PUMPS

- In this chapter, students will learn about
  (1) Pumps.
  (2) Classification of pumps.
  (3) Construction and working of reciprocating and centrifugal types of pumps.

Pumps

- Pump is device which transfers/lifts the liquid from one place to another
- It is used to increase the potential energy of liquid.
- It requires external work to operate a pump.
- Pump is generally operated with the help of electric motor.

Classification of pumps

- Pump is broadly classified as (1) positive displacement pumps and (2) dynamic pressure pumps.

(1) Positive Displacement Pumps

- A pump which transfers/lifts the liquid due to its movement in fixed space is known as positive displacemnt pumps.
- In this type of pumps, liquid is enclosed properly and moved from one place to another place.
- Positive displacement pumps can be reciprocating type or rotary type.
- Further classification of positive displacement type pumps are as under.

Classification of Positive Displacement Pumps	
Reciprocating type pumps • A positive displacement pump in which liquid is lifted due to reciprocating motion is known as reciprocating type pump.	Piston Pump
	Plunger Pump
	Bucket Pump
	Single Acting Pump
	Double Acting Pump
Rotary type pumps • A positive displacement pump in which liquid is lifted due to rotary motion is known as rotary type pump.	Gear Pump
	Vane Pump
	Screw Pump

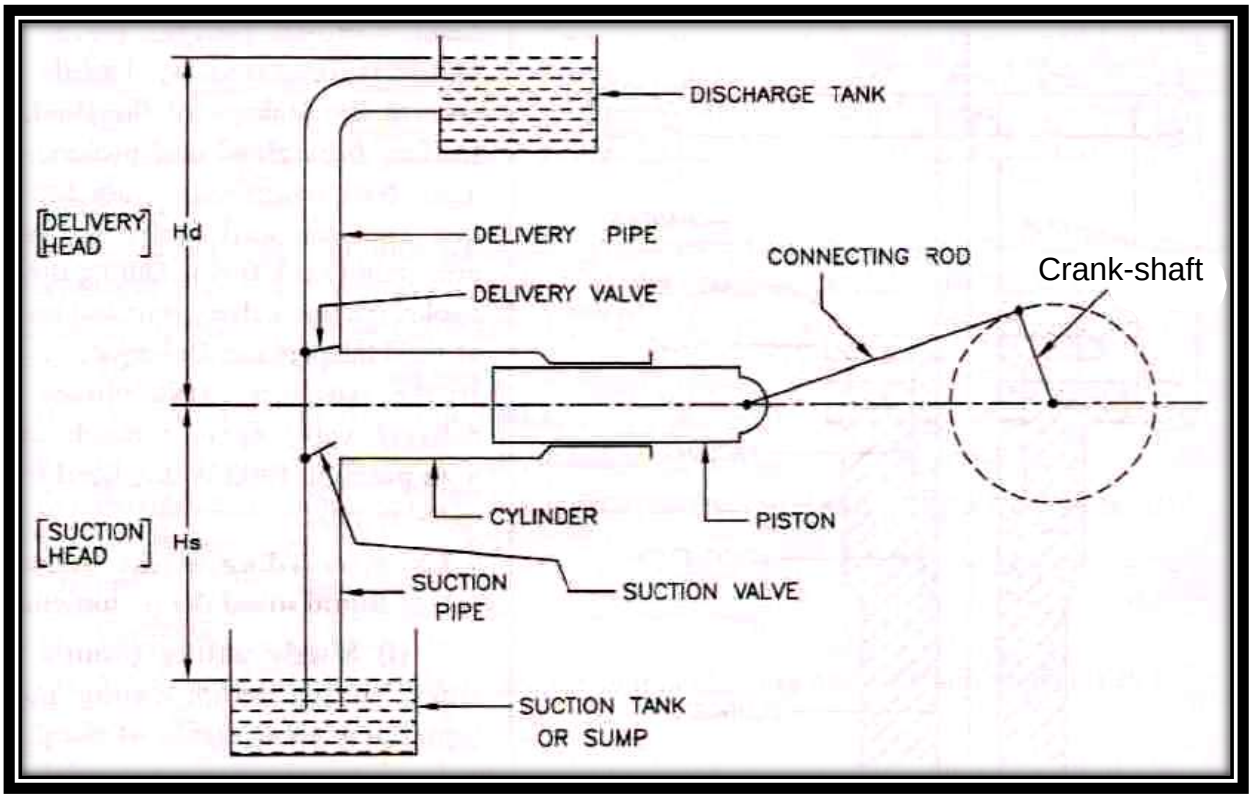
(2) Dynamic Pressure Pumps (Non-Positive Displacemnent Pumps)

- A pump in which liquid is transferred/lifted due to continuously generated pressure is known as dynamic pressure pumps.
- In this type of pumps, pressure of the liquid is increased due to rotary motion.
- Dynamic pressure pumps are always rotary type pumps.

Classification of Dynamic Pressure Pumps	
Centrifugal pumps • A dynamic pressure pump in which liquid is lifted due to centrifugal force is known as centrifugal pump.	Volute Casing type pump
	Volute Casing with Vortex chamber type pump
	Diffuser type pump
	Single stage pump
	Multi stage pump
Turbine pumps	
Propeller pumps	

Reciprocating Pump – Piston Pump – Single Acting Pump

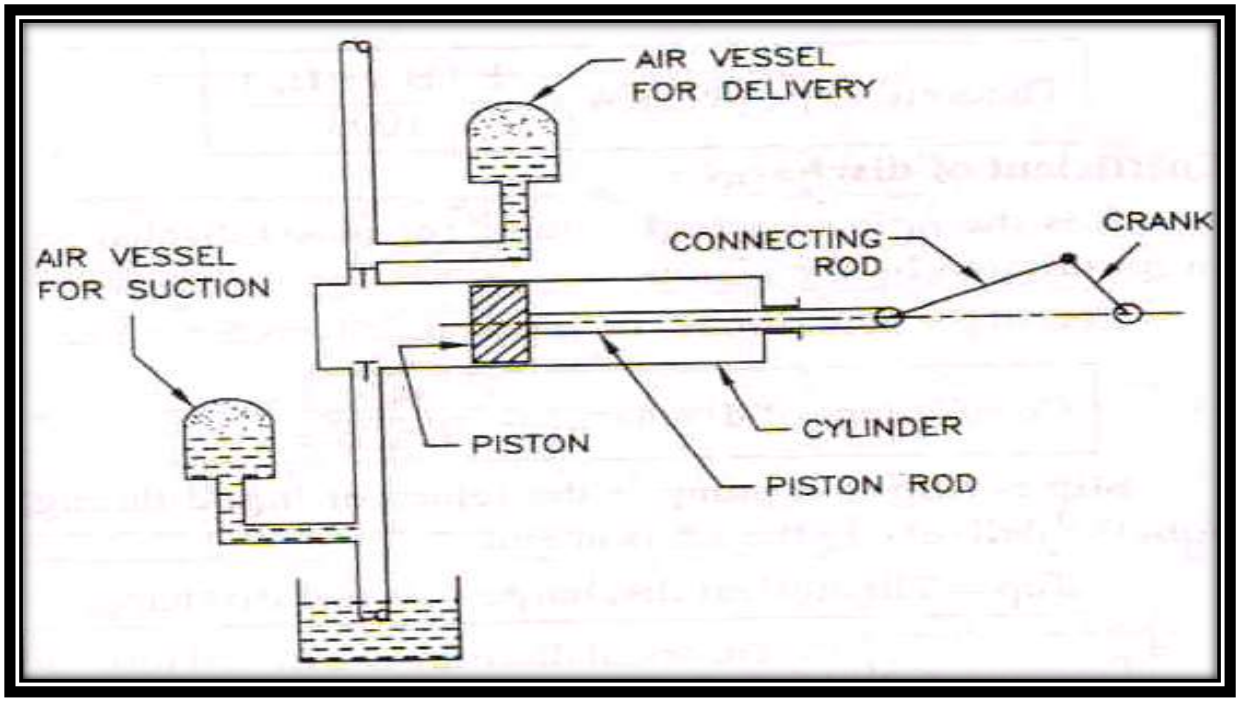
Construction and working of single acting reciprocating piston pump	
Construction	• It contains a fixed cylinder in which piston reciprocates. • Piston is connected to crank-shaft through connecting rod. ● Crank-shaft is connected to electrical motor. • Suction pipe connects the cylinder with sump and discharge (delivery) pipe connects cylinder with overhead tank. • Suction valve and discharge valve are located in suction pipe and discharge pipe respectively. • Both the valves are one way valves i.e. non return valve (NRV) which allows the flow of liquid in one direction only.



Working	First Stroke (Suction Stroke)	• Electrical motor is switched on. • As electrical motor rotates, crank shaft also rotates. • Crank shaft rotates from 0^O to 180^O. • Piston reciprocates from left end side of the cylinder to right hand side of the cylinder. • Due to movement of piston, partial vacuum is created. • Thus, suction valve opens and water from the sump enters the cylinder.
	Second Stroke (Discharge Stroke)	• Crank rotates from 180^O to 360^O (0^O). • Piston reciprocates from right end side of the cylinder to left hand side of the cylinder. • Due to movement of piston, the space inside the cylinder reduces continuously and water inside the cylinder is compressed to high pressure. • Due to high pressure, delivery valve opens and allows high pressure water to enter into overhead tank. • Then cycle is repeated.
	• Thus, during suction stroke, only water is filled inside the cylinder and during discharge stroke water is lifted to overhead tank. • Discharge of water to overhead tank is available only during discharge stroke only. • Thus, this type of pump provides the discharge intermittently. • In this type of pump, as the width of the reciprocating member is less than the stroke length of the cylinder, it is known as piston pump. • In this type of pump, water is in contact with only one the side of piston. So, it is known as single acting pump.	

Reciprocating Pump – Piston Pump – Single Acting Pump with Air Vessels

Construction and working of single acting reciprocating piston pump with Air Vessels	
Construction	• The pump consists of a piston that reciprocates in a closely fitted cylinder. • Suction and delivery pipes are provided with a non return valve known as suction valve in suction pipe and delivery valve in delivery pipe. • The pump is driven by crank and connecting rod mechanism operated by a power source which may be an electric motor, steam engine or IC engine. • The liquid acts at only one side of piston. • Air vessels are connected to suction & delivery pipe both. • An air vessel is a vessel which is filled with the compressed air at the top.

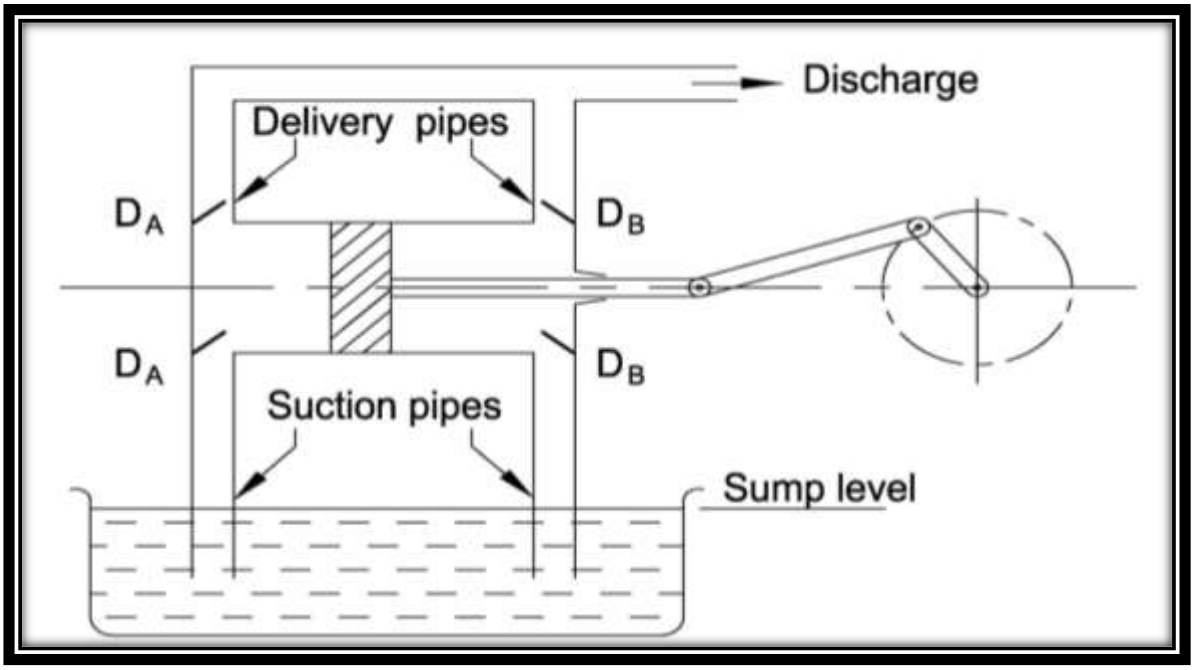


r ki	First Stroke	• When crank turns clockwise from I.D.C to O.D.C the

	(Suction Stroke)	piston moves towards right at this time vacuum develops on the left side of the cylinder. • Due to this phenomenon the suction valve opens and liquid is forced from the sump in to the cylinder on the left side of the piston. • When piston moves, I.D.C. to the middle of the cylinder, vacuum created is more, so more liquid is lifted from the sump and at that time, space between the piston and cylinder head is less. • During this time, the excess liquid enters the air vessel provided in the suction line and compresses the air. • When piston moves from middle of cylinder to O.D.C., vacuum created is less, so less liquid is lifted from the sump and at that time, space between the piston and cylinder is more. • During this time, the air exerts the pressure on the liquid inside the air vessel and pushes the liquid into cylinder.
	Second Stroke (Discharge Stroke)	• When the piston moves from O.D.C to I.D.C, space between piston and cylinder head decreases continuously. • So, high pressure is developed in the cylinder and this increase in pressure closes the suction valve and opens the delivery valve. • Consequently, the liquid is forced out of the cylinder in the discharge pipe. • As similar to the suction stroke, air vessel stores the excess liquid when more quantity of liquid at high pressure is available and gives back the same liquid when the liquid in delivery pipe is at low pressure. • When the piston reaches I.D.C, the delivery stroke is completed.
	• Thus, air vessel in suction and delivery pipe help to maintain the constant flow of liquid in both the pipes.	

Reciprocating Pump – Piston Pump – Double Acting Pump

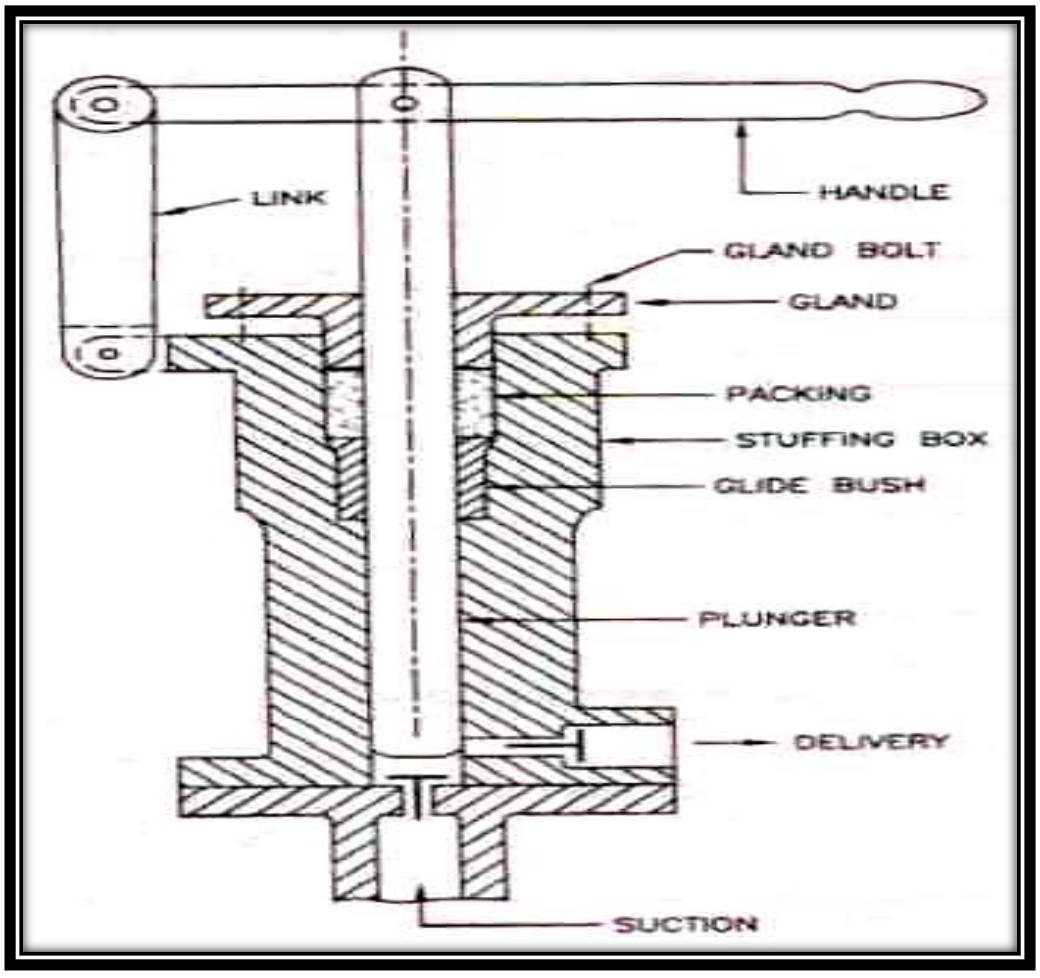
Construction and working of double acting reciprocating piston pump	
Construction	• It contains a fixed cylinder in which piston reciprocates. • Piston is connected to crank shaft through connecting rod and crank. • Crank is connected to electrical motor. • Suction pipes are connected to both the sides of the piston below the cylinder and discharge (delivery) pipes are also connected to both the sides of the piston but above the cylinder. • Two suction valves (S1 and S2) and discharge valves (D1 and D2) are located in suction pipes and discharge pipes respectively. • All the valves are one way valves i.e. non return valve (NRV) which allows the flow of liquid in one direction only.



Working	First Stroke	• Electrical motor is switched on. • As electrical motor rotates, crank shaft also rotates. • Crank shaft rotates from 0^O to 180^O. • Piston reciprocates from left end side of the cylinder to right hand side of the cylinder. ❖ **Process Left Hand Side of the Piston** • Due to movement of piston, partial vacuum is created at the left hand side of the piston. • Thus, suction valve, S1 opens and water from the sump enters the cylinder in the left side of the piston. ❖ **Process Right Hand Side of the Piston** • Due to movement of piston, gap between piston and right side end of the cylinder reduces continuously and water inside the cylinder is compressed to high pressure at right side of the piston. • Due to high pressure, delivery valve, D2 opens and allows high pressure water to enter into overhead tank. • *Thus, left hand side of the piston, suction is going on and right hand side of the piston discharge of water to overhead tank is going on.*
	Second Stroke	• Crank rotates from 180^O to 360^O (0^O). • Piston reciprocates from right end side of the cylinder to left hand side of the cylinder. ❖ **Process Left Hand Side of the Piston** • Due to movement of piston, gap between piston and left side end of the cylinder reduces continuously and water inside the cylinder is compressed to high pressure at left side of the piston. • Due to high pressure, delivery valve, D1 opens and allows high pressure water to enter into overhead tank. ❖ **Process Right Hand Side of the Piston** • Due to movement of piston, partial vacuum is created at the right hand side of the piston. • Thus, suction valve, S2 opens and water from the sump enters the cylinder in the right side of the piston. • *Thus, left hand side of the piston, discharge of water to overhead tank is going on and right hand side of the piston suction is going on.* • Then cycle is repeated.

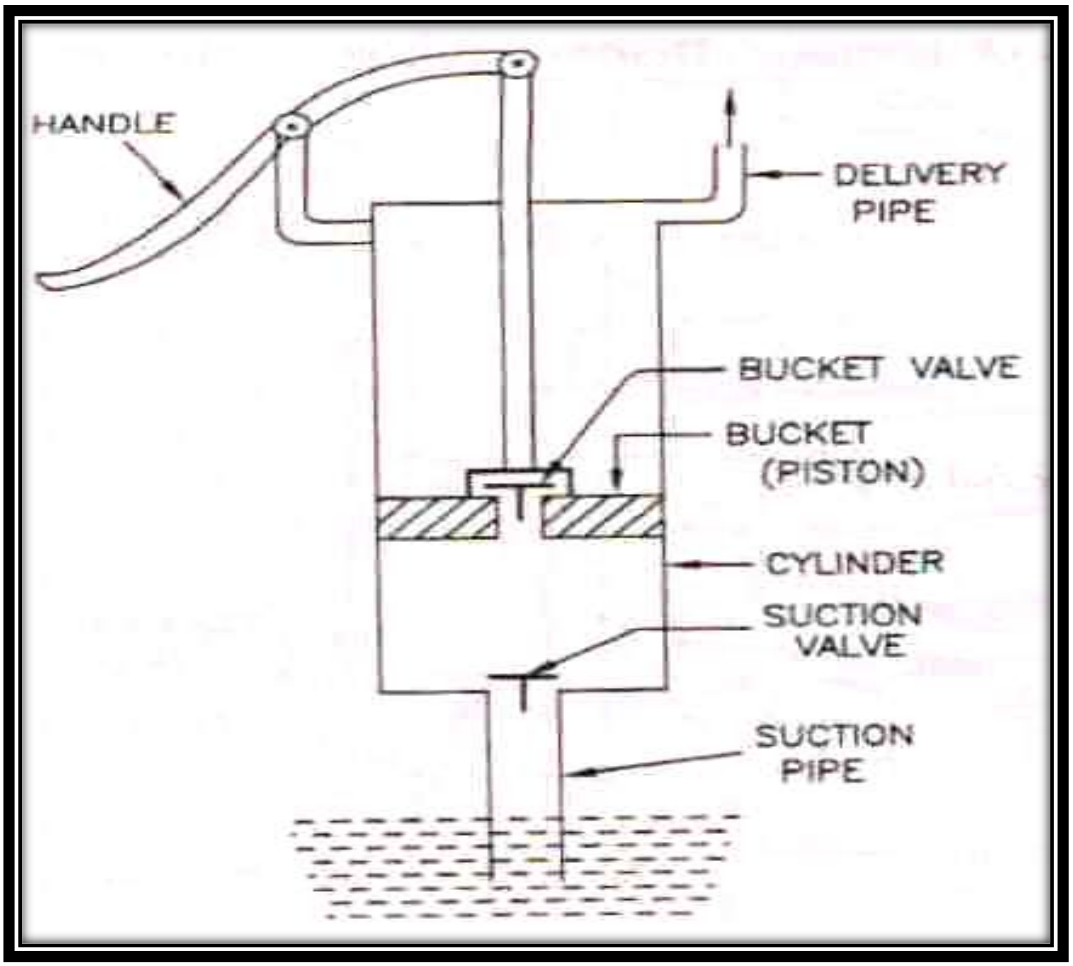
	• Thus, during both the strokes, water is lifted to overhead tank. • Discharge of water to overhead tank is available during both the strokes. • Thus, this type of pump provides the discharge continuously. • In this type of pump, as the width of the reciprocating member is less than the stroke length of the cylinder, it is known as piston pump. • In this type of pump, water is in contact with both the sides of piston. So, it is known as double acting pump.

Plunger Pump



Construction and working of plunger pump		
Construction		• It contains a fixed cylinder known as body or frame of a plunger pump. • A plunger reciprocates inside the fixed cylinder. • Plunger is connected to handle. • Suction pipe and suction valve are connected to bottom of the cylinder. • Discharge pipe and discharge valve are connected to one side of a cylinder.
Working	First Stroke (Suction Stroke)	• As the handle is moved down, plunger moves up in the cylinder. • Thus, partial vacuum is generated in the cylinder and water is lifted through suction pipe and enters the cylinder through suction valve.
	Second Stroke (Discharge Stroke)	• As the handle is moved up, plunger moves down in the cylinder. • Water is compressed inside the cylinder and due to high pressure of water, discharge valve opens and water comes out.
	• In this type of pump, as the width of the reciprocating member is more than the stroke length of the cylinder, it is known as plunger pump.	

Bucket Pump

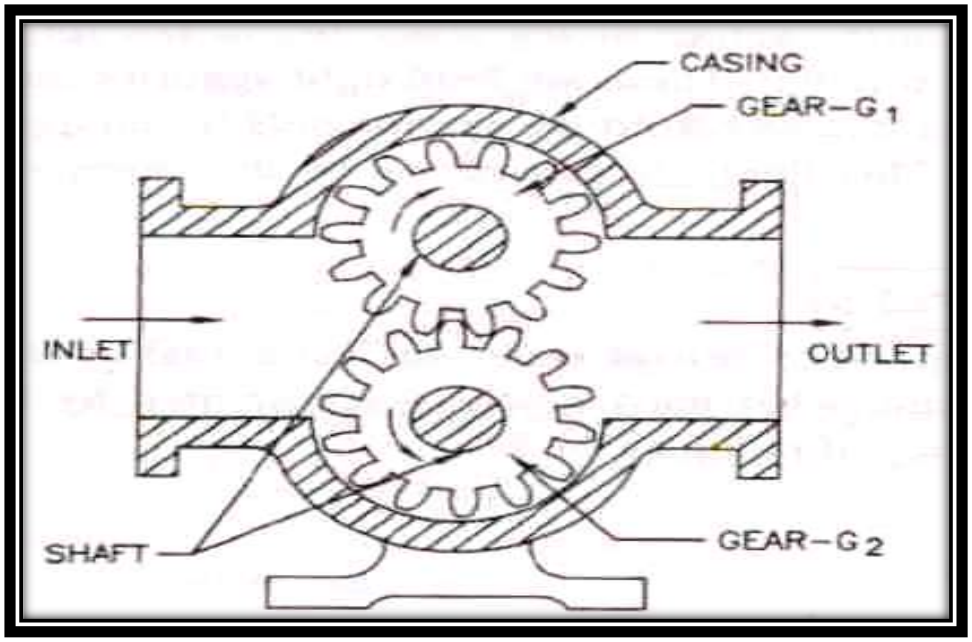


Construction and working of bucket pump	
Construction	• It contains a fixed cylinder known as body or frame of the bucket pump. • A valve known as bucket valve is located in inside the piston. Thus, it is known as bucket. • Piston is connected to hand lever. • Suction pipe and suction valve are connected to the bottom side of the cylinder. • Discharge pipe and discharge valves are connected to top side of the cylinder.

Working	First Stroke (Suction Stroke and Discharge Stroke)	• As the hand lever is moved down, bucket moves up. • Due to this movement of bucket, partial vacuum is generated below the bucket and water available above the bucket is compressed. • Thus, water is lifted and filled in side the cylinder below bucket region and water comes out from top side of the cylinder. • So, there is a suction process below the bucket and discharge process above the bucket during the stroke.
	Second Stroke (Transfer Stroke)	• As the hand lever is moved up, bucket moves down. • Due to this movement of bucket water below the bucket transfers to above the bucket through the bucket valve located in bucket. • Thus, during this stroke only water transfers.
	• In this type of pump, a valve is located in the reciprocating member. Thus, it is known as bucket pump.	

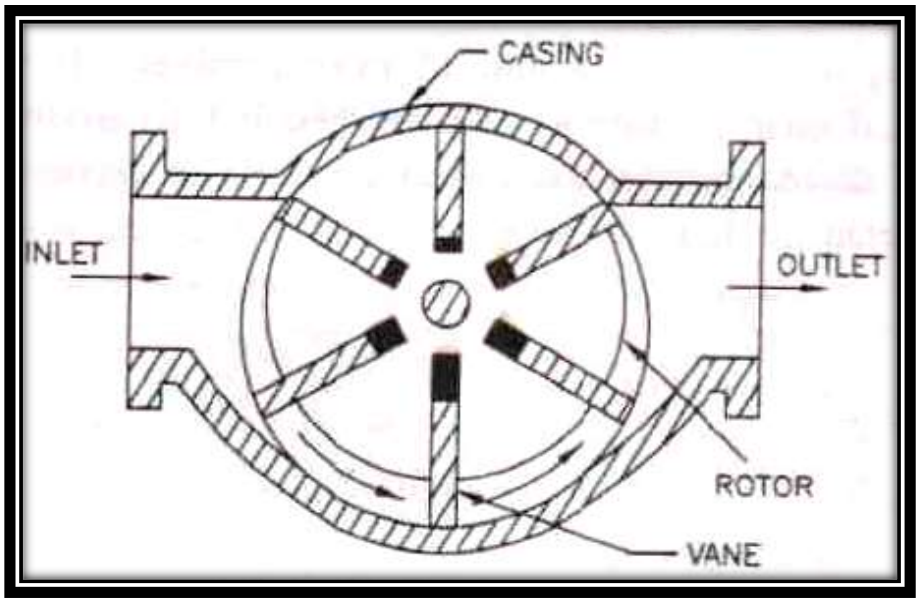
Rotary Pump

Gear Pump



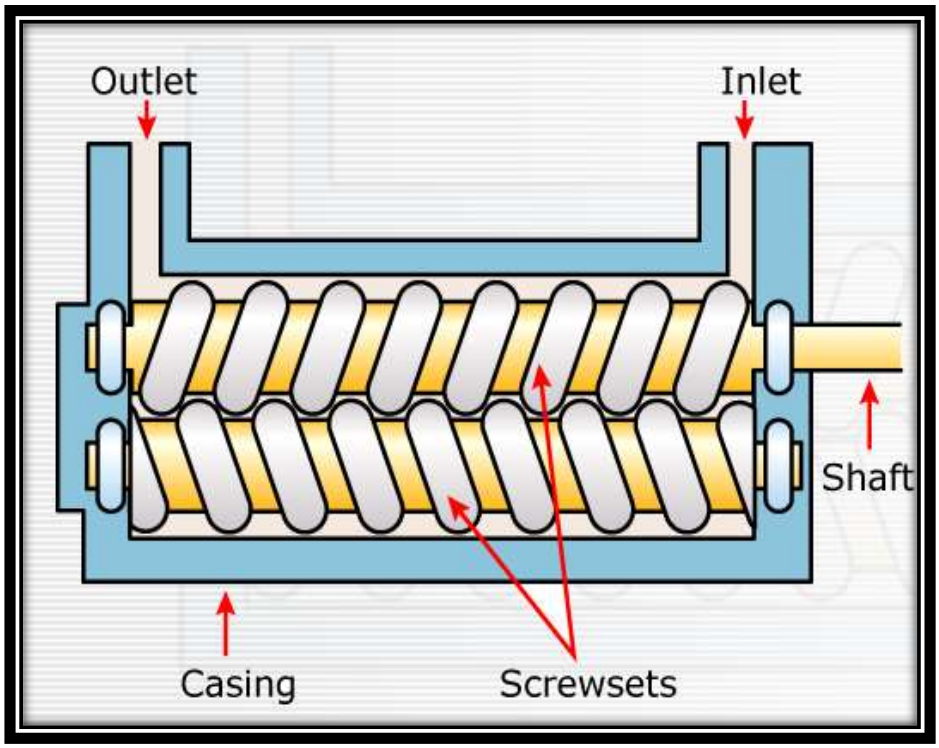
Construction and working of gear pump	
Construction	• It contains two interconnected gears. • These gears are placed in casing. • One gear is connected to electric motor. This gear is known as driving gear and another gear is known as driven gear. • As electric motor rotates, driving gear rotates which in turn rotates the driven gear. • At one side there is suction & another side discharge.
Working	• As electric motor rotates, driving gear rotates which in turn rotates the driven gear. • Both the gears rotate in opposite direction. • When inter-meshed teeth of both the gears disengage, partial vacuum is created in side the gear pump. Thus, liquid enters through the suction. • Then liquid is enclosed (entrapped) between two teeth of a gear and casing. • Now, enclosed liquid has to move along with the gears. Thus, liquid is pumped to the discharge section.

Vane Pump



Construction and working of vane pump	
Construction	• It contains a rotor mounted on shaft of electric motor. • On the periphery of rotor, grooves are prepared. • Sliding vanes are arranged in each groove with springs. Thus, when we press the sliding vane, it moves inside the groove and comes out when we release the pressure on it. • The rotor is placed in the casing eccentrically, i.e. centre of rotor and center of casing are not same. • Due to this arrangement, there is non-uniform gap between rotor and casing. • Sliding vanes are always in contact with casing. • At one side there is suction and another side discharge.
Working	• As electric motor rotates, rotor also rotates and fluid enters the pump. • Fluid is entrapped between two vanes and casing. • Thus, entrapped fluid has to rotate along with the rotor from suction to discharge section. • When fluid moves from suction to discharge section, gap between rotor and casing also decreases. Thus, fluid is compressed. • Compressed fluid comes out from the discharge section.

Screw Pump

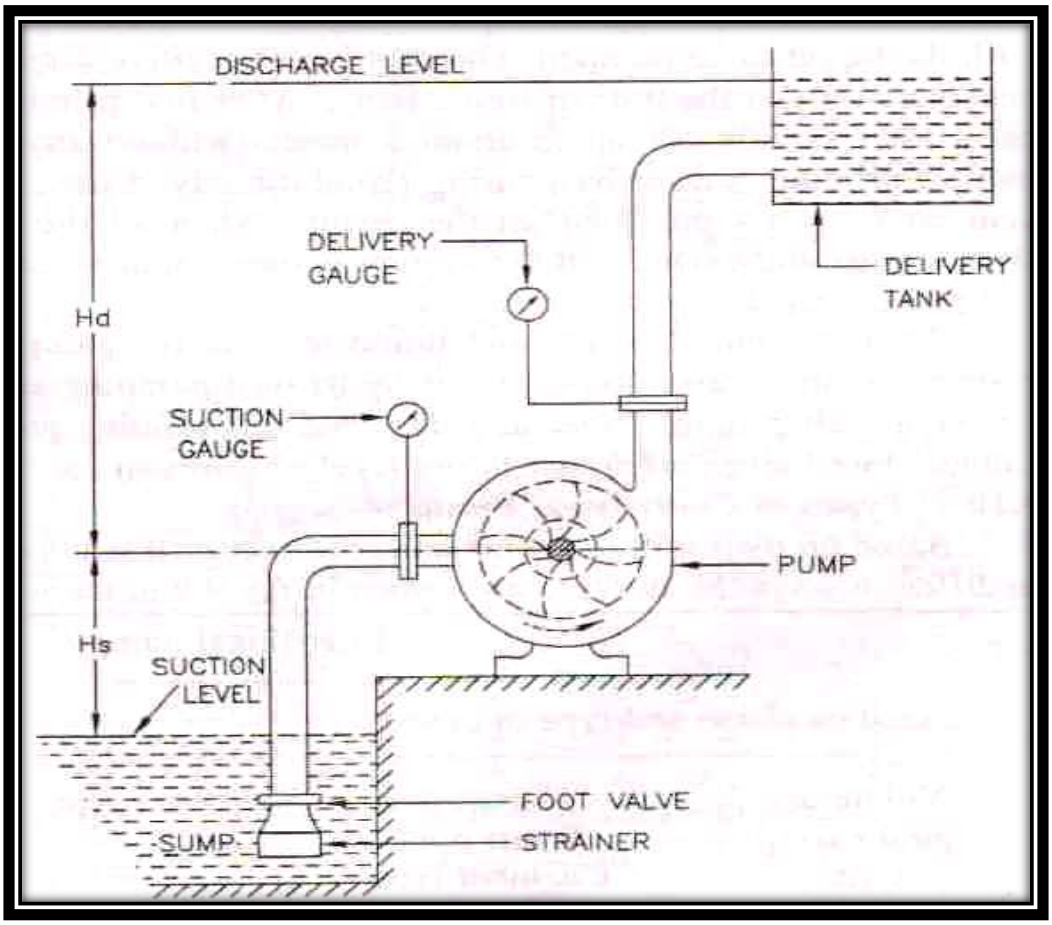


Construction and working of screw pump	
Construction	• It contains two interconnected screws. • These screws are placed in casing. • One screw is connected to electric motor. This screw is known as driving screw and another screw is known as driven screw. • As electric motor rotates, driving screw rotates which in turn rotates the driven screw. • At one end there is suction and another end discharge.
Working	• As electric motor rotates, driving screw rotates which in turn rotates the driven screw and fluid enters the pump. • Then liquid is enclosed (entrapped) between the passage of both the screws and moves from suction to discharge side.

Centrifugal Pump

- The pumps which employ centrifugal force for transferring liquids from one place to another are called the centrifugal pumps.
- These pumps are also called as roto-dynamic pump as the liquids are handled by a rotating impeller with a stationary casing.

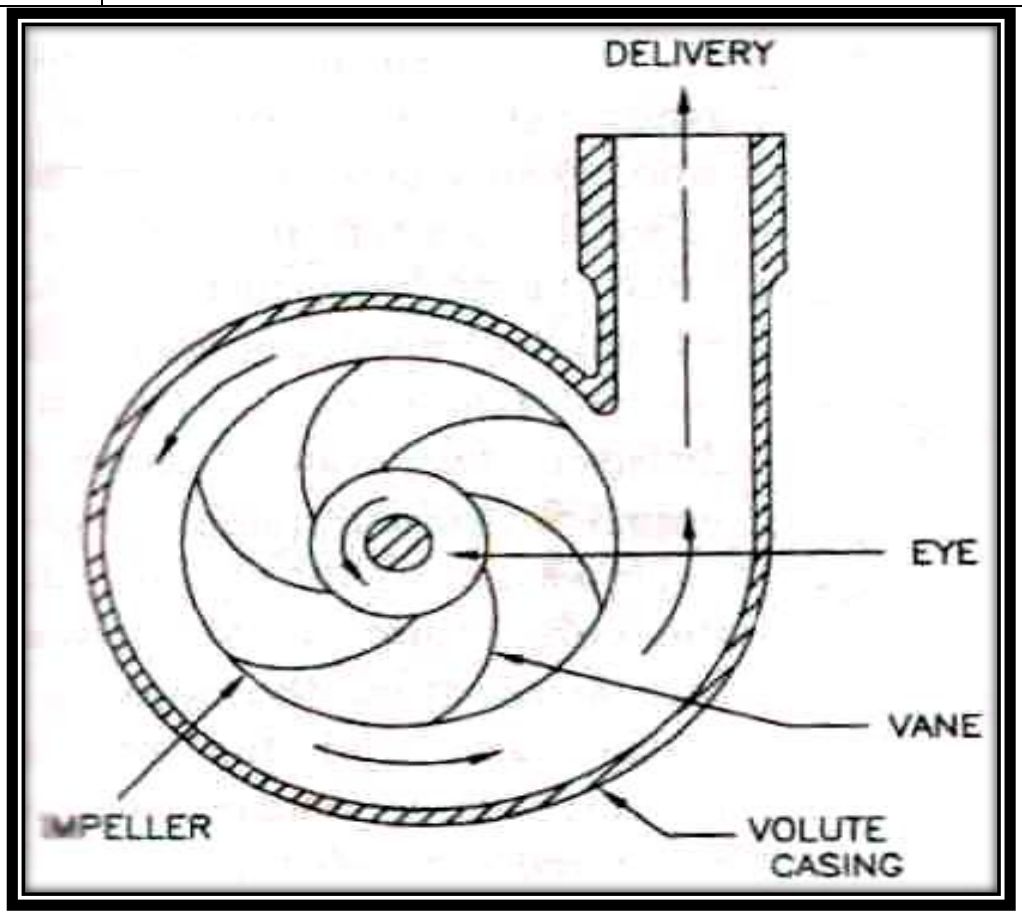
Construction and Working of Centrifugal Pump	
Construction	*Casing* • It is an air tight passage around the impeller. • The area of casing is continuously increasing from inlet to outlet. • It is designed in such a way that, when water passes through it, kinetic energy of water is converted into pressure energy. • There are three types of casing, viz., (a) Volute casing (b) Volute casing with vortex chamber and (c) Diffuser pump.
	Impeller • It is made up of a series of vanes. • It is mounted on a shaft which is connected to electric motor. • As electric motor rotates, impeller also rotates. • When water comes into contact with impeller, its kinetic energy increases and enters into casing. • There are three types of impeller, viz., (1) Open type impeller used for totally impure liquid, (2) Semi closed impeller used for partially impure liquid and (c) Closed impeller used for pure liquid.
	Suction pipe • It connects the sump with inlet of the pump. • Foot valve is provided at the end of the suction pipe. It is a non-return valve. It does not allow the water to drain out from suction pipe to the sump. • Strainer is also provided at the end of the suction pipe before the foot valve. The water from sump first passes through strainer. It does not allow any impurities to enter into the suction pipe.
	Discharge pipe • It connects the outlet of the pump with overhead tank.
	Priming cup • Priming cup is provided on top of the casing for priming.



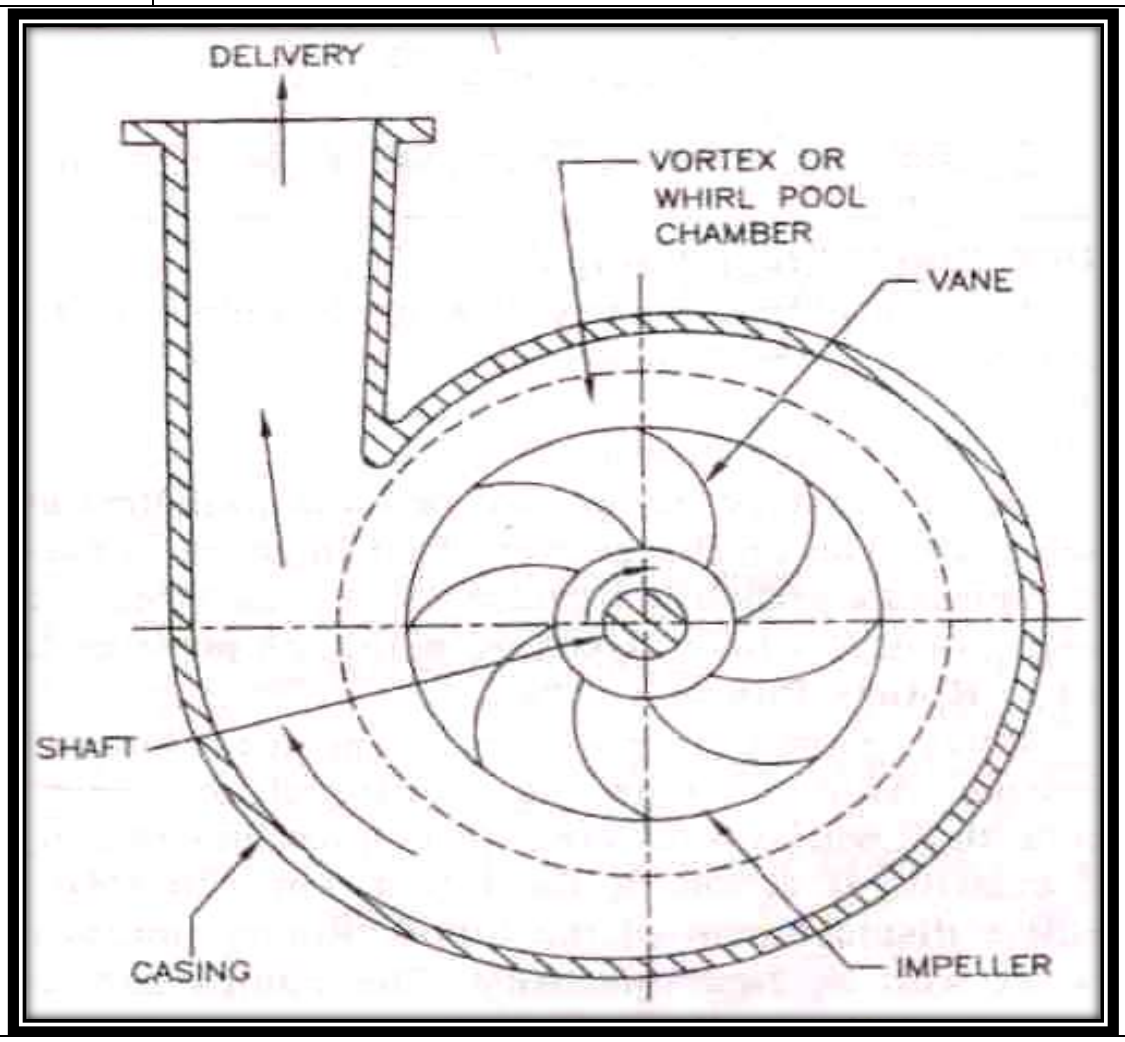
Working	• Initially, priming cup is opened and water is filled in the suction pipe, impeller and casing. • Then, electric motor is switched on. • As the electric motor rotates, impeller of the pump also rotates. • So, water in contact with impeller also rotates with the impeller and with high kinetic energy it leaves the impeller and enters the casing. • As, water leaves the impeller at high velocity, vacuum is created in the impeller and water is lifted from the sump. • Water at high velocity enters the casing, in which the kinetic energy of water is converted into pressure energy and then enters into the discharge pipe. • Through discharge pipe, water is lifted to the overhead tank.

Classification of Centrifugal Pump According To the Type of Casing

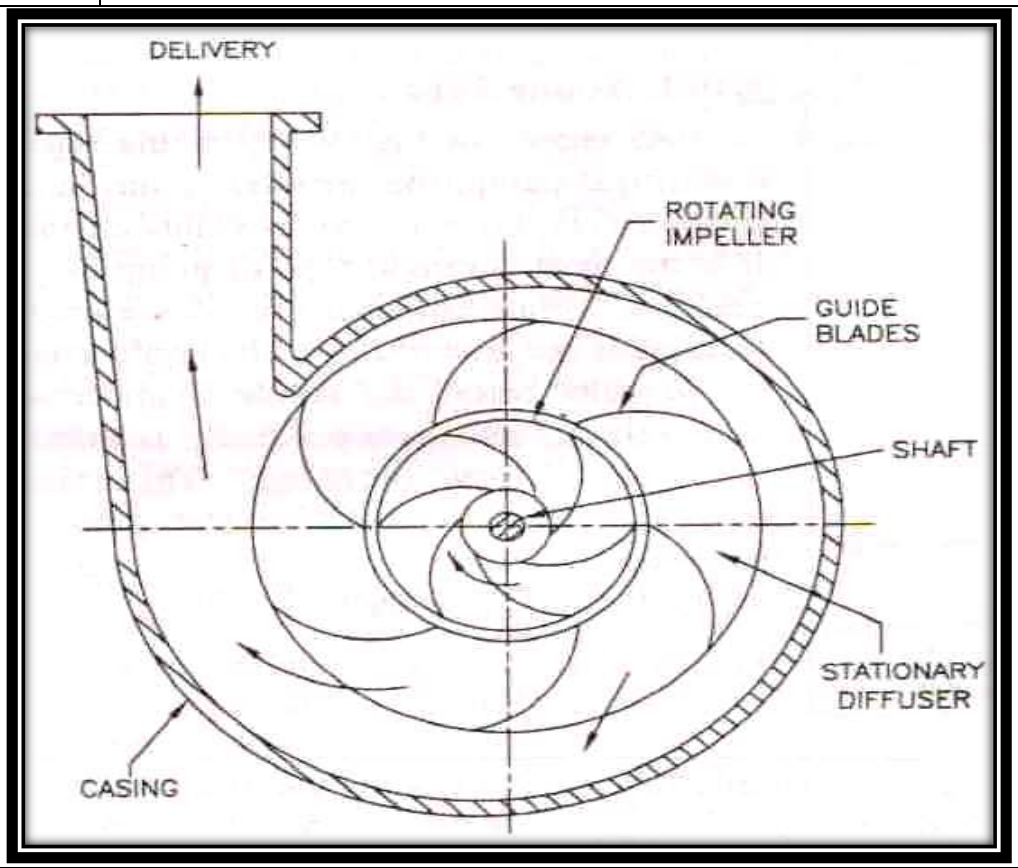
Working of different types of centrifugal pump based on type of casing	
Volute Casing Centrifugal Pump	• The impeller is located in the casing. • But the impeller and casing are not concentric. Thus, the gap between impeller and casing is not uniform. • The impeller is located in such a way that, gap between impeller and casing continuously increases from inlet of water to outlet of water. (converging type) • This type of casing is known as volute casing. • In the volute casing, kinetic energy of water is converted in pressure energy.



Volute Casing with Vortex Chamber (Whirlpool Chamber) type Centrifugal Pump	• An imaginary circular gap is maintained between impeller and volute casing. • This type of casing is known as volute casing with vortex chamber (whirlpool chamber). • The function of the imaginary circular gap (vortex chamber, whirlpool chamber) is to convert kinetic energy of water into pressure energy. • Thus, a pump with volute casing gives less discharge compared to a pump with volute chasing and vortex chamber.



Diffuser Pump (Turbine Pump)	• When the guide vanes are provided in the whirlpool (vortex) chamber, the pump is called diffuser type of pump. • Fixed guide vanes are provided around the impeller periphery. • The ring of guide vanes is known as diffuser. • The water leaving the impeller flows through the fixed guide vanes. • As the passage along the guide vanes is of continuously increasing, the kinetic energy of water is converted into pressure energy. (Velocity of the water decreases and the pressure of water increases) • This type of pump gives more pressure compared to the vortex type and the volute type pumps. • This type of pump has more efficiency.



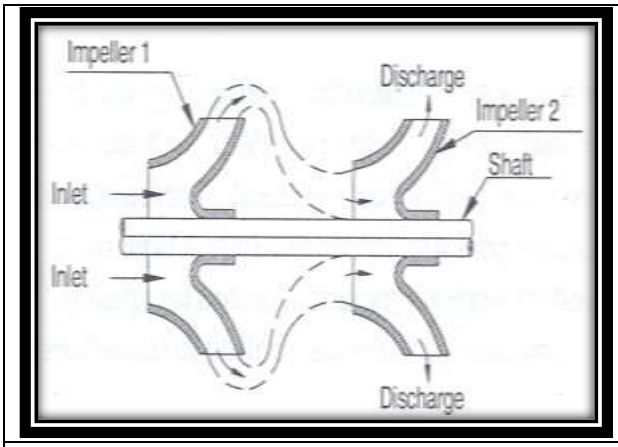
Priming

- Priming means removal of air, gas or vapour from pump casing, impeller and from the suction pipe by filling them with the liquid to be pumped.
- The priming of the centrifugal pump is necessary only at the time of the starting the pump.
- After pump starts, necessary vacuum is created at impeller to lift the water from the sump from about 8 m. depth.

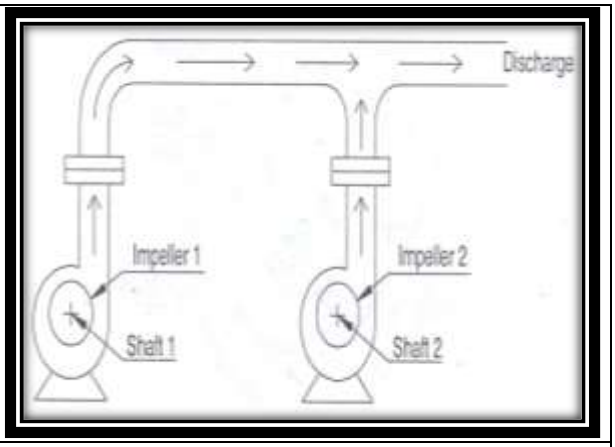
Different Priming Methods	
Manual Priming	• In small centrifugal pumps, priming is done by pouring the liquid directly into the casing using a funnel with an air vent cock opening provided on the casing. • Sometimes, priming cup is also provided at the top of casing for priming the centrifugal pump. • When the system is filled throughout with the liquid to be pumped, it is seen that air has been removed from the suction pipe, impeller and casing. Now the air vent cock is closed and the pump is started.
Self Priming	• When the pump is idle and the liquid level in the pump remains full in the suction pipe and casing, the pump can remove the air by its own through pumping action at the time of starting. This is known as self priming. • Specially designed self-priming pumps are available with the use of suitable foot valve and proper liquid level of reservoir for the suction line.
Vacuum Priming	• Using vacuum creating devices like vacuum pumps, etc. vacuum is generated inside the centrifugal pump to lift the water from sump to casing and impeller. • Then after pump is started. • This is known as vacuum priming.

Single Stage and Multi Stage Centrifugal Pump

<table>
<tr><td colspan="2">Single Stage Pump
When a pump is having only one casing and one impeller, it is known as single stage pump.
Thus, pressure of water is increased in one stage only. (one set of impeller and casing)</td></tr>
<tr><td rowspan="2">Multi Stage Pump
When a pump is having more than one casing and one impeller, it is known as multi stage pump.
Thus, pressure of water is increased in more than one stage. (more than one set of impeller and casing)
There are two types of multi stage pump, viz., (1) Pumps in series and (2) Pumps in parallel</td><td><u>Pumps in Series</u>
When pumps are connected in series i.e. output of one pump enters another pump, the arrangement is known as pumps in series.
Due to this arrangement, less quantity of water can be lifted to high height.</td></tr>
<tr><td><u>Pumps in Parallel</u>
When pumps are connected in parallel i.e. output of all the pumps are mixed, the arrangement is known as pumps in parallel.
Due to this arrangement, more quantity of water can be lifted to low height.</td></tr>
</table>



Pumps in Series



Pumps in Parallel

Difference between reciprocating pump and centrifugal pump

Reciprocating Pump	Centrifugal Pump
It is positive displacement type pump.	It is non-positive displacement type pump.
It does not provide continuous and/or uniform discharge.	It provides continuous and uniform discharge.
It is mainly used for less discharge at high head.	It is mainly used for more discharge at low head.
It operates at low speed.	It operates at high speed.
Maintenance cost is high.	Maintenance cost is less.
It can lift less viscous liquids. (non-sticky liquids)	It can lift high viscous. liquids (highly sticky liquids)

Reference Books:

(1). Elements of Mechanical Engineering – MCQ and Numerical as per GTU, By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-3-330-07021-9)

(2). Elements of Mechanical Engineering – Laboratory Manual (as per GTU), By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-620-2-05650-2)

(3). Elements of Mechanical Engineering – Tutorial (as per GTU), By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-613-9-82424-3)

(4). Basic Mechanical Engineering (Elements of Mechanical Engineering), By J. P. Hadiya, H. G. Katariya and S. M. Bhatt, Books India Publications.

(5). Thermodynamics: An Engineering Approach Seventh Edition in SI Units, Yunus A. Cengel, Michael A. Boles, McGraw-Hill, 2011.

(6). Basic Mechanical Engineering, By Pravin Kumar, Pearson Publications.

(7). Engineering Thermodynamics, By Rayner Joel.

(8). Thermal Science and Engineering, By Dr. D. S. Kumar, S. K. Kataria & sons Publications.

(9). Fundamental of Mechanical Engineering, By G. S. Sawhney, PHI Publications.

(10). Elements of Mechanical Engineering, By Sadhu Singh, S. Chand Publication.

(11). Elements of Mechanical Engineering, By P. S.Desai and S. B.Soni.