

# ***CE6451 FLUID MECHANICS AND MACHINERY***

## **Two Marks Questions & Answers**

### **UNIT I : INTRODUCTION**

1. Define density or mass density.  
Density of a fluid is defined as the ratio of the mass of a fluid to its volume.  
**Density,  $\rho = \text{mass/volume (Kg/m}^3\text{)}$**   
 **$\rho_{\text{water}} = 1000 \text{ Kg/m}^3$**
  
2. Define specific weight or weight density.  
Specific weight or weight density of a fluid is defined as the ratio between the weight of a fluid to its volume.  
**Specific weight,  $\gamma = \text{weight/volume (N/m}^3\text{)}$**   
 **$\gamma = \rho g$**   
 **$\gamma_{\text{water}} = 9810 \text{ N/m}^3$**
  
3. Define specific volume.  
Specific volume of a fluid is defined as the volume of fluid occupied by an unit wt or unit mass of a fluid.  
**Specific volume vs = volume/ wt =  $1/\gamma = 1/\rho g$  ----- for liquids**  
**Specific volume vs = volume/ mass =  $1/\rho$ ----- for gases**
  
4. Define dynamic viscosity.  
Viscosity is defined as the property of fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.  
$$\zeta = \mu \frac{du}{dy}$$
  
 $\mu$  – dynamic viscosity or viscosity or coefficient of viscosity (N-s/m<sup>2</sup>)  
**1 N-s/m<sup>2</sup> = 1 Pa-s = 10 Poise**
  
5. Define Kinematic viscosity.  
It is defined as the ratio between the dynamic viscosity and density of fluid.  
 **$v = \mu/\rho$  (m<sup>2</sup>/s)**  
**1 m<sup>2</sup>/s = 10000 Stokes (or) 1 stoke = 10<sup>-4</sup> m<sup>2</sup>/s**
  
6. Types of fluids.  
Ideal fluid, Real fluid, Newtonian fluid, Non-Newtonian fluid, Ideal Plastic fluid.
  
7. Define Compressibility.  
It is defined as the ratio of volumetric strain to compressive stress.

**Compressibility,  $\beta = (d \text{ Vol/ Vol}) / dp$  (m<sup>2</sup>/N)**

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## 8. Define Surface Tension.

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

$$\text{Surface Tension, } \sigma = \text{Force/Length} \quad (\text{N/m})$$

$$\sigma_{\text{water}} = 0.0725 \text{ N/m}$$

$$\sigma_{\text{Mercury}} = 0.52 \text{ N/m}$$

9. Surface tension on liquid droplet,  $\sigma = pd/4$ 

Surface tension on a hollow bubble,  $\sigma = pd/8$

Surface tension on a liquid jet,  $\sigma = pd/2$

$\sigma$  – surface tension (N/m)

$d$  – diameter (m)

$p$  – pressure inside (N/m<sup>2</sup>)

$$p_{\text{total}} = p_{\text{inside}} + p_{\text{atm}}$$

$$p_{\text{atm}} = 101.325 \times 10^3 \text{ N/m}^2$$

## 10. Define Capillarity.

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

$$\text{Capillary Rise or fall, } h = (4\sigma \cos\theta) / \rho g d$$

$$\theta = 0 \text{ for glass tube and water}$$

$$\theta = 130^\circ \text{ for glass tube and mercury}$$

## 11. Define Vapour Pressure.

When vaporization takes place, the molecules start accumulating over the free liquid surface exerting pressure on the liquid surface. This pressure is known as Vapour pressure of the liquid.

## 12. Define Control Volume.

A control volume may be defined as an identified volume fixed in space. The boundaries around the control volume are referred to as control surfaces. An open system is also referred to as a control volume.

## 13. Write the continuity equation.

The equation based on the principle of conservation of mass is called continuity equation.

$$\delta u / \delta x + \delta v / \delta y + \delta w / \delta z = 0 \text{ ----- three dimensional flow}$$

$$\delta u / \delta x + \delta v / \delta y = 0 \text{ ----- two dimensional flow}$$

$$Q = a_1 v_1 = a_2 v_2 \text{ ----- one dimensional flow}$$

## 14. List the types of fluid flow.

Steady and unsteady flow

Uniform and non-uniform flow

Laminar and Turbulent flow

Compressible and incompressible flow

Rotational and ir-rotational flow

One, Two and Three dimensional flow

15. Define Steady and Unsteady flow.

**Steady flow**

Fluid flow is said to be steady if at any point in the flowing fluid various characteristics such as velocity, density, pressure, etc do not change with time.

$$\frac{\partial V}{\partial t} = 0 \quad \frac{\partial \rho}{\partial t} = 0 \quad \frac{\partial p}{\partial t} = 0$$

**Unsteady flow**

Fluid flow is said to be unsteady if at any point flowing fluid any one or all characteristics which describe the behaviour of the fluid in motion change with time.

$$\frac{\partial V}{\partial t} \neq 0 \quad \frac{\partial \rho}{\partial t} \neq 0 \quad \frac{\partial p}{\partial t} \neq 0$$

16. Define Uniform and Non-uniform flow.

**Uniform flow**

When the velocity of flow of fluid does not change both in direction and magnitude from point to point in the flowing fluid for any given instant of time, the flow is said to be uniform.

$$\frac{\partial V}{\partial s} = 0 \quad \frac{\partial \rho}{\partial s} = 0 \quad \frac{\partial p}{\partial s} = 0$$

**Non-uniform flow**

If the velocity of flow of fluid changes from point to point in the flowing fluid at any instant, the flow is said to be non-uniform flow.

$$\frac{\partial V}{\partial s} \neq 0 \quad \frac{\partial \rho}{\partial s} \neq 0 \quad \frac{\partial p}{\partial s} \neq 0$$

17. Compare Laminar and Turbulent flow.

**Laminar and Turbulent flow**

A flow is said to be laminar if Reynolds number is less than 2000 for pipe flow. Laminar flow is possible only at low velocities and high viscous fluids. In laminar type of flow, fluid particles move in laminas or layers gliding smoothly over the adjacent layer.

**Turbulent flow**

In Turbulent flow, the flow is possible at both velocities and low viscous fluid. The flow is said to be turbulent if Reynolds number is greater than 4000 for pipe flow. In Turbulent type of flow fluid, particles move in a zig – zag manner.

18. Define Compressible and incompressible flow

**Compressible flow**

The compressible flow is that type of flow in which the density of the fluid changes from point to point i.e. the density is not constant for the fluid. It is expressed in kg/sec.

$$\rho \neq \text{constant}$$

**Incompressible flow**

The incompressible flow is that type of flow in which the density is constant for the fluid flow. Liquids are generally incompressible. It is expressed in m<sup>3</sup>/s.

$$\rho = \text{constant}$$


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19. Define Rotational and Ir-rotational flow.

**Rotational flow**

Rotational flow is that type of flow in which the fluid particles while flowing along stream lines and also rotate about their own axis.

**Ir-rotational flow**

If the fluid particles are flowing along stream lines and do not rotate about their own axis that type of flow is called as ir-rotational flow

20. Define One, Two and Three dimensional flow.

**One dimensional flow**

The flow parameter such as velocity is a function of time and one space co-ordinate only.  $u = f(x), \quad v = 0 \quad \& \quad w = 0.$

**Two dimensional flow**

The velocity is a function of time and two rectangular space co-ordinates.

$$u = f_1(x,y), \quad v = f_2(x,y) \quad \& \quad w = 0.$$

**Three dimensional flow**

The velocity is a function of time and three mutually perpendicular directions.

$$u = f_1(x,y,z), \quad v = f_2(x,y,z) \quad \& \quad w = f_3(x,y,z).$$

21. Write the Bernoulli's equation applied between two sections

$$p_1/\rho g + v_1^2/2g + Z_1 = p_2/\rho g + v_2^2/2g + Z_2$$

$p/\rho g$  = pressure head  $v^2/2g$

= kinetic head

$Z$  = datum head

22. State the assumptions used in deriving Bernoulli's equation

Flow is steady;

Flow is laminar;

Flow is irrotational;

Flow is incompressible;

Fluid is ideal.

23. Write the Bernoulli's equation applied between two sections with losses.

$$p_1/\rho g + v_1^2/2g + Z_1 = p_2/\rho g + v_2^2/2g + Z_2 + h_{loss}$$

24. List the instruments works on the basis of Bernoulli's equation.

Venturi meter;

Orifice meter;

Pitot tube.

25. Define Impulse Momentum Equation (or) Momentum Equation.

The total force acting on fluid is equal to rate of change of momentum.

According to Newton's second law of motion,

$$F = ma$$

$$F dt = d(mv)$$

## UNIT II : FLOW THROUGH CIRCULAR CONDUITS

1. Mention the range of Reynold's number for laminar and turbulent flow in a pipe.  
If the Reynold,s number is less than 2000, the flow is laminar. But if the Reynold's number is greater than 4000, the flow is turbulent flow.
2. What does Haigen-Poiseulle equation refer to?  
The equation refers to the value of loss of head in a pipe of length 'L' due to viscosity in a laminar flow.
3. What is Hagen poiseuille's formula?

$$(P_1 - P_2) / \rho g = h_f = 32 \mu \bar{U} L / \rho g D^2$$

The expression is known as Hagen poiseuille formula.

Where  $P_1 - P_2 / \rho g$  = Loss of pressure head,  $\bar{U}$  = Average velocity,  
 $\mu$  = Coefficient of viscosity,  $D$  = Diameter of pipe,  
 $L$  = Length of pipe

4. Write the expression for shear stress?  
**Shear stress  $\zeta = - (\partial p / \partial x) (r/2)$**   
 **$\zeta_{max} = - (\partial p / \partial x) (R/2)$**
  5. Give the formula for velocity distribution: -  
 The formula for velocity distribution is given as  
 **$u = - (1/4 \mu) (\partial p / \partial x) (R^2 - r^2)$**   
 Where  $R$  = Radius of the pipe,  $r$  = Radius of the fluid element
  6. Give the equation for average velocity : -  
 The equation for average velocity is given as  
 **$\bar{U} = - (1/8\mu) (\partial p / \partial x) R^2$**   
 Where  $R$  = Radius of the pipe
  7. Write the relation between  $U_{max}$  and  $\bar{U}$ ?  
 **$U_{max} / \bar{U} = \{ - (1/4 \mu) (\partial p / \partial x) R^2 \} / \{ - 1/8\mu (\partial p / \partial x) R^2 \}$**   
 **$U_{max} / \bar{U} = 2$**
  8. Give the expression for the coefficient of friction in viscous flow?  
 Coefficient of friction between pipe and fluid in viscous flow  **$f = 16/ Re$**   
 Where,  $f = Re =$  Reynolds number
  9. What are the factors to be determined when viscous fluid flows through the circular pipe?  
 The factors to be determined are:
    - i. Velocity distribution across the section.
    - ii. Ratio of maximum velocity to the average velocity.
    - iii. Shear stress distribution.
    - iv. Drop of pressure for a given length.
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10. Define kinetic energy correction factor?

Kinetic energy factor is defined as the ratio of the kinetic energy of the flow per sec based on actual velocity across a section to the kinetic energy of the flow per sec based on average velocity across the same section. It is denoted by ( $\alpha$ ).

K. E factor ( $\alpha$ ) = K.E per sec based on actual velocity / K.E per sec based on Average velocity

11. Define momentum correction factor ( $\beta$ ):

It is defined as the ratio of momentum of the flow per sec based on actual velocity to the momentum of the flow per sec based on average velocity across the section.

$\beta$  = Momentum per sec based on actual velocity / Momentum Per sec based on average velocity

12. Define Boundary layer.

When a real fluid flow passed a solid boundary, fluid layer is adhered to the solid boundary. Due to adhesion fluid undergoes retardation thereby developing a small region in the immediate vicinity of the boundary. This region is known as boundary layer.

13. What is mean by boundary layer growth?

At subsequent points downstream of the leading edge, the boundary layer region increases because the retarded fluid is further retarded. This is referred as growth of boundary layer.

14. Classification of boundary layer.

(i) Laminar boundary layer, (ii) Transition zone, (iii) Turbulent boundary layer.

15. Define Laminar boundary layer.

Near the leading edge of the surface of the plate the thickness of boundary layer is small and flow is laminar. This layer of fluid is said to be laminar boundary layer.

The length of the plate from the leading edge, upto which laminar boundary layer exists is called as laminar zone. In this zone the velocity profile is parabolic.

16. Define transition zone.

After laminar zone, the laminar boundary layer becomes unstable and the fluid motion transformed to turbulent boundary layer. This short length over which the changes taking place is called as transition zone.

17. Define Turbulent boundary.

Further downstream of transition zone, the boundary layer is turbulent and continuous to grow in thickness. This layer of boundary is called turbulent boundary layer.

18. Define Laminar sub Layer

In the turbulent boundary layer zone, adjacent to the solid surface of the plate the velocity variation is influenced by viscous effects. Due to very small thickness, the velocity distribution is almost linear. This region is known as laminar sub layer.

19. Define Boundary layer Thickness.

It is defined as the distance from the solid boundary measured in y-direction to the point, where the velocity of fluid is approximately equal to 0.99 times the free stream velocity (U) of the fluid. It is denoted by  $\delta$ .

20. List the various types of boundary layer thickness.

Displacement thickness( $\delta^*$ ), Momentum thickness( $\theta$ ), Energy thickness( $\delta^{**}$ )

21. Define displacement thickness.

The displacement thickness ( $\delta$ ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in flow rate on account of boundary layer formation.

$$\delta^* = \int [1 - (u/U)] dy$$

22. Define momentum thickness.

The momentum thickness ( $\theta$ ) is defined as the distance by which the boundary should be displaced to compensate for the reduction in momentum of the flowing fluid on account of boundary layer formation.

$$\theta = \int [(u/U) - (u/U)^2] dy$$

23. Define energy thickness

The energy thickness ( $\delta^{**}$ ) is defined as the distance 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.

$$\delta^{**} = \int [(u/U) - (u/U)^3] dy$$

24. What is meant by energy loss in a pipe?

When the fluid flows through a pipe, it loses some energy or head due to frictional resistance and other reasons. It is called energy loss. The losses are classified as; Major losses and Minor losses

25. Explain the major losses in a pipe.

The major energy losses in a pipe is mainly due to the frictional resistance caused by the shear force between the fluid particles and boundary walls of the pipe and also due to viscosity of the fluid.

26. Explain minor losses in a pipe.

The loss of energy or head due to change of velocity of the flowing fluid in magnitude or direction is called minor losses. It includes: sudden expansion of the pipe, sudden contraction of the pipe, bend in a pipe, pipe fittings and obstruction in the pipe, etc.

27. State Darcy-Weisbach equation **OR** What is the expression for head loss due to friction?

$$h_f = 4fLv^2 / 2gd$$

where,  $h_f$  = Head loss due to friction (m),      L = Length of the pipe (m),  
 $d$  = Diameter of the pipe (m),                      V = Velocity of flow (m/sec)  
 $f$  = Coefficient of friction

28. What are the factors influencing the frictional loss in pipe flow?

Frictional resistance for the turbulent flow is,

- i. Proportional to  $v^n$  where  $v$  varies from 1.5 to 2.0.
- ii. Proportional to the density of fluid.
- iii. Proportional to the area of surface in contact.
- iv. Independent of pressure.
- v. Depend on the nature of the surface in contact.

29. Write the expression for loss of head due to sudden enlargement of the pipe.

$$h_{\text{exp}} = (V_1 - V_2)^2 / 2g$$

Where,

$h_{\text{exp}}$  = Loss of head due to sudden enlargement of pipe.

$V_1$  = Velocity of flow at pipe 1;  $V_2$  = Velocity of flow at pipe 2.

30. Write the expression for loss of head due to sudden contraction.

$$h_{\text{con}} = 0.5 V^2 / 2g$$

$h_{\text{con}}$  = Loss of head due to sudden contraction.  $V$  = Velocity at outlet of pipe.

31. Write the expression for loss of head at the entrance of the pipe.

$$h_i = 0.5 V^2 / 2g$$

$h_i$  = Loss of head at entrance of pipe.  $V$  = Velocity of liquid at inlet of the pipe.

32. Write the expression for loss of head at exit of the pipe.

$$h_o = V^2 / 2g$$

where,  $h_o$  = Loss of head at exit of the pipe.

$V$  = Velocity of liquid at inlet and outlet of the pipe.

33. Give an expression for loss of head due to an obstruction in pipe

$$\text{Loss of head due to an obstruction} = V^2 / 2g (A / C_c (A - a) - 1)^2$$

Where,  $A$  = area of pipe,  $a$  = Max area of obstruction,

$V$  = Velocity of liquid in pipe  $A - a$  = Area of flow of liquid at section 1-1

34. What is compound pipe or pipes in series?

When the pipes of different length and different diameters are connected end to end, then the pipes are called as compound pipes or pipes in series.

35. What is mean by parallel pipe and write the governing equations.

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:

$$Q_1 = Q_2 + Q_3 \quad h_{f1} = h_{f2}$$

36. Define equivalent pipe and write the equation to obtain equivalent pipe diameter.

The single pipe replacing the compound pipe with same diameter without change in discharge and head loss is known as equivalent pipe.

$$L = L_1 + L_2 + L_3$$

$$(L/d^5) = (L_1/d_1^5) + (L_2/d_2^5) + (L_3/d_3^5)$$



37. What is meant by Moody's chart and what are the uses of Moody's chart?

The basic chart plotted against Darcy-Weisbach friction factor against Reynold's Number (Re) for the variety of relative roughness and flow regimes. The relative roughness is the ratio of the mean height of roughness of the pipe and its diameter ( $\epsilon/D$ ).

Moody's diagram is accurate to about 15% for design calculations and used for a large number of applications. It can be used for non-circular conduits and also for open channels.

38. Define the terms a) Hydraulic gradient line [HGL] b) Total Energy line [TEL]

Hydraulic gradient line: It is defined as the line which gives the sum of pressure head and datum head of a flowing fluid in a pipe with respect the reference line.

**HGL = Sum of Pressure Head and Datum head**

Total energy line: Total energy line 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 some reference line.

**TEL = Sum of Pressure Head, Datum head and Velocity head**

### UNIT III : DIMENSIONAL ANALYSIS

1. Define dimensional analysis.

Dimensional analysis is a mathematical technique which makes use of the study of dimensions as an aid to solution of several engineering problems. It plays an important role in research work.

2. Write the uses of dimension analysis?

- It helps in testing the dimensional homogeneity of any equation of fluid motion.
- It helps in deriving equations expressed in terms of non-dimensional parameters.
- It helps in planning model tests and presenting experimental results in a systematic manner.

3. List the primary and derived quantities.

**Primary or Fundamental quantities:** The various physical quantities used to describe a given phenomenon can be described by a set of quantities which are independent of each other. These quantities are known as fundamental quantities or primary quantities. Mass (M), Length (L), Time (T) and Temperature ( $\theta$ ) are the fundamental quantities.

**Secondary or Derived quantities:** All other quantities such as area, volume, velocity, acceleration, energy, power, etc are termed as derived quantities or secondary quantities because they can be expressed by primary quantities.

4. Write the dimensions for the followings.

**Dynamic viscosity ( $\mu$ ) –  $ML^{-1}T^{-2}$ ,      **Force (F) -  $MLT^{-2}$ ,**  
**Mass density ( $\rho$ ) –  $ML^{-3}$ ,                      **Power (P) - $ML^2T^{-3}$******

5. Define dimensional homogeneity.  
An equation is said to be dimensionally homogeneous if the dimensions of the terms on its LHS are same as the dimensions of the terms on its RHS.
  6. Mention the methods available for dimensional analysis.  
Rayleigh method, Buckingham  $\pi$  method
  7. State Buckingham's  $\pi$  theorem.  
It states that "if there are 'n' variables (both independent & dependent variables) in a physical phenomenon and if these variables contain 'm' functional dimensions and are related by a dimensionally homogeneous equation, then the variables are arranged into n-m dimensionless terms. Each term is called  $\pi$  term".
  8. List the repeating variables used in Buckingham  $\pi$  theorem.  
**Geometrical Properties – l, d, H, h, etc,**  
**Flow Properties – v, a, g,  $\omega$ , Q, etc,**  
**Fluid Properties –  $\rho$ ,  $\mu$ ,  $\gamma$ , etc.**
  9. Define model and prototype.  
The small scale replica of an actual structure or the machine is known as its Model, while the actual structure or machine is called as its Prototype. Mostly models are much smaller than the corresponding prototype.
  10. Write the advantages of model analysis.
    - Model test are quite economical and convenient.
    - Alterations can be continued until most suitable design is obtained.
    - Modification of prototype based on the model results.
    - The information about the performance of prototype can be obtained well in advance.
  11. List the types of similarities or similitude used in model analysis.  
Geometric similarities, Kinematic similarities, Dynamic similarities
  12. Define geometric similarities  
It exists between the model and prototype if the ratio of corresponding lengths, dimensions in the model and the prototype are equal. Such a ratio is known as "Scale Ratio".
  13. Define kinematic similarities  
It exists between the model and prototype if the paths of the homogeneous moving particles are geometrically similar and if the ratio of the flow properties is equal.
  14. Define dynamic similarities  
It exists between model and the prototype which are geometrically and kinematically similar and if the ratio of all forces acting on the model and prototype are equal.
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15. Mention the various forces considered in fluid flow.

Inertia force,                      Viscous force,                      Gravity force,  
 Pressure force,                      Surface Tension force,                      Elasticity force

16. Define model law or similarity law.

The condition for existence of completely dynamic similarity between a model and its prototype are denoted by equation obtained from dimensionless numbers. The laws on which the models are designed for dynamic similarity are called Model laws or Laws of Similarity.

17. List the various model laws applied in model analysis.

Reynold's Model Law,                      Froude's Model Law,  
 Euler's Model Law,                      Weber Model Law,                      Mach Model Law

18. State Reynold's model law

For the flow, where in addition to inertia force the viscous force is the only other predominant force, the similarity of flow in the model and its prototype can be established, if the Reynold's number is same for both the systems. This is known as Reynold's model law.  $Re_{(p)} = Re_{(m)}$

19. State Froude's model law

When the forces of gravity can be considered to be the only predominant force which controls the motion in addition to the force of inertia, the dynamic similarities of the flow in any two such systems can be established, if the Froude number for both the system is the same. This is known as Froude Model Law.  $Fr_{(p)} = Fr_{(m)}$

20. State Euler's model law

In a fluid system where supplied pressures are the controlling forces in addition to inertia forces and other forces are either entirely absent or in-significant the Euler's number for both the model and prototype which known as Euler Model Law.

21. State Weber's model law

When surface tension effect predominates in addition to inertia force then the dynamic similarity is obtained by equating the Weber's number for both model and its prototype, which is called as Weber Model Law.

22. State Mach's model law

If in any phenomenon only the forces resulting from elastic compression are significant in addition to inertia forces and all other forces may be neglected, then the dynamic similarity between model and its prototype may be achieved by equating the Mach's number for both the systems. This is known Mach Model Law.

23. Classify the hydraulic models.

The hydraulic models are classified as: Undistorted model & Distorted model

24. Define undistorted model

An undistorted model is that which is geometrically similar to its prototype, i.e. the scale ratio for corresponding linear dimensions of the model and its prototype are same.

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## 25. Define distorted model

Distorted models are those in which one or more terms of the model are not identical with their counterparts in the prototype.

## 26. Define Scale effect

An effect in fluid flow that results from changing the scale, but not the shape, of a body around which the flow passes.

## 27. List the advantages of distorted model.

- The results in steeper water surface slopes and magnification of wave heights in model can be obtained by providing true vertical structure with accuracy.
- The model size can be reduced to lower down the cost.
- Sufficient tractive force can be developed to produce bed movement with a small model.

## 28. Write the dimensions for the followings.

Quantities	Symbol	Unit	Dimension
Area	A	m <sup>2</sup>	L <sup>2</sup>
Volume	V	m <sup>3</sup>	L <sup>3</sup>
Angle	A	Deg. Or Rad	M <sup>0</sup> L <sup>0</sup> T <sup>0</sup>
Velocity	v	m/s	LT <sup>-1</sup>
Angular Velocity	ω	Rad/s	T <sup>-1</sup>
Speed	N	rpm	T <sup>-1</sup>
Acceleration	a	m/s <sup>2</sup>	LT <sup>-2</sup>
Gravitational Acceleration	g	m/s <sup>2</sup>	LT <sup>-2</sup>
Discharge	Q	m <sup>3</sup> /s	L <sup>3</sup> T <sup>-1</sup>
Discharge per meter run	q	m <sup>2</sup> /s	L <sup>2</sup> T <sup>-1</sup>
Mass Density	ρ	Kg/m <sup>3</sup>	ML <sup>3</sup>
Sp. Weight or Unit Weight		N/m <sup>3</sup>	ML <sup>-2</sup> T <sup>-2</sup>
Dynamic Viscosity	μ	N-s/m <sup>2</sup>	ML <sup>-1</sup> T <sup>-1</sup>
Kinematic viscosity		m <sup>2</sup> /s	L <sup>2</sup> T <sup>-1</sup>
Force or Weight	F or W	N	MLT <sup>-2</sup>
Pressure or Pressure intensity	p	N/m <sup>2</sup> or Pa	ML <sup>-1</sup> T <sup>-2</sup>
Modulus of Elasticity	E	N/m <sup>2</sup> or Pa	ML <sup>-1</sup> T <sup>-2</sup>
Bulk Modulus	K	N/m <sup>2</sup> or Pa	ML <sup>-1</sup> T <sup>-2</sup>
Workdone or Energy	W or E	N-m	ML <sup>2</sup> T <sup>-2</sup>
Torque	T	N-m	ML <sup>2</sup> T <sup>-2</sup>
Power	P	N-m/s or J/s or Watt	ML <sup>2</sup> T <sup>-3</sup>

## UNIT IV : ROTO DYNAMIC MACHINES

1. What are fluid machines or Hydraulic machines?

The machines which use the liquid or gas for the transfer of energy from fluid to rotor or from rotor to fluid are known as fluid machines.

2. How are fluid machines classified?

Fluid machines are classified into two categories depending upon transfer of energy:

1. Turbines – hydraulic energy is converted to mechanical energy and then electrical energy. 2. Pumps – electrical energy is converted to mechanical energy and then hydraulic energy.

3. What are called turbines?

Hydraulic turbines are the machines which use the energy of water and convert it into mechanical energy. The mechanical energy developed by a turbine is used in running the electrical generator which is directly coupled to the shaft.

4. What is known as Euler's equation for turbo-machines?

The general expression for the work done per second on impeller is

$$\rho Q [Vw_1 u_1 \pm Vw_2 u_2]$$

5. Define Gross Head of a turbine.

The difference between head race level and tail race level is known as Gross Head

6. Define Net head of a turbine.

It is also called effective head and is defined as the head available at the inlet of the turbine.

$$H = H_g - h_f$$

7. What are the efficiencies of a turbine?

Hydraulic efficiency	Mechanical efficiency
Volumetric efficiency	Overall efficiency

8. Define Hydraulic efficiency.

It is defined as the ratio of the power given by water to the runner of a turbine to the power supplied by the water at the inlet of the turbine.

$$\eta_h = \frac{\text{Power delivered to runner (runner power)}}{\text{Power supplied at inlet (water power)}}$$

$$\text{Water power} = \gamma Q H = (1/2) m v^2$$

9. Define Mechanical efficiency.

The ratio of the power available at the shaft of the turbine to the power delivered to the runner is defined as mechanical efficiency.

$$\eta_m = \frac{\text{Power available at the shaft (shaft power)}}{\text{Power delivered to runner (runner power)}}$$

10. Define volumetric efficiency.

The ratio of the volume of the water actually striking the runner to the volume of water supplied to the turbine is defined as volumetric efficiency.

11. Define Overall efficiency.

It is defined as the ratio of the power available at the shaft of the turbine to the power supplied by the water at the inlet of the turbine.

$$\eta_o = \frac{\text{Power available at the shaft (shaft power)}}{\text{Power supplied at inlet (water power)}}$$

$$\eta_o = \eta_h \eta_m \eta_v \quad (\text{or}) \quad \eta_o = \eta_h \eta_m$$

12. What are an impulse turbine and a reaction turbine?

#### **Impulse Turbine:**

If at the inlet of the turbine, the energy available is only kinetic energy, the turbine is known as impulse turbine. The pressure at the inlet of the turbine is atmosphere. This turbine is used for high heads. The water strikes the bucket along the tangent of the runner. Ex: Pelton Wheel Turbine.

#### **Reaction Turbine:**

If at the inlet of the turbine, the water possesses kinetic energy as well as pressure energy, the turbine is known as reaction turbine. As the water flows through the runner, the water is under pressure and the pressure energy goes on changing into kinetic energy. The runner is completely enclosed in an air-tight casing and the runner and casing is completely full of water. This turbine is used for medium heads. Ex: Francis Turbine.

13. Define Jet Ratio.

It is defined as the ratio of the pitch diameter (D) of the Pelton wheel to the diameter of the jet (d). It is denoted by 'm' and is given as  $m = D/d$

14. Classification of hydraulic turbines:

**(a) Based on type of energy available at inlet**

Impulse turbine (Pelton wheel)

Reaction turbine (Francis turbine, Kaplan turbine, Propeller turbine)

**(b) Based on head available at inlet**

High head turbine – [ > 250 m ] - (Pelton wheel)

Medium head turbine – [ 60 to 250 m ] - (Francis turbine)

Low head turbine – [ < 60 m ] – (Kaplan turbine, Propeller turbine)

**(c) Based on specific speed**

High specific speed turbine – (Kaplan turbine, Propeller turbine)

Medium specific speed turbine - (Francis turbine)

Low specific speed turbine - (Pelton wheel)

**(d) Based on direction of flow through runner**

Tangential flow turbine

Radial flow turbine

Axial flow turbine

Mixed flow turbine

15. Define Radial flow reaction turbine and their types.

If water flows in the radial direction in the turbine then it is referred as radial flow turbine.

Types:

**Inward radial flow reaction turbine:** If the water flows from outwards to inwards through the runner, the turbine is known as inward radial flow reaction turbine. Here the outer diameter of the runner is inlet diameter whereas the inner diameter of the runner is outlet diameter.

**Outward radial flow reaction turbine:** If the water flows from inwards to outwards through the runner, the turbine is called as outward radial flow reaction turbine. Here the outer diameter of the runner is outlet diameter whereas the inner diameter of the runner is inlet diameter.

16. What is mean by Draft Tube?

The draft tube is a pipe of gradually increasing area which connects the outlet of the runner to the tail race. One end of the draft tube is connected to the outlet of the runner while the other end is sub-merged below the level of water in the tail race.

17. Why do draft tubes have enlarging passage area in the direction of flow?

The pressure at the exit of the reaction turbine is generally less than atmospheric and this makes the water NOT to discharge directly to the tail race. By the introduction of draft tube, which has enlarged area in the direction of flow, the kinetic head reduces and pressure head increases. There by discharge of water to the tail race safely.

18. Uses of draft tube:

Discharges water to tail race safely

Converts a large proportion of rejected kinetic energy into useful pressure energy

Net head of the turbine is increased.

19. Types of draft tube:

Conical draft tube, Simple elbow tube, Moody spreading tube and Elbow draft tube with circular inlet and rectangular outlet.

20. Define specific speed of a turbine.

It is defined as the speed of the turbine which is geometrically similar and it will develop unit power when working under unit head.

$$N_s = N \sqrt{P} / (H)^{5/4}$$

21. Define Runaway speed of Turbine.

The max speed reached by the turbine after the removal of the external load is called runaway speed of turbine. The various rotating components of the turbine should be designed to remain safe at the runaway speed.

22. List the characteristic curves of Hydraulic turbine.

Main Characteristic Curves (or) Constant Head Curves

Operating Characteristic Curves (or) Constant Speed Curves

Muschel Curves (or) Constant Efficiency Curves

23. What is roto dynamic pump?

When the increase in pressure is developed by rotating impeller or by action of centrifugal force then the pump is called as roto dynamic pump.

24. Define Centrifugal pump.

Hydraulic pump means it converts mechanical energy into hydraulic energy. If the mechanical energy is converted into pressure energy means of centrifugal force acting on the fluid, the hydraulic machine is called Centrifugal Pump.

25. Define Specific speed of a centrifugal pump.

The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver 1 m<sup>3</sup>/s against a head of 1 m.

$$N_s = N \sqrt{Q} / (H)^{3/4} \quad (\text{OR}) \quad N_s = N \sqrt{P} / (H)^{5/4}$$

26. Efficiencies of a Centrifugal Pump:

**Manometric Efficiency:**

The ratio of the manometric head to the head imparted by the impeller to the water is known as manometric efficiency.

$$\eta_{\text{mano}} = \frac{\text{Manometric Head}}{\text{Head imparted by impeller to water}} = \frac{g H_m}{V_{w2} u_2}$$

Head imparted by impeller to water =  $V_{w2} u_2 / g$

**Mechanical Efficiency:**

The ratio of the power available at the impeller to the power at the shaft of the centrifugal pump is known as mechanical efficiency.

$$\eta_{\text{mech}} = \frac{\text{Power at the impeller}}{\text{Shaft Power}}$$

Power at the impeller = workdone by impeller per sec =  $\rho Q V_{w2} u_2$

**Overall Efficiency:**

The ratio of power output of the pump to the power input to the pump is called as overall efficiency.

$$\eta_o = \frac{\text{Weight of water lifted} \times H_m}{\text{Shaft Power}}$$

27. Define Manometric Head.

The manometric head is defined as the head against which a centrifugal pump has to work.

$H_m$  = head imparted by the impeller to the water – loss of head

$H_m = V_{w2} u_2 / g - \text{loss of head}$

$H_m = h_s + h_d + h_{fs} + h_{fd} + v_d^2 / 2g$



28. Differentiate static head & manometric head.

Sl. No.	Static Head	Manometric Head
1	The vertical head distance to liquid surface in sump to overhead tank.	Total head that must be produced by pump to satisfy the external requirements.
2	Loss of head in the pump is not considered.	The friction head loss & kinetic head are considered.
3	$H = H_s + H_d$	$H_m = H_s + H_d + h_{fd} + v_d^2/2g$

29. Minimum speed for starting a Centrifugal Pump,  $H_m = u_2^2/2g - u_1^2/2g$

30. What is mean by multi stage pump?

If more than one impeller is used in pump then such type is known as multistage pump.

**Impellers in series** – Number of impellers are mounted on a common shaft. This increases the total head. Total head =  $n H_m$

**Impellers in parallel** – Impellers are mounted in separate shaft. This increases the discharge. Total discharge =  $n Q$

31. Compare Centrifugal Pump & Reciprocating Pump.

Sl. No.	Centrifugal Pump	Reciprocating Pump
1	Its discharging capacity is more.	Its discharging capacity is low.
2	It can be used for lifting highly viscous liquids.	It can handle only pure water or less viscous liquids.
3	Its maintenance cost is low.	Its maintenance cost is high.
4	It can be operated at very high speed.	High speed may cause cavitations and separation.

32. Define Priming of a centrifugal pump.

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.

33. Define cavitation.

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

34. What are pump characteristics?

Pump characteristic means the characteristic curves of a pump. Characteristic curves of centrifugal pumps are defined as those curves which are plotted from the results of a number of tests on the centrifugal pump. These curves are necessary to predict the behaviour and performance of the pump when the pump is working under different flow rate, head and speed.

## UNIT V : POSITIVE DISPLACEMENT MACHINES

1) What is a reciprocating pump?

Reciprocating pump is a positive displacement pump. This means the liquid is first sucked into the cylinder and then displaced or pushed by the thrust of a piston.

2) What is single acting pump and double acting pump?

If the water is in contact with one side of the piston the pump then it is known as single acting reciprocating pump. For one complete revolution one suction stroke and one delivery stroke occurs.

If the water is in contact with both sides of the piston the pump then it is called double acting reciprocating pump. For one complete revolution two suction strokes and two delivery strokes occurs.

3) What is Discharge through a Reciprocating Pump?

**For Single acting Reciprocating Pump: Discharge ( $Q_T$ )=ALN/60**

**For Double acting Reciprocating Pump:  $Q_T = 2ALN/60$**

A=Area of the Cylinder ( $m^2$ ), L=Length of Stroke (m), N=Speed of Crank (rpm)

4) What is the Workdone by Reciprocating Pump per sec?

**For Single acting Reciprocating Pump: Workdone =  $\rho gALN(h_s+hd)/60$**

**For Double acting Reciprocating Pump: Work done=  $2\rho gALN(h_s+hd)/60$**

Where,  $\rho$ =Density of Water ( $kg/m^3$ ), A=Area of the Cylinder ( $m^2$ ),

L= Stroke Length (m), N=Speed (rpm),  $h_s$ ,  $h_d$ =Suction and Delivery head (m).

5) Define slip and % slip.

The difference between the theoretical discharge ( $Q_T$ ) and actual discharge ( $Q_{act}$ ) is known as slip of the pump.

$$\text{Slip} = Q_T - Q_{act}$$

$$\% \text{ Slip} = [ (Q_T - Q_{act})/Q_T ] \times 100$$

If  $Q_{act}$  is more than the  $Q_T$  then slip will be -ive.

If  $Q_{act}$  lesser than  $Q_T$  then the slip will be +ive.

6) Define coefficient of discharge of reciprocating pump?

It is defined as the ratio of actual discharge to theoretical discharge of reciprocating pump.  $C_d=Q_a/Q_{th}$ . If  $C_d > 1$  then -ive slip occurs and if  $C_d < 1$  then +ive slip occurs.

7) Write the expression for pressure head due to acceleration in suction and delivery pipes.

**Pressure head due to acceleration in suction pipe,  $h_{as} = (l_s/g) (A/a_s) \omega^2 r \text{Coswt}$**

Where,  $l_s$  - length of suction pipe; A – area of piston cylinder,

$a_s$  – area of suction pipe;  $\omega$  – angular velocity; r – radius of crank.

**Pressure head due to acceleration in delivery pipe,  $h_{ad} = (l_d/g) (A/a_d) \omega^2 r \text{Coswt}$**

Where,  $l_d$  - length of delivery pipe; A – area of piston cylinder,

$a_d$  – area of delivery pipe;  $\omega$  – angular velocity; r – radius of crank.

**Max pressure head due to acceleration,  $h_a = (l/g) (A/a) \omega^2 r$**

- 8) Write the expression for head due to friction in suction and delivery pipes.

**Head loss due to friction in suction pipe is,**  

$$h_{fs} = (4fl_s/2gd_s) [ (A/a_s) \omega^2 r \text{Sin}\omega t ]^2$$

Where,  $f$  – coefficient of friction;  $l_s$  - length of suction pipe;  $A$  – area of piston cylinder,  $a_s$  – area of suction pipe;  $d_s$  – diameter of suction pipe;  $\omega$  – Angular velocity;  $r$  – radius of crank.

**Head loss due to friction in delivery pipe is,**  

$$h_{fd} = (4fl_d/2gd_d) [ (A/a_d) \omega^2 r \text{Sin}\omega t ]^2$$

Where,  $f$  – coefficient of friction;  $l_d$  - length of delivery pipe;  $a_d$  – area of delivery pipe;  $d_d$  – diameter of delivery pipe;

- 9) Define indicator diagram?

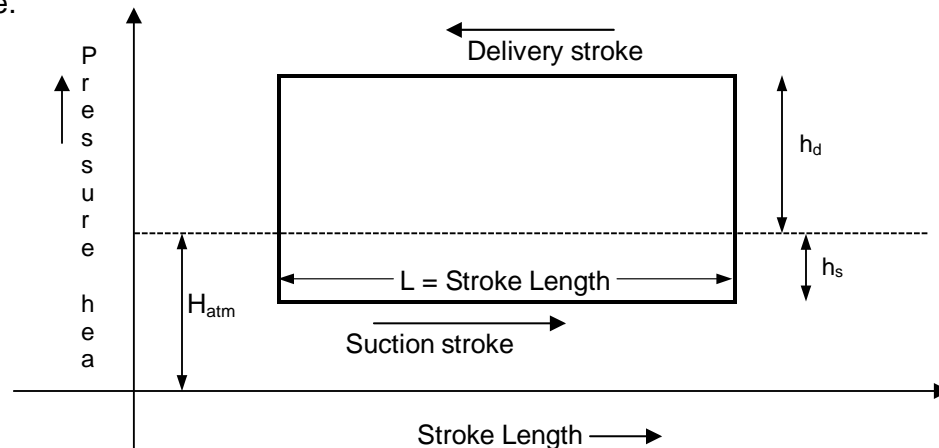
The indicator diagram for a reciprocating pump is defined as the graph drawn between the pressure head in the cylinder and the distance traveled by the piston for one complete revolution of the crank.

- 10) Define ideal indicator diagram?

It is defined as the graph between pressure head in the cylinder and stroke length of the crank under ideal condition is known as ideal indicator diagram.

During the suction stroke, the pressure in the cylinder is below atmospheric pressure.

During the delivery stroke, the pressure in the cylinder is above atmospheric pressure.



- 11) What is the relation between Work done of a Pump and Area of Indicator Diagram ?

Work done by the pump is proportional to the area of the Indicator diagram.

- 12) What is the Work done by the Pump per sec due to acceleration and friction in the suction and delivery Pipes?

**For single acting : Workdone/sec =  $pgALN(h_s+h_d+0.67h_{fs}+0.67h_{fd})/60$**

**For Double acting : Workdone/sec =  $2pgALN(h_s+h_d+0.67h_{fs}+0.67h_{fd})/60$**

Where,  $h_{fs}$ ,  $h_{fd}$  = loss of head due to friction in suction and delivery pipes.

13) What is an air vessel?

An air vessel is a closed chamber containing compressed air in the top 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 air vessel, the air gets compressed further and when the liquid flows out of the vessel, the air will expand into the chamber.

14) What is the purpose of an air vessel fitted in the pump?

- 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 pipes, and
- To run the pump at a high speed with out separation.

15) What is the work saved by fitting an air vessel in a single acting, double acting pump?

Work saved by fitting air vessels in a single acting pump is 84.87%, In a double acting pump the work saved is 39.2%.

16) Define Cavitation.

If the pressure in the cylinder is below the vapour pressure, the dissolved gases will be liberated from the liquid and air bubbles are formed. This process is termed as cavitation.

17) Define separation pressure and separation pressure head.

Due to cavitation process the continuous flow of fluid will get affected and separation takes place. The pressure at which separation takes place is known as separation pressure and the head corresponding to separation pressure is called separation pressure head.

For water the limiting value of separation pressure head is,

$$\begin{aligned} h_{\text{sep}} &= -7.8 \text{ m (Gauge pressure)} \\ h_{\text{sep}} &= 10.3 - 7.8 = 2.5 \text{ m (Absolute pressure)} \end{aligned}$$

18) How will you obtain the maximum speed during suction stroke?

The absolute pressure head will be minimum at the beginning of suction stroke. Thus, in the cylinder the separation taking place at the beginning of suction stroke only. In this case, the absolute pressure head will be equal to the separation pressure.

$$h_{\text{sep}} = H_{\text{atm}} - (h_s + h_{\text{as}}) \quad [\text{or}] \quad h_{\text{as}} = H_{\text{atm}} - h_s - h_{\text{sep}}$$

But maximum pressure head due to acceleration in suction pipe is ,

$$h_{\text{as}} = (l_s/g) (A/a_s) \omega^2 r$$

Equating both the angular velocity( $\omega$ ) and Speed (N) are obtained. This N is the maximum speed of the pump during the suction stroke without separation.

19) How will you obtain the maximum speed during delivery stroke?

The absolute pressure head will be minimum at the end of delivery stroke. Thus, in the cylinder the separation taking place at the end of delivery stroke only. In this case, the absolute pressure head will be equal to the separation pressure.

$$h_{\text{sep}} = H_{\text{atm}} + h_s - h_{\text{ad}} \quad [\text{or}] \quad h_{\text{ad}} = H_{\text{atm}} + h_d - h_{\text{sep}}$$

But maximum pressure head due to acceleration in delivery pipe is ,

$$h_{\text{ad}} = (l_d/g) (A/a_d) \omega^2 r$$

Equating both the angular velocity ( $\omega$ ) and Speed (N) are obtained. This N is the maximum speed of the pump during the delivery stroke without separation.

20) What is mean by Maximum speed of a Reciprocating Pump?

The maximum speed at which no separation flow is taking place in the cylinder is called maximum speed of a reciprocating pump. It will be the least value of speeds obtained from maximum speed during suction stroke and maximum speed during delivery stroke.

21) Write the workdone saved by fitting the air vessel in reciprocating pump.

By fitting the air vessel the head loss due to friction in suction and delivery pipe is reduced. This reduction in the head loss saves a certain amount of energy. Therefore, the workdone saved is given by,

$$\left. \begin{array}{l} \text{Workdone saved by} \\ \text{friction} \\ \text{Fitting airvessel} \end{array} \right\} = \left\{ \begin{array}{l} \text{workdone against friction} \\ \text{without airvessel} \end{array} \right\} - \left\{ \begin{array}{l} \text{workdone against} \\ \text{with airvessel} \end{array} \right\}$$

22) Write the formula for workdone against friction with air vessel in reciprocating pump.

$$\text{Workdone against friction with airvessel} = [K/\pi] \rho g Q [4fl/2gd] [(A/a) \omega r]^2$$

Where,

K = 1 for single acting reciprocating pump

K = 2 for double acting reciprocating pump

Q = theoretical discharge ( $\text{m}^3/\text{s}$ )

Q =  $ALN/60$  for single acting reciprocating pump

Q =  $2ALN/60$  for double acting reciprocating pump

f = coefficient of friction

l = length of pipe (m)

d = diameter of pipe (m)

A = area of piston ( $\text{m}^2$ )

a = area of pipe ( $\text{m}^2$ )

$\omega$  = angular velocity (rad/s)

$\omega = 2\pi N/60$

r = radius of crank

23) What will be the total % work saved by fitting the air vessel?

For single acting reciprocating pump = 84.8 %

For double acting reciprocating pump = 39.2 %