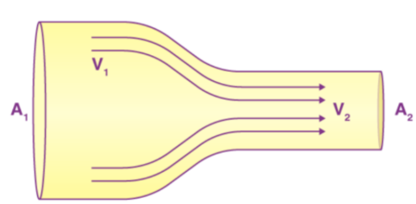
ABES ENGINEERING COLLEGE, GHAZIABAD
Department of Mechanical Engineering 2022-23
Fundamentals of Mechanical Engineering (BME 101/201)

QUESTION BANK	**Unit IV**
Topic	**Introduction to Fluid Mechanics and Applications**
Course	**B. Tech**
Semester	**I/II**

Q. NO.	Short Types Question (2 Marks)
1.	**<u>Define fluids and properties of ideal fluids.</u>** **Ans.** Fluid is a substance that continuously deform (flows) under an applied shear stress/force. Idea fluid is incompressible, inviscid (viscosity = 0) and has no surface tension.
2.	**<u>Calculate the specific gravity of one liter of a liquid that weighs 7N.</u>** **Ans.** Given: Volume of water (V) = 1 Liter or 1/1000 m^3 Weight of liquid (W) = 7 N Specific gravity of liquid (s) = density of liquid (ρ_1)/density of wate r(ρ_2) Where density of liquid (ρ_1) = mass of liquid (m) /volume of liquid (V) (ρ_1) = W/gV (as W = mg) (ρ_1) = (7×1000)/9.81 = 713.5 kg/m^3 ρ_2 = 1000 kg/m^3 s = ρ_1/ ρ_2 = 713.5/1000 **s = 0.7135 Ans.**
3.	**<u>State Newton's law of viscosity.</u>** It states that the shear stress (τ) on a fluid element is directly proportional to the rate of shear strain ($\frac{du}{dy}$). The constant of proportionality is called as the co-efficient of viscosity. Mathematically; $\tau = \mu \frac{du}{dy}$
4.	**<u>Define density, specific gravity and specific weight.</u>**

	<u>Density:</u> Density or mass density of a fluid is defined as the ratio of the mass of fluid to its volume. Thus, mass per unit volume of a fluid is called as density (ρ). $\rho = \frac{Mass\ of\ Fluid}{Volume\ of\ fluid}$ (kg/m$^{3)}$ **<u>Specific Gravity (S)</u>:** Specific gravity is defined as the ratio of weihght density (or density) of a fluid to the weight density (or density) of a standard fluid. <u>For liquids;</u> water at 4 degree centigrade is taken as standard fluid and its weight density (or density) is taken as 1000 Kg.m^3 <u>For Gases;</u> air is taken as standard fluid. <u>Mathematically;</u> $S = \frac{\textbf{Weight density (density) of fluid}}{\textbf{Weight density (density)of standard fluid}}$ **Specific Weight or Weight Density (ω):** Specific weight or weight density of a fluid os the ratio between the weight of a fluid to its volume. Thus; weight per unit volume of a fluid is called weight density and it is denoted by the symbol ω. Mathematically; $\omega = \frac{Weight\ of\ fluid}{Volume\ of\ fluid}$
5.	**<u>State and explain continuity equation.</u>** The continuity equation is simply a mathematical expression of the principle of conservation of mass. It states that all **mass flow rates into** a control volume are equal to all **mass flow rates out** of the control volume plus the rate of change of mass within the control volume  **$Q = A_1V_1 = A_2V_2$**
6.	**<u>What is the function of spear head in Pelton turbine assembly?</u>** The function of spear head is to control the quantity of water striking the buckets.

7. **Differentiate between impulse and reaction turbines.**

The water at inlet of impulse turbine possesses only kinetic energy whereas, the water at inlet of reaction turbine posses kinetic energy and potential energy both.

Impulse turbine is high head whereas, reaction turbine is low/medium head turbine.

8. **Why we use draft tube in reaction turbine? Explain.**

The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. The water at exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race. This tube of increasing area is called draft tube.

Q. NO.	Long Types Question (5 Marks)

9. **Explain and derive Pascal's law with help of a neat sketch. What are its practicalapplications?**

▶ 2.2 PASCAL'S LAW

It states that the pressure or intensity of pressure at a point in a static fluid is equal in all directions. This is proved as :

The fluid element is of very small dimensions *i.e.*, dx, dy and ds.

Consider an arbitrary fluid element of wedge shape in a fluid mass at rest as shown in Fig. 2.1. Let the width of the element perpendicular to the plane of paper is unity and p_x, p_y and p_z are the pressures or intensity of pressure acting on the face AB, AC and BC respectively. Let $\angle ABC = \theta$. Then the forces acting on the element are :

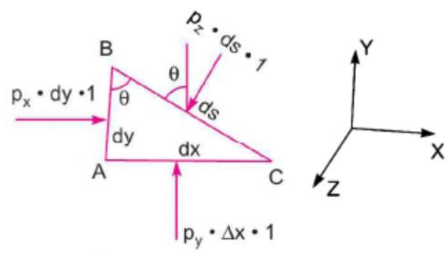


Fig. 2.1 *Forces on a fluid element.*

1. Pressure forces normal to the surfaces, and
2. Weight of element in the vertical direction.

The forces on the faces are :

Force on the face AB $= p_x \times$ Area of face AB

$= p_x \times dy \times 1$

Similarly force on the face $AC = p_y \times dx \times 1$

Force on the face BC $= p_z \times ds \times 1$

Weight of element $=$ (Mass of element) $\times g$

$$= (\text{Volume} \times \rho) \times g = \left(\frac{AB \times AC}{2} \times 1\right) \times \rho \times g,$$

where ρ = density of fluid.

Resolving the forces in x-direction, we have

$$p_x \times dy \times 1 - p\,(ds \times 1)\sin(90° - \theta) = 0$$

or $$p_x \times dy \times 1 - p_z\, ds \times 1 \cos\theta = 0.$$

But from Fig. 2.1, $ds \cos\theta = AB = dy$

$\therefore$ $$p_x \times dy \times 1 - p_z \times dy \times 1 = 0$$

or $$p_x = p_z \quad \text{...(2.1)}$$

Similarly, resolving the forces in y-direction, we get

$$p_y \times dx \times 1 - p_z \times ds \times 1 \cos(90° - \theta) - \frac{dx \times dy}{2} \times 1 \times \rho \times g = 0$$

or

$$p_y \times dx - p_z\, ds \sin\theta - \frac{dxdy}{2} \times \rho \times g = 0.$$

But $ds \sin\theta = dx$ and also the element is very small and hence weight is negligible.

$\therefore \quad p_y dx - p_z \times dx = 0$

or

$$p_y = p_z \qquad \text{...(2.2)}$$

From equations (2.1) and (2.2), we have

$$p_x = p_y = p_z \qquad \text{...(2.3)}$$

The above equation shows that the pressure at any point in x, y and z directions is equal.

Since the choice of fluid element was completely arbitrary, which means the pressure at any point is the same in all directions.

10.

What do you understand by the following terms, (i) Absolute pressure, gauge pressure and vacuum pressure (ii) Kinematic Viscosity

1. Absolute pressure is defined as the pressure which is measured with reference to absolute vacuum pressure.

2. Gauge pressure is defined as the pressure which is measured with the help of a pressure measuring instrument, in which the atmospheric pressure is taken as datum. The atmospheric pressure on the scale is marked as zero.

3. Vacuum pressure is defined as the pressure below the atmospheric pressure.

The relationship between the absolute pressure, gauge pressure and vacuum pressure are shown in Fig. 2.7.

Mathematically :

(i) Absolute pressure

= Atmospheric pressure + Gauge pressure

or $\quad p_{ab} = p_{atm} + p_{gauge}$

(ii) Vacuum pressure

= Atmospheric pressure – Absolute pressure.

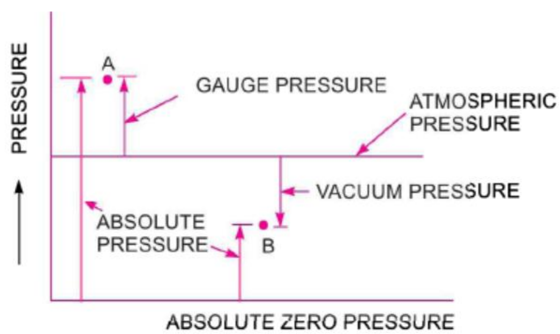


Fig. 2.7 *Relationship between pressures.*

1.3.2 Kinematic Viscosity. It is defined as the ratio between the dynamic viscosity and density of fluid. It is denoted by the Greek symbol (ν) called 'nu'. Thus, mathematically,

$$\nu = \frac{\text{Viscosity}}{\text{Density}} = \frac{\mu}{\rho} \qquad \text{...(1.4)}$$

11.

What are hydraulic turbines? Give a brief classification of the same along with suitableexamples.

Hydraulic Turbines:

Turbines are defined as the hydraulic machines which convert hydraulic energy into mechanical energy. This mechanical energy is used in running an electric generator which is directly coupled to the shaft of the turbine. Thus, the mechanical energy is converted into electrical energy. The electric power which is obtained from the hydraulic energy (energy of water) is known as Hydroelectric power.

CLASSIFICATION OF HYDRAULIC TURBINES

The hydraulic turbines are classified according to the type of energy available at the inlet of the turbine, direction of flow through the vanes, head at the inlet of the turbine and specific speed of the turbines. Thus, the following are the important classifications of the turbines:

1. According to the type of energy at inlet:
   (a) Impulse turbine, and (b) Reaction turbine.
2. According to the direction of flow through runner:
   (a) Tangential flow turbine, (b) Radial flow turbine, (c) Axial flow turbine, and (d) Mixed flow turbine.
3. According to the head at the inlet of turbine:
   (a) High head turbine, (b) Medium head turbine, and (c) Low head turbine.
4. 4. According to the specific speed of the turbine:
   (a) Low specific speed turbine, (b) Medium specific speed turbine, and (c) High specific speed turbine.

12. **A cubical block weighing 300 N and having 0.8 cm edge is allowed to slide down an inclined plane surface making an angle of 30° with the horizontal on which there is a uniform layer of oil 1.5 mm thick. If the expected steady state velocity of the block is 0.3 m/s, determine the viscosity of the oil.**

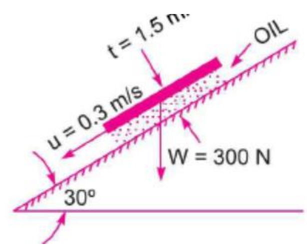
Solution. Given :

Area of plate, $A = 0.8 \times 0.8 = 0.64 \text{ m}^2$

Angle of plane, $\theta = 30°$

Weight of plate, $W = 300$ N

Velocity of plate, $u = 0.3$ m/s



Thickness of oil film, $t = dy = 1.5 \text{ mm} = 1.5 \times 10^{-3}$ m

Let the viscosity of fluid between plate and inclined plane is μ.

Component of weight W, along the plane $= W \cos 60° = 300 \cos 60° = 150$ N

Thus the shear force, F, on the bottom surface of the plate = 150 N

and shear stress, $\tau = \dfrac{F}{\text{Area}} = \dfrac{150}{0.64}$ N/m^2

Now using equation (1.2), we have

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

where du = change of velocity $= u - 0 = u = 0.3$ m/s

$dy = t = 1.5 \times 10^{-3}$ m

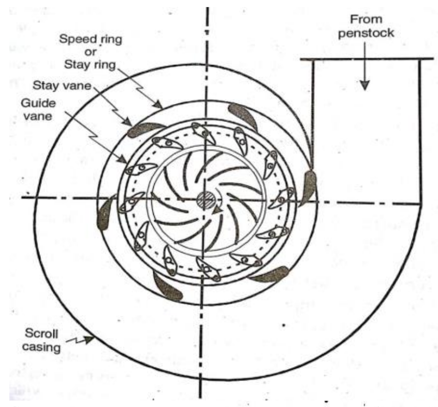
$$\therefore \quad \frac{150}{0.64} = \mu \frac{0.3}{1.5 \times 10^{-3}}$$

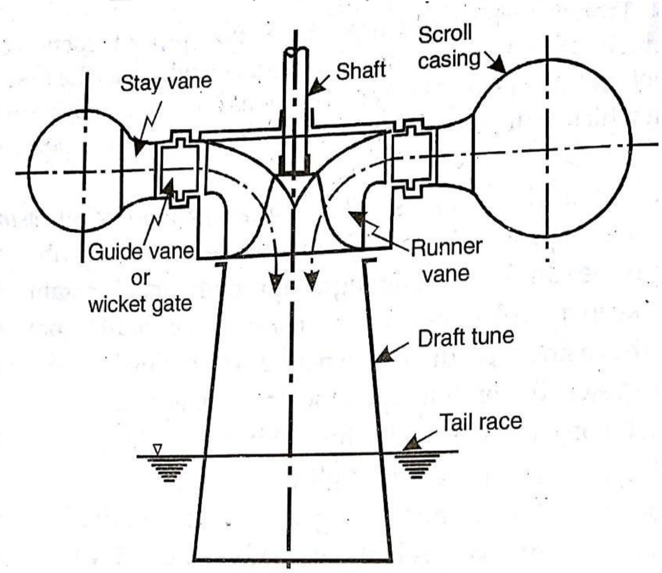
$$\therefore \quad \mu = \frac{150 \times 1.5 \times 10^{-3}}{0.64 \times 0.3} = 1.17 \text{ N s/m}^2 = 1.17 \times 10 = \mathbf{11.7 \text{ poise. Ans.}}$$

Q. NO.	Long Types Question (7 Marks)
13.	**Explain the construction and working of a Francis turbine with a neat and clean diagram.**

Francis turbine (reaction turbine)

Reaction turbine means that the water at the inlet of the turbine possesses kinetic energy as well as pressure energy. As the water flows through the runner, a part of pressure energy goes on changing into kinetic energy. Thus, the water through the runner is under pressure. The runner is completely enclosed in an air-tight casing and casing and the runner is always full of water.





The water is allowed to enter the spiral casing of the turbine, which lead the water through the stay vanes and guide vanes. The spiral case is kept in decreasing diameter so as to maintain the flow pressure. The stay vanes being stationary at their place. The angle of guide vanes decides the angle of attack of water at the runner blades thus make sure the maximum output of the turbine. The runner blades are stationary and can-not pitch or change their angle so it's all about the guide vanes which controls the power output of a turbine. The performance and efficiency of the turbine is dependent on the design of the runner blades. In a Francis turbine, runner blades are divided into two parts. The lower half is made in the shape

of small bucket so that it uses the impulse action of water to rotate the turbine. The upper part of the blades uses the reaction force of water flowing through it. Thus, runner blades make use of both pressure energy and kinetic energy of water and rotates the runner in most efficient way. The water coming out of runner blades would lack both the kinetic energy and pressure energy, so we use the draft tube to recover the pressure as it advances towards tail race.

	construction of Francis turbine Main Parts of a Radial Flow Reaction Turbine. The main parts of a radial flow reaction turbine are: 1. Casing, 2. Guide mechanism, 3. Runner, and 4. Draft-tube. 1. **Casing:** As mentioned above that in case of reaction turbine, casing and runner are always full of water. The water from the penstocks enters the casing which is of spiral shape in which area of cross-section of the casing goes on decreasing gradually. The casing completely surrounds the runner of the turbine. The casing made of spiral shape, so that the water may enter the runner at constant velocity throughout the circumference of the runner. The casing is made of concrete, cast steel etc. 2. **Guide Mechanism:** It consists of a stationary circular wheel all-round the runner of the turbine. The stationary guide vanes are fixed on the guide mechanism. The guide vanes allow the water to strike the vanes fixed on the runner without shock at inlet. Also, by a suitable arrangement, the width between two adjacent vanes of guide mechanism can be altered so that the amount of water striking the runner can be varied. 3. **Runner:** It is a circular wheel on which a series of radial curved vanes are fixed. The surface of the vanes are made very smooth. The radial curved vanes are so shaped that the water enters and leaves the runner without shock. The runners are made of cast steel, cast iron or stainless steel. They are keyed to the shaft. 4. **Runner Blades:** The performance and efficiency of the turbine is dependent on the design of the runner blades. In a Francis turbine, runner blades are divided into 2 parts. The lower half is made in the shape of small bucket so that it uses the impulse action of water to rotate the turbine. The upper part of the blades uses the reaction force of water flowing through it. These two forces together make the runner to rotate. 5. **Draft tube:** The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. The water at exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race. This tube of increasing area is called draft tube.
14.	**<u>Explain the construction and working of a reciprocating pump with a neat and clean diagram.</u>** **Reciprocating Pumps:** If the mechanical energy is converted in to pressure energy by sucking the liquid in to a cylinder in which a piston is reciprocating backward and forward, which exerts the thrust on the liquid and increases its hydraulic energy or pressure energy, the hydraulic machine will be termed as reciprocating pump.

Working of Single acting reciprocating pump

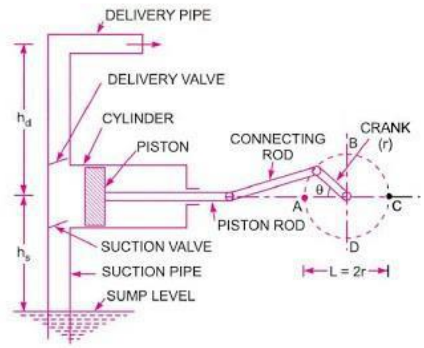


Figure shows a **single acting** reciprocating pump, which consists of a piston which moves forwards and backwards in a close-fitting cylinder. The movement of the piston is obtained by connecting the piston rod to crank by means of a connecting rod. The crank is rotated by means of an electric motor. Suction and delivery pipes with suction valve and delivery valve are connected to the cylinder. The suction and delivery valves are one-way valves or non-return valves, which allow the water to flow in one direction only. Suction valve allows water from suction pipe to the cylinder which delivery valve allows water from cylinder to delivery pipe only.

When crank starts rotating, the piston moves to and fro in the cylinder. When crank is at A., the piston is at the extreme left position in the cylinder. As the crank is rotating from A to C, (i.e., from $\Theta = 0°$ to $\Theta = 180°$), the piston is moving towards right in the cylinder. The movement of the piston towards right creates a partial vacuum in the cylinder. But on the surface of the liquid in the sump atmospheric pressure is acting, which is more than the pressure inside the cylinder. Thus, the liquid is forced in the suction pipe from the sump. This liquid opens the suction valve and enters the cylinder. When crank is rotating from C to A (i.e., from $\Theta = 180°$ to $\Theta = 360°$), the piston from its extreme right position starts moving towards left in the cylinder. The movement of the piston towards left increases the pressure of the liquid inside the cylinder more than atmospheric pressure. Hence suction valve closes

15. **Explain the construction and working of a Pelton turbine with a neat and clean diagram.**

The Pelton wheel or Pelton turbine is a tangential flow impulse turbine. The water strikes the bucket along the tangent of the runner. The energy available at the inlet of the turbine is only kinetic energy. The pressure at the inlet and outlet of the turbine is atmospheric. This turbine is used for high heads and is named after L.A. Pelton, an American Engineer.

Working of Pelton (impulse) Turbine

The water stored at a high head is made to flow through the penstock and reaches the nozzle of the Pelton turbine. The nozzle increases the kinetic energy of the water and directs the water in the form of a jet which strikes on the buckets of the runner tangentially. The water jet exerts a force on the bucket called as Impulse force. This made the runner to rotate at very high speed. The quantity of water striking the buckets is controlled by the needle valve (spear) present inside the nozzle. The generator is attached to the shaft of the runner which converts the mechanical energy of the runner into electrical energy.

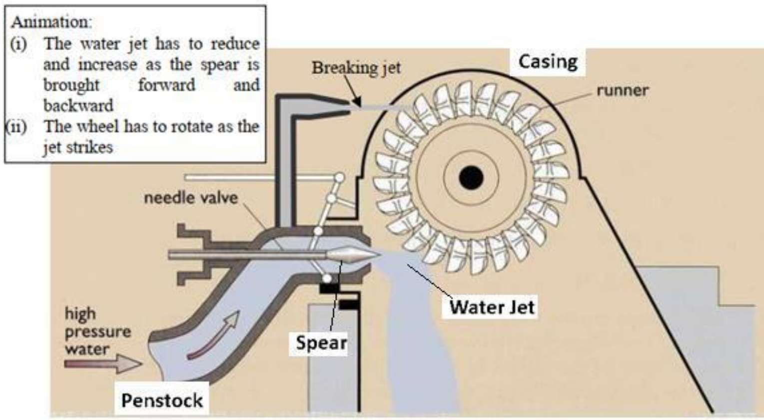


Figure shows the layout of a hydroelectric power plant in which the turbine is Pelton wheel. The water from the reservoir flows through the penstocks at the outlet of which a nozzle is fitted. The main parts of the Pelton turbine are:

1. Nozzle and flow regulating arrangement (spear),
2. Runner and buckets,
3. Casing, and
4. Breaking jet.

1. **Nozzle and Flow Regulating Arrangement:** The amount of water striking the buckets of the runner is controlled by providing a spear in the nozzle as shown in Figure. The spear is a conical needle which is operated either by a hand wheel or automatically in an axial direction depending upon the size of the unit. When the spear is pushed forward into the nozzle the amount of water striking the runner is reduced. On the other hand, if the spear is pushed back, the amount of water striking the runner increases.

2. **Runner with Buckets**: Figure shows the runner of a Pelton wheel. It consists of a circular disc on the periphery of which a number of buckets evenly spaced are fixed. The shape of the buckets is of a double hemispherical cup or bowl. Each bucket is divided into two symmetrical parts by a dividing wall which is known as splitter. The jet of water strikes on the splitter. The splitter divides the jet into two equal parts and the jet comes out at the outer edge of the bucket. The buckets are shaped in such a way that the jet gets deflected through 160° or 170°. The buckets are made of cast iron, cast steel bronze or stainless steel depending upon the head at the inlet of the turbine.

Casing: Figure shows a Pelton turbine with a casing. The function of the casing is to prevent the splashing of the water and to discharge water to tail race. It also acts as safeguard against accidents. It is made of cast iron or fabricated steel plates. The casing of the Pelton wheel does not perform any hydraulic function.

4. **Breaking Jet**: 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.

16. **What are the hydraulic pumps? With a neat sketch illustrate the construction and working of Centrifugal pump.**

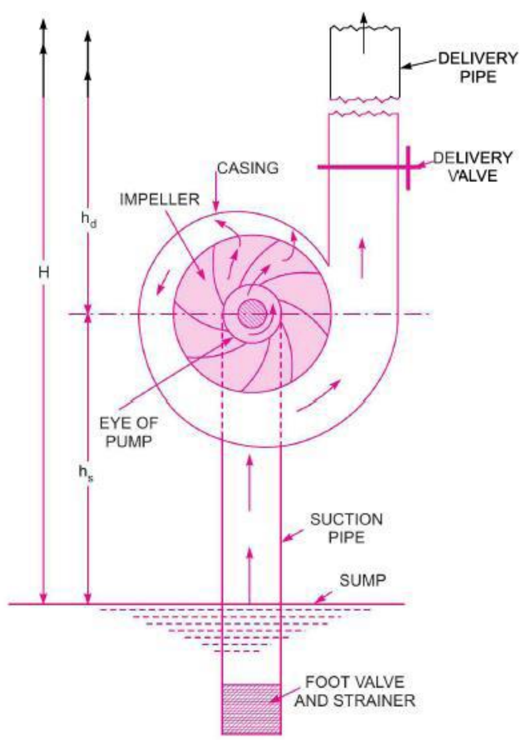
Ans. Hydraulic pumps are devices designed to convert mechanical energy to hydraulic energy. They are used to move water from lower points to higher points with a required discharge and pressure head.

Centrifugal pump:

If the mechanical energy is converted into pressure energy by means of centrifugal force acting on the fluid, the hydraulic machine is called centrifugal pump.

Working of Centrifugal pump

The centrifugal pump acts as a reverse of an inward radial flow reaction turbine. This means that the flow in centrifugal pumps is in the radial outward directions. The centrifugal pump works on the principle of forced vortex flow which means that when a certain mass of liquid is rotated by an external torque, the rise in pressure head of the rotating liquid takes place. The rise in pressure head at any point of the rotating liquid is proportional to the square of tangential velocity of the liquid at that point (i.e., **rise in pressure head**$=\frac{V^2}{2g}$ or $\frac{r^2\omega^2}{2g}$). Thus, at the outlet of the impeller, where radius is more, the rise in pressure head will be more and the liquid will be discharged at the outlet with a high-pressure head. Due to this high-pressure head, the liquid can be lifted to a high level.



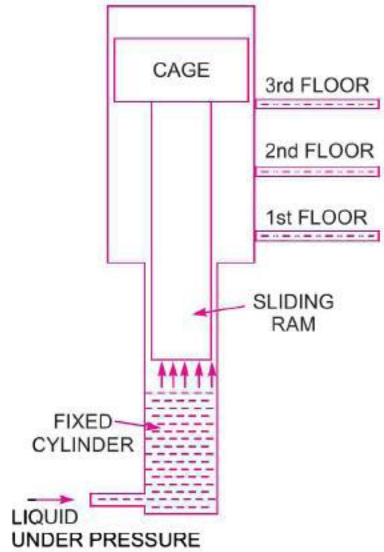
Main parts of a centrifugal pump.

CONSTRUCTION OF CENTRIFUGAL PUMP

The following are the main parts of a centrifugal pump:

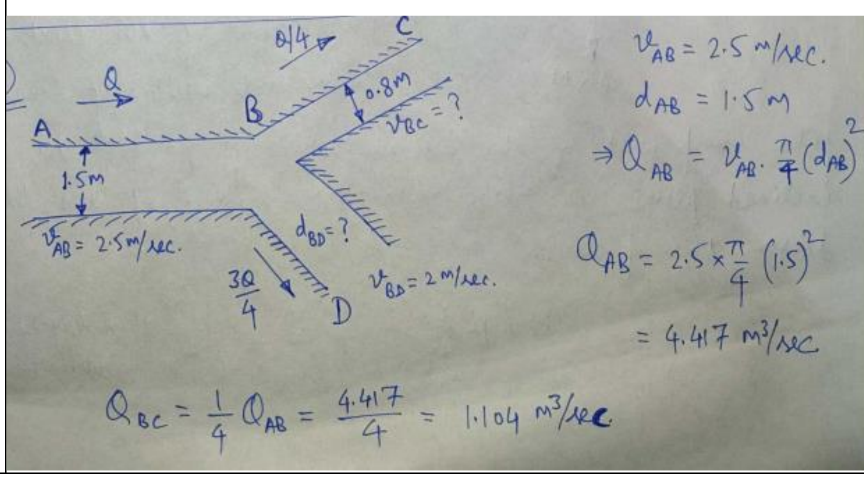
1. Impeller.
2. Casing.

	3. Suction pipe with a foot valve and a strainer. 4. Delivery pipe. 1. Impeller: The rotating part of a centrifugal pump is called 'impeller'. It consists of a series of backward curved vanes. The impeller is mounted on a shaft which is connected to the shaft of an electric motor. 2. Casing: The casing of a centrifugal pump is similar to the casing of a reaction turbine. It is an airtight passage surrounding the impeller and is designed in such a way that the kinetic energy of the water discharged at the outlet of the impeller is converted into pressure energy before the water leaves the casing and enters the delivery pipe. 3. Volute Casing: Figure shows the volute casing, which surrounds the impeller. It is of spiral type in which area of flow increases gradually. The increase in area of flow decreases the velocity of flow. The decrease in velocity increases the pressure of the water flowing through the casing. 4. Suction Pipe with a Foot valve and a Strainer: A pipe whose one end is connected to the inlet of the pump and other end dips into water in a sump is known as suction pipe. A foot valve which is a non-return valve or one-way type of valve is fitted at the lower end of the suction pipe. The foot valves open only in the upward direction. A strainer is also fitted at the lower end of the suction pipe. 5. Delivery Pipe: A pipe whose one end is connected to the outlet of the pump and other end delivers the water at a required height is known as delivery pipe. 6. Suction Head (h_s): It 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 to be lifted as shown in Figure. This height is also called suction lift and is denoted by 'h_s'. 7. Delivery Head (h_d): The vertical distance between the center line of the pump and the water surface in the tank to which water is delivered is known as delivery head. This is denoted by 'h_d'. 8. Static Head (Hs): The sum of suction head and delivery head is known as static head. This is represented by "H_s' and is written as $Hs=h_s + h_d$
17.	**<u>Explain the construction and working of suspended type hydraulic lift.</u>** **Ans.** A hydraulic lift is a device for moving objects or passenger using force created by the pressure on a liquid inside a cylinder that moves a piston upward. Incompressible oil is pumped into the cylinder, which forces the piston upward. When a valve opens to release the oil, the piston lowers by gravitational force. The principle for hydraulic lifts is based on Pascal's law for generating force or motion, which states that pressure change on an incompressible liquid in a confined space is passed equally throughout the liquid in all directions. The hydraulic lifts are of two types, namely, 1. Direct acting hydraulic lift, and 2. Suspended hydraulic lift.



It consists of a ram, sliding in fixed cylinder as shown in Fig. At the top of the sliding ram, a cage (on which the persons may stand or goods may be placed) is fitted. The liquid under pressure flows into the fixed cylinder. This liquid exerts force on the sliding ram, which moves vertically up and thus raises the cage to the required height. The cage is moved in the downward direction, by removing the liquid from the fixed cylinder.

18. **<u>Water flows through a pipe AB 1.5 m diameter at 2.5 m/sec At B, the pipe branches into BC and BD. Branch BC is 0.8 meter in diameter and carries one fourth of the flow in AB. The flow velocity in branch BDis 2 m/sec. Find the volume flow rate in AB, the velocity in BC, and the diameter of BD.</u>**



$$Q_{BD} = \frac{3Q_{AB}}{4} = 3.313\ m^3/sec.$$

Now, $Q_{BC} = \frac{\pi}{4}(d_{BC})^2 \cdot V_{BC}$

$$1.104 = \frac{\pi}{4}(0.8)^2 \cdot v_{BC}$$

$$\Rightarrow v_{BC} = \frac{1.104}{\frac{\pi}{4}(0.8)^2} = \boxed{2.196\ m/sec}$$ Ans

Also, $Q_{BD} = \frac{\pi}{4}(d_{BD})^2 \cdot v_{BD}$ (here, $v_{BD} = 2$ m/sec given)

$$\Rightarrow \frac{\pi}{4}(d_{BD})^2 = \frac{3.313}{2} = 1.6565\ m^2$$

$$\Rightarrow d_{BD} = \sqrt{\frac{1.6565 \times 4}{\pi}} = \boxed{1.45\ m}$$ Ans

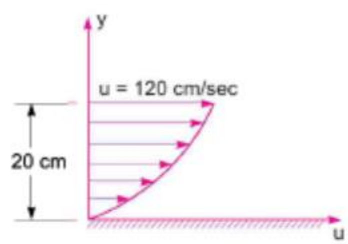
19. **If the velocity profile of a fluid over a plate is parabolic with the vertex 20 cm from the plate, where the velocity is 120 cm/sec. Calculate the velocity gradients and shear stresses at a distance of 0, 10 and 20 cm from the plate, if the viscosity of the fluid is 8.5 poise.**

Solution. Given :

Distance of vertex from plate = 20 cm

Velocity at vertex, $u = 120$ cm/sec

Viscosity, $\mu = 8.5 \text{ poise} = \frac{8.5}{10}\frac{\text{N s}}{\text{m}^2} = 0.85.$



The velocity profile is given parabolic and equation of velocity profile is

$$u = ay^2 + by + c \qquad ...(i)$$

where a, b and c are constants. Their values are determined from boundary conditions as :

(a) at $y = 0$, $u = 0$

(b) at $y = 20$ cm, $u = 120$ cm/sec

(c) at $y = 20$ cm, $\frac{du}{dy} = 0$.

Substituting boundary condition (a) in equation (i), we get

$$c = 0.$$

Boundary condition (b) on substitution in (i) gives

$$120 = a(20)^2 + b(20) = 400a + 20b \qquad ...(ii)$$

Boundary condition (c) on substitution in equation (i) gives

$$\frac{du}{dy} = 2ay + b \qquad ...(iii)$$

or $$0 = 2 \times a \times 20 + b = 40a + b$$

Solving equations (ii) and (iii) for a and b

From equation (iii), $b = -40a$

Substituting this value in equation (ii), we get

$$120 = 400a + 20 \times (-40a) = 400a - 800a = -400a$$

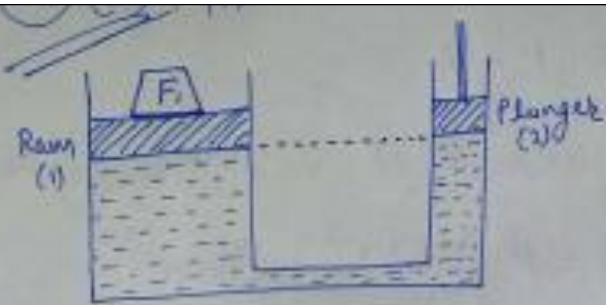
$$\therefore \quad a = \frac{120}{-400} = -\frac{3}{10} = -0.3$$

$$\therefore \quad b = -40 \times (-0.3) = 12.0$$

Substituting the values of a, b and c in equation (i),

$$u = -0.3y^2 + 12y.$$

	Velocity Gradient $$\frac{du}{dy} = -0.3 \times 2y + 12 = -0.6y + 12$$ at $y = 0$, Velocity gradient, $\left(\frac{du}{dy}\right)_{y=0} = -0.6 \times 0 + 12 = \mathbf{12/s.\ Ans.}$ at $y = 10$ cm, $\left(\frac{du}{dy}\right)_{y=10} = -0.6 \times 10 + 12 = -6 + 12 = \mathbf{6/s.\ Ans.}$ at $y = 20$ cm, $\left(\frac{du}{dy}\right)_{y=20} = -0.6 \times 20 + 12 = -12 + 12 = \mathbf{0.\ Ans.}$ **Shear Stresses** Shear stress is given by, $\tau = \mu \frac{du}{dy}$ (*i*) Shear stress at $y = 0$, $\tau = \mu \left(\frac{du}{dy}\right)_{y=0} = 0.85 \times 12.0 = 10.2\ N/m^2$. (*ii*) Shear stress at $y = 10$, $\tau = \mu \left(\frac{du}{dy}\right)_{y=10} = 0.85 \times 6.0 = 5.1\ N/m^2$. (*iii*) Shear stress at $y = 20$, $\tau = \mu \left(\frac{du}{dy}\right)_{y=20} = 0.85 \times 0 = \mathbf{0.\ Ans.}$
20.	**In a hydraulic jack mechanism, the diameter of ram is 11 cm and that of plunger is 2.5cm. A force of 75 N is applied on the plunger. Find the load lifted by the ram, when (a)ram and plunger are at the same level, (b) Plunger is 450 mm above the ram level. Given: density of the fluid is 1000 Kg/m^3.**



Ram side

$F_1 = ?$

Ram area $(A_1) = \frac{\pi}{4}\times(11)^2$ cm^2

Plunger side

$F_2 = 75$ N

Plunger area $(A_2) = \frac{\pi}{4}\times(2.5)^2$ cm^2

Now, since ram and plunger are at the same level, hence pressure at ram side = pressure at plunger side

i.e. $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

$$\Rightarrow \frac{F_1}{\frac{\pi}{4}(11)^2} = \frac{75}{\frac{\pi}{4}(2.5)^2} \Rightarrow \boxed{F_1 = 1452\ N}$$ Ans

(ii)

When ram and plunger has a vertical gap of 450 mm, then according to hydrostatics principle,

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} + h\rho g$$ (here, $h = 450$ mm)

$$\Rightarrow \frac{F_1}{\frac{\pi}{4}(11\times10^{-2})^2} = \frac{75}{\frac{\pi}{4}(2.5\times10^{-2})^2} + 1000\times9.81\times(450\times10^{-3})$$

$= 152788.745 + 4414.5$

$= 157203.245$

$$\Rightarrow \boxed{F_1 = 1493.95\ N}$$ Ans

21. **The dynamic viscosity of an oil, used for lubrication between a shaft and sleeve is 6 poise. The shaft is of diameter 0.4 m and rotates at 190 r.p.m. Calculate the power lostin the bearing for a sleeve length of 90 mm. The thickness of the oil film is 1.5 mm.**

Solution. Given :

Viscosity $\mu = 6$ poise

$$= \frac{6}{10}\frac{\text{N s}}{\text{m}^2} = 0.6\ \frac{\text{N s}}{\text{m}^2}$$

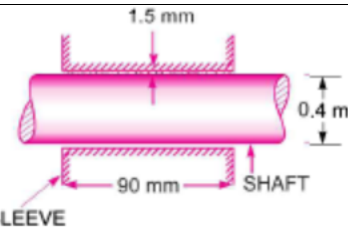


Fig. 1.5

Dia. of shaft, $D = 0.4$ m

Speed of shaft, $N = 190$ r.p.m

Sleeve length, $L = 90 \text{ mm} = 90 \times 10^{-3}$ m

Thickness of oil film, $t = 1.5 \text{ mm} = 1.5 \times 10^{-3}$ m

Tangential velocity of shaft, $u = \frac{\pi D N}{60} = \frac{\pi \times 0.4 \times 190}{60} = 3.98$ m/s

Using the relation $\tau = \mu \frac{du}{dy}$

where du = Change of velocity $= u - 0 = u = 3.98$ m/s

dy = Change of distance $= t = 1.5 \times 10^{-3}$ m

$$\tau = 10 \times \frac{3.98}{1.5 \times 10^{-3}} = 1592 \text{ N/m}^2$$

This is shear stress on shaft

$\therefore$ Shear force on the shaft, F = Shear stress × Area

$$= 1592 \times \pi D \times L = 1592 \times \pi \times .4 \times 90 \times 10^{-3} = 180.05 \text{ N}$$

Torque on the shaft, $T = \text{Force} \times \frac{D}{2} = 180.05 \times \frac{0.4}{2} = 36.01$ Nm

$\therefore$ *Power lost $= \frac{2\pi NT}{60} = \frac{2\pi \times 190 \times 36.01}{60} =$ **716.48 W. Ans.**