m$ $V_{f1} = 3$ m/s

Solution:

Discharge

$$Q = \pi D_1 B_1 V_{f1}$$

$$Q = \pi * 0.1 * 0.05 * 3$$

$$\boldsymbol{Q = 0.0471\ m^3/s}$$

Velocity of flow at outlet

$$Q = \pi D_2 B_2 V_{f2}$$

$$0.0471 = \pi * 0.3 * 0.02 * V_{f2}$$

$$\boldsymbol{V_{f2} = 2.5\ m/s}$$

4.86) A pump is to discharge 0.82 m^3/s at a head of 42 m when running at 300 rpm. What type of pump will be required? ***[AU, Nov / Dec - 2011]***

Given:

$Q = 0.82\ m^3/s$ $H_m = 42m$ N = 300rpm

Solution:

$$N_s = \frac{N\sqrt{Q}}{{H_m}^{3/4}}$$

$$N_s = \frac{300\sqrt{0.82}}{42^{3/4}}$$

$$\boldsymbol{N_s = 16.466}$$

Specific speed lies between 10 to 30, so **slow speed radial flow pump** is recommended

UNIT – V – TURBINES

PART - A

5.1) Classify Hydrodynamic machines. *[AU, April / May - 2010]*

- Power producing machines (Hydraulic turbines)
  - Impulse turbine
  - Reaction turbine
- Power absorbing machines (Hydrodynamic pumps)
  - Mixed flow pumps
  - Axial flow pumps

5.2) How are hydraulic turbines classified

[AU, May / June - 2009, 2014, Nov / Dec - 2009 April / May - 2011]

According to the type of energy at inlet

- Impulse turbine
- Reaction turbine

According to the direction of flow through runner

- Tangential flow turbine
- Radial flow turbine
- Axial flow turbine
- Mixed flow turbine

According to the head at the inlet of the turbine

- High head turbine
- Medium head turbine
- Low head turbine

According to the specific speed of the turbine

- Low specific speed turbine
- Medium specific speed turbine
- High specific speed turbine

5.3) How do you classify turbines based on flow direction and working medium?

[AU, April / May - 2017]

According to the direction of flow through runner

- Tangential flow turbine
- Radial flow turbine
- Axial flow turbine
- Mixed flow turbine

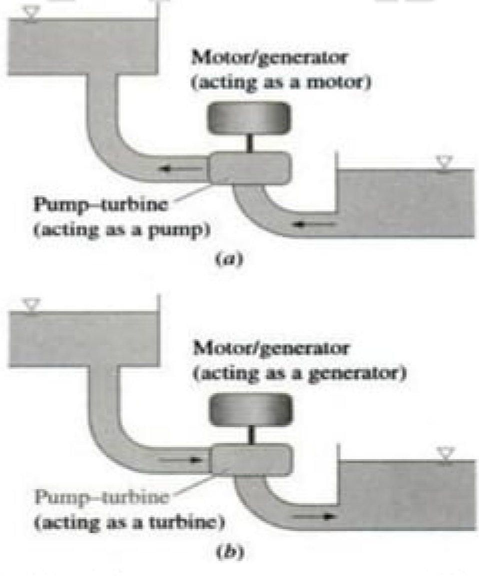
According to the head at the inlet of the turbine

- High head turbine
- Medium head turbine
- Low head turbine

5.4) What is a pump turbine? Is it the same as turbine pump?

[AU, April / May - 2015]

There are applications in which the same turbo machine is used as both a pump and turbine; these devices appropriately called as Pump Turbine. Pump turbine is not as the same as turbine pump, turbine pump is meant only for pumping of liquids.



5.5) What are high head turbines? *[AU, Nov / Dec - 2009]*

The turbines operating head is above 250m then the turbines are called as high head turbines.

5.6) List the range of head for various turbines. *[AU, April / May - 2015]*

S.No	Head based Turbine	Head (m)	Discharge	Type of Turbine
1	Low head	2 – 5	High	Kaplan or Propeller
2	Medium head	16 – 70	High or Medium	Kaplan or Francis
3	High head	71 – 500	Medium or Low	Francis or Pelton
4	Very High head	> 500	Low	Pelton

5.7) State and concise on Euler turbine equation. *[AU, Nov / Dec - 2014]*

The Euler turbine equation relates the power added to or removed from the flow, to characteristics of a rotating blade row. The equation is based on the concepts of conservation of angular momentum and conservation of energy.

$$c_p(T_{Tc} - T_{Tb}) = \omega(r_c v_c - r_b v_b).$$

The above Equation is called the Euler Turbine Equation. It relates the temperature ratio (and hence the pressure ratio) across a turbine or compressor to the rotational speed and the change in momentum per unit mass. Note that the velocities used in this equation are what we will later call absolute frame velocities (as opposed to relative frame velocities).

If angular momentum increases across a blade row, then $T_{Tc} > T_{Tb}$ and work was done on the fluid (a compressor).

If angular momentum decreases across a blade row, then $T_{Tc} < T_{Tb}$ and work was done by the fluid (a turbine).

5.8) State the principles on which turbo-machines are based.

[AU, Nov / Dec - 2010]

Turbo machines are based on the principle of fluid momentum. The fluid momentum is gradually changed into rotation motion of the mechanical member.

5.9) What is the difference between radial flow and axial flow turbo machines?

[AU, Nov / Dec - 2016]

Radial Flow	Axial Flow
❖ The flow of water is in radial direction ❖ Examples: old Francis turbine (for Inward radial flow) and Fourneyron turbine (for Outward radial flow)	❖ The flow of water is in the direction parallel to the axis of the shaft ❖ Example: Kaplan turbine and propeller turbine.

5.10) Explain specific speed. ***[AU, Nov / Dec - 2005]***

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head. The specific speed of the turbine is used in comparing the different types of turbines as every type of turbine has different specific speed.

5.11) Define specific speed. ***[AU, Nov / Dec - 2009]***

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head.

5.12) Define specific speed of a turbine. ***[AU, Nov / Dec – 2003, 2008, 2009, May / June–2007, 2009, April / May –2010, 2011]***

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head.

5.13) Define specific speed of a turbine. What is its usefulness?

[AU, Nov / Dec - 2007]

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head. The specific speed of the turbine is used in comparing the different types of turbines as every type of turbine has different specific speed.

5.14) How is specific speed of a turbine defined? *[AU, May / June - 2006]*

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head.

5.15) What is meant by specific speed of a turbine? *[AU, April / May - 2010]*

It is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head.

5.16) Define specific speed and unit speed of a turbine. *[AU, April / May - 2015]*

Specific speed is defined as the speed of a turbine which is identical in shape, geometrical dimensions, blade angles, gate opening etc., with the actual turbine but of such a size that it will develop unit power when working under unit head.

Unit speed is the speed of the turbine under unit head.

5.17) Write the equation for specific speed for pumps and also for turbine.

[AU, Nov / Dec - 2012]

Specific speed of pump

$$N_s = \frac{N\sqrt{Q}}{{H_m}^{3/4}}$$

N = Speed of the pump

Q = Discharge of the pump

H_m = Manometric head

Specific speed of turbine

$$N_s = \frac{N\sqrt{P}}{H^{5/4}}$$

N = Speed of the turbine

P = Power developed

H = Head

5.18) Why not the specific speed of a hydraulic turbine is calculated using watts, instead of metric horse power? *[AU, April / May - 2015]*

A metric horsepower-hour (hp·h) is an outdated unit of energy, not used in the SI system of units. The unit represents an amount of work a horse is supposed capable of delivering during an hour. 1 metric hp·h = 2.65 MJ.

5.19) What is hydraulic turbine? *[AU, May / June - 2006]*

Hydraulic turbines are the machines which convert the energy of flowing water into mechanical energy

5.20) Classify turbines according to flow. *[AU, Nov / Dec - 2005]*

According to the direction of flow through runner

- Tangential flow turbine
- Radial flow turbine
- Axial flow turbine
- Mixed flow turbine

5.21) Explain the working of impulse turbine. *[AU, April / May - 2011]*

Impulse turbine works on the principle of impulse. In these turbines, the head or pressure energy of water is first converted into kinetic energy by means of a nozzle or set of nozzles kept close to the runner. This high velocity jet produced by nozzle is allowed to impinge on the set of buckets fixed on the outer periphery of the wheel or runner. The direction of the jet is changed by buckets. The change of momentum of water causes the wheel to rotate, thus the mechanical energy is produced. It should be noted that the pressure of water is atmospheric and remains constant while passing over the runner.

Examples: Pelton wheel, Girard turbine, Turgo turbine

5.22) List down the main components of pelton wheel. *[AU, May / June - 2016]*

The main components of Pelton Wheel are

- Nozzle and flow regulating arrangements
- Runner and Buckets
- Casing
- Braking jet

5.23) What is reaction turbine? Give examples *[AU, April / May - 2003]*

In reaction turbines, a part of pressure energy is first converted into kinetic energy before supplied to the runner. Therefore, the water enters the runner having partly the pressure energy and partly the kinetic energy and both these energies are reduced simultaneously while passing over the runner and produce mechanical energy. Hence, these turbines work on the principle of impulse reaction. The runner of these being under pressure above atmospheric, it requires the blades of turbine to run in closed passages which are completely filled with water in all conditions.

Examples: Francis, Kaplan and Propeller turbines

5.24) Differentiate between reaction turbine and impulse turbine.

[AU, Nov / Dec - 2003, April / May - 2008, 2015, 2017, May / June - 2012]

Impulse turbine	Reaction turbine
❖ All the potential energies are converted into kinetic energy by nozzle before entering to turbine runner	❖ Only a portion of fluid energy are converted into kinetic energy before entering to turbine runner
❖ Blades are only action when they are i.e in front of nozzle	❖ Blades are action at all time
❖ Water may be allowed to enter a part or whole of the wheel circumference.	❖ Water is admitted over the circumference of the wheel
❖ Wheel does not run full and air has free access to the buckets	❖ Water completely fills the vane passage throughout the operation of the turbine
❖ Unit is installed above the tail race	❖ Unit is kept entirely submerged in water below the tail race.
❖ Flow regulation is possible without loss	❖ Flow regulation is possible with loss
❖ Flow is regulated by needle valve fitted into the nozzle	❖ Flow is regulated by means of guide vane assembly.

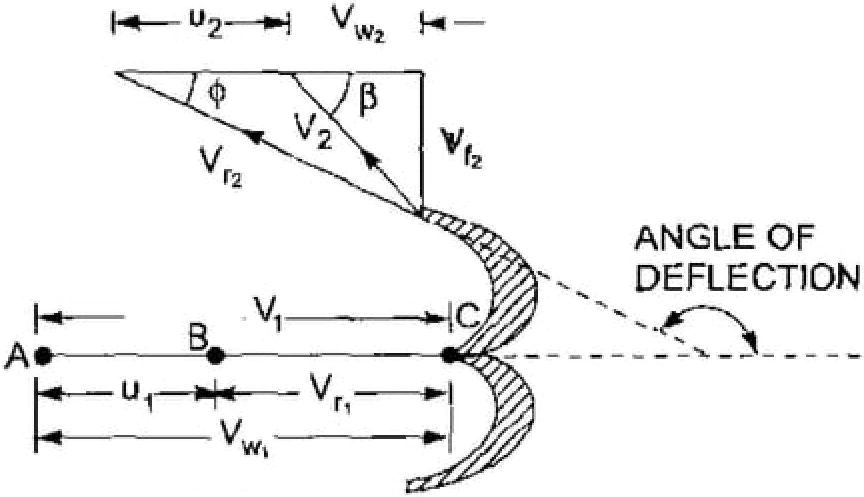
5.25) What is a 'breaking jet' in Pelton wheel/turbine?

[AU, May / June - 2007, Nov / Dec – 2007, 2012]

When the nozzle is completely closed by moving the spear in the forward direction the amount of water striking the runner reduces to zero. But the runner due to inertia goes on revolving for a long time. To stop the runner in a short time, a small nozzle is provided which directs the jet of water on the back of the vanes. This jet of water is called breaking jet.

5.26) Draw velocity triangle diagram for Pelton wheel turbine.

[AU, Nov / Dec - 2008]



5.27) Define the flow ratio of reaction radial flow turbine. ***[AU, Nov / Dec - 2012]***

The ratio of the velocity of flow at inlet (V_{f1}) to the velocity given $\sqrt{2gH}$ is known as flow ratio.

$$flow\ ratio = \frac{V_{f1}}{\sqrt{2gH}}$$

5.28) In what respects outward flow reaction turbine differs from inward flow reaction turbine? Which one is better and why? ***[AU, May / June - 2016]***

Inward Flow Reaction Turbine	Outward Flow Reaction Turbine
❖ Water enters at outer periphery of runner and flows radially inwards towards center	❖ Water enters at center of runner and flows radially outwards and discharges at the outer periphery of runner

❖ The centrifugal head, $h = \frac{u_2^2 - u_1^2}{2g}$ $u_2 < u_1$ imparted to water during flow an runner is negative since $u_2 < u_1$	❖ The centrifugal head imported to water during flow on runner is positive since $u_2 > u_1$
❖ Negative head due to centrifugal action reduces the relative velocity at outlet since $\frac{V_{r2}^2 - V_{r1}^2}{2g} = \frac{u_2^2 - u_1^2}{2g}$	❖ Positive head due to centrifugal action increases the relative velocity at outlet
❖ As the speed increases, it reduces the discharge due to negative centrifugal head on water. Therefore, it provides a self – governing effect on turbine	❖ As the speed increases, it increases the discharge due to positive centrifugal head on water. It further increases the power and speed, hence, the turbine tends to race.

5.29) Explain the type of flow in Francis turbine. ***[AU, Nov / Dec - 2016]***

It is inward flow reaction turbine. Water enters the runner in radial direction outlet leaves in axial direction at inlet.

5.30) List the main parts of Kaplan turbine. ***[AU, Nov / Dec - 2012]***

- ❖ Scroll casing
- ❖ Guide vanes mechanism
- ❖ Hub with vanes or runner of the turbine
- ❖ Draft tube

5.31) Differentiate between Kaplan turbine and propeller turbine.

[AU, May / June - 2016]

Kaplan Turbine	Propeller Turbine
❖ The blades of turbine is adjustable ❖ The turbine is suited for high flow conditions	❖ The blades of turbine is fixed ❖ The turbine is suited for low flow conditions

5.32) What is draft tube? *[AU, Nov / Dec – 2012, 2016]*

Draft tube is a pipe of gradually increasing area which connects the outlet of runner to the tail race. It is used for discharging water from the exit of the turbine to tail race.

5.33) What is draft tube? In which type of turbine is mostly used?

[AU, Nov / Dec - 2003]

Draft tube is a pipe of gradually increasing area which connects the outlet of runner to the tail race. It is used for discharging water from the exit of the turbine to tail race. It is mostly used in reaction turbine.

5.34) Write short notes on draft tube. *[AU, Nov / Dec - 2015]*

Draft tube is a pipe of gradually increasing area which connects the outlet of runner to the tail race. It is used for discharging water from the exit of the turbine to tail race.

5.35) Write the function of draft tube in turbine outlet?

[AU, April / May - 2005, 2008, Nov / Dec - 2011]

- ❖ It permits a negative head to be established at the outlet of the runner and thereby increase the net head on the turbine. The turbine may be placed above the tail race without any loss of net head and hence turbine may be inspected properly.
- ❖ It converts a large proportion of the kinetic energy ($V^2/2g$) rejected at the outlet of the turbine into useful pressure energy. Without the draft tube, the kinetic energy rejected at the outlet of the turbine will go waste to the tail race.

- Hence by using draft-tube, the net head on the turbine increases. The turbine develops more power and also the efficiency of the turbine increases.

5.36) What is the function of draft tube?

[AU, May / June– 2007, Nov / Dec - 2009]

- It permits a negative head to be established at the outlet of the runner and thereby increase the net head on the turbine. The turbine may be placed above the tail race without any loss of net head and hence turbine may be inspected properly.
- It converts a large proportion of the kinetic energy ($V^2/2g$) rejected at the outlet of the turbine into useful pressure energy. Without the draft tube, the kinetic energy rejected at the outlet of the turbine will go waste to the tail race.
- Hence by using draft-tube, the net head on the turbine increases. The turbine develops more power and also the efficiency of the turbine increases.

5.37) What are the different types of draft tubes? ***[AU, Nov / Dec - 2009]***

- Conical draft tube
- Simple elbow tubes
- Moody spreading tubes
- Elbow draft tubes with circular inlet and rectangular outlet

5.38) Why does a Pelton wheel not possess any draft tube?

[AU, May / June - 2012]

In case of Pelton wheel the available head is converted into kinetic energy before entry to runner buckets and the turbine operate under atmospheric pressure conditions. The velocity of the water leaving at the turbine exit is small, therefore the exit of the runner is above the tail race level and there is no need for draft tube.

5.39) Mention the importance of Euler turbine equation. ***[AU, Nov / Dec - 2011]***

Euler's turbine equation plays a central role in turbo machinery as it connects the specific work and geometry and velocities in the impeller

5.40) What is Thoma's Cavitation factor? *[AU, April / May - 2017]*

Prof. Thoma suggested the cavitation factor "**σ**" to determine the safe zone where turbine can work without being affected by cavitation. Critical value of cavitation factor is given by,

$$\sigma_c = \frac{(H_{atm} - H_v) - H_s - h_{fs}}{H}$$

5.41) What are the different efficiencies of turbine to determine the characteristics of turbine? *[AU, Nov / Dec - 2006 May / June– 2012]*

$$\text{Mechanical Efficiency} = \frac{\text{Power at the shaft of the turbine}}{\text{Power delivered by water to the runner}}$$

$$\text{Volumetric Efficiency} = \frac{\text{Volume of Water or steam actually striking the runner}}{\text{Volume of water supplied to the turbine}}$$

$$\text{Overall Efficiency} = \frac{\text{Shaft Power at turbine}}{\text{Power supplied at the inlet of the turbine}}$$

5.42) Define -volumetric efficiency of turbine. *[AU, Nov / Dec – 2014, 2015]*

$$\text{Volumetric Efficiency} = \frac{\text{Volume of Water or steam actually striking the runner}}{\text{Volume of water supplied to the turbine}}$$

5.43) Define hydraulic efficiency and jet ratio of a Pelton wheel.

[AU, Nov / Dec - 2010]

Hydraulic efficiency is the ratio between work done per second to kinetic energy of jet per second.

$$\eta_h = \frac{work\ done\ per\ second}{kinetic\ energy\ of\ jet\ per\ second}$$

5.44) Define hydraulic efficiency of turbine?

[AU, May / June – 2013, Nov / Dec - 2016]

Hydraulic efficiency is the ratio of the power produced by the turbine runner and the power supplied by the water at the turbine inlet.

5.45) What is meant by hydraulic efficiency of turbine?

[AU, Nov / Dec – 2012, 2013]

Hydraulic efficiency is the ratio of the power produced by the turbine runner and the power supplied by the water at the turbine inlet.

5.46) Define hydraulic efficiency and overall efficiency of a turbine.

[AU, Nov / Dec - 2012]

Hydraulic efficiency is the ratio of the power produced by the turbine runner and the power supplied by the water at the turbine inlet.

Overall efficiency is the ratio of power available at the turbine shaft to the power available from the water jet

5.47) Define overall efficiency and plant efficiency of turbines.

[AU, May / June– 2007, 2012]

Overall efficiency is the ratio of power available at the turbine shaft to the power available from the water jet

Plant Efficiency of a plant is the percentage of the total energy content of a power plant's fuel that is converted into electricity.

5.48) What is meant by Governing of Turbines? *[AU, April / May - 2017]*

Governing system or governor is the main controller of the hydraulic turbine. The governor varies the water flow through the turbine to control its speed or power output. Generating units speed and system frequency may be adjusted by the governor.

5.49) What is the difference between a turbine and a pump?

[AU, Nov / Dec – 2010, May / June - 2012]

Turbine	Pump
❖ Turbines convert hydraulic energy into mechanical entry ❖ It is energy producing machine ❖ Flow takes place from high pressure side to low pressure side ❖ Flow is decelerated	❖ Pump convert mechanical energy into hydraulic entry ❖ It is energy absorbing machine ❖ Flow takes place from low pressure side to high pressure side ❖ Flow is accelerated

5.50) Differentiate between pumps and turbines.

[AU, May / June, Nov / Dec – 2007, 2008]

Turbine	Pump
❖ Turbines convert hydraulic energy into mechanical entry ❖ It is energy producing machine ❖ Flow takes place from high pressure side to low pressure side ❖ Flow is decelerated	❖ Pump convert mechanical energy into hydraulic entry ❖ It is energy absorbing machine ❖ Flow takes place from low pressure side to high pressure side ❖ Flow is accelerated

5.51) A shaft transmits 150 Kw at 600 rpm. What is the torque in Newton – meters? *[AU, April / May - 2011]*

Given:

$P = 150 * 10^3$ W N = 600rpm

Solution:

Power

$$P = \frac{2\pi NT}{60}$$

$$150 * 10^3 = \frac{2 * \pi * 600 * T}{60}$$

$$\boldsymbol{T = 1989.436\ N - m}$$

5.52) The mean velocity of the buckets of the Pelton wheel is 10 m/s. The jet supplies water at 0.7 m³/s at a head of 30 m. The jet is deflected through an angle of 160° by the bucket. Find the hydraulic efficiency. Take C_V = 0.98.

[AU, April / May - 2010]

Given:

u = 10m/s Q = 0.7 m^3/s H = 30m

jet is deflected through an angle of 160°

Solution:

Assume speed ratio

$$K_u = 0.45$$

Velocity of jet

$$V_1 = \frac{u}{K_u} = \frac{12}{0.45}$$

$$\boldsymbol{V_1 = 26.67\ m/s}$$

Blade angel

$$\Phi = 180 - 160 = 20°$$

Hydraulic efficiency

$$\eta_h = \frac{2u\,(V_1 - u)(1 + cos\Phi)}{{V_1}^2}$$

$$\eta_h = \frac{2 * 12\,(26.67 - 12)(1 + cos20°)}{26.67^2}$$

$$\boldsymbol{\eta_h = 0.96 = 96\ \%}$$

5.53) A water turbine has a velocity of 8.5m/s at the entrance of draft tube and velocity of 2.2m/s at exit. The frictional loss is 0.15m and the tail race water is 4m below the entrance of draft tube. Calculate the pressure head at entrance.

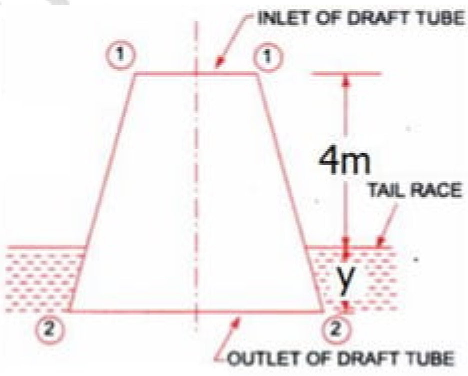
[AU, April / May - 2011]

Given:

Velocity at inlet, $V_1 = 8.5$ m/s

Velocity at outlet, $V_2 = 2.2$ m/s

Frictional Loss $h_f = 0.1$ m/s



Vertical Height Between tail race and inlet of draft – tube = 4m

Let y = Vertical Height Between tailrace and outlet of draft – tube

Applying Bernoulli's Equation at the inlet and outlet of draft-tube and taking reference line passing through section 2- 2, we get

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

Where

$Z_1 = 4 + y$

$\frac{P_2}{\rho g}$ = Atmospheric pressure head + y = $\frac{P_a}{\rho g} + y$

$Z_2 = 0$

$$\frac{P_1}{\rho g} + \frac{8.5^2}{2 * 9.81} + (4 + y) = \left(\frac{P_a}{\rho g} + y\right) + \frac{2.2^2}{2 * 9.81} + 0 + 0.1$$

Taking the atmospheric pressure head as zero

$$\frac{P_1}{\rho g} + \frac{8.5^2}{2 * 9.81} + (4 + y) = (0 + y) + \frac{2.2^2}{2 * 9.81} + 0 + 0.1$$

$$\boldsymbol{\frac{P_1}{\rho g} = -7.3357\, m}$$

The negative sign means vacuum pressure head