KUPPAM ENGINEERING COLLEGE

DEPARTMENT OF CIVIL ENGINEERING

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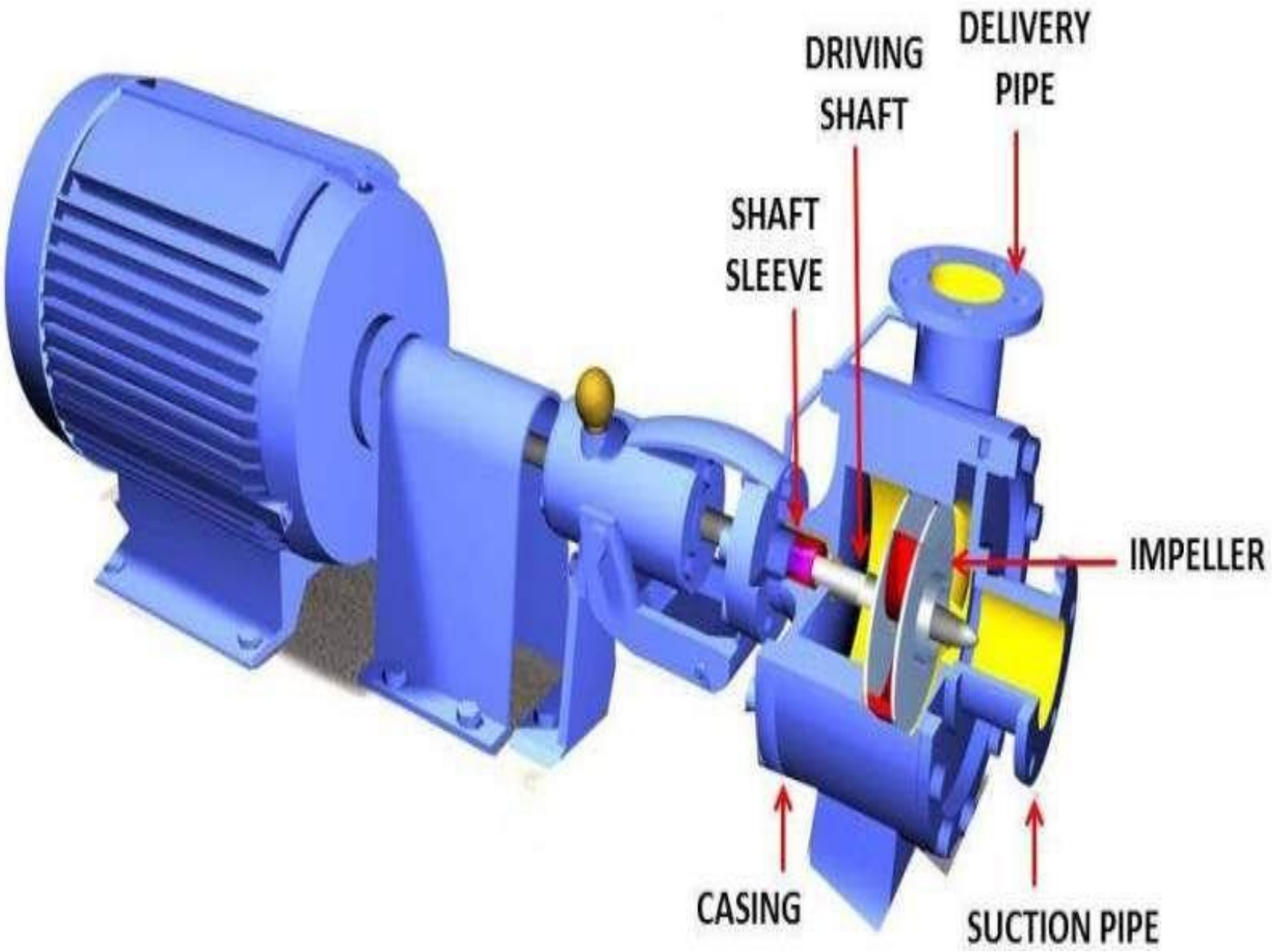
UNIT 5: CENTRIFUGAL PUMPS

SYLLABUS

- PUMPS: Introduction, working principle of centrifugal pump, work done by impeller; heads, losses and efficiencies; Minimum starting speed; priming; specific speed; limiting of suction lift, net positive suction head(NPSH); Performance and characteristics curves; Cavitation effects; Multistage centrifugal pumps; troubles and remedies-Introduction to reciprocating pump.

INTRODUCTION

- It converts mechanical energy into hydraulic energy (pressure energy) by virtue of centrifugal force.
- Flow is in radial outward direction.
- It works on principle of forced vortex flow.
- Common uses include water, sewage, petroleum and petrochemical pumping.

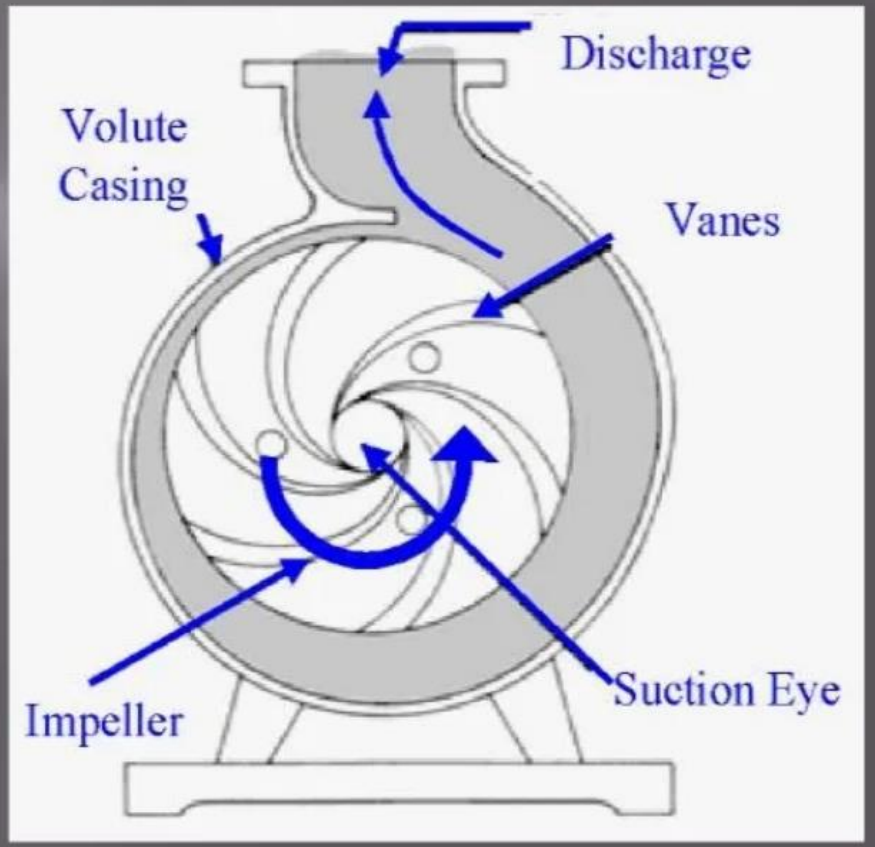

DRIVING SHAFT
DELIVERY PIPE
SHAFT SLEEVE
IMPELLER
CASING
SUCTION PIPE

PRINCIPLE

- It works on the principle of forced vortex flow means when a certain mass of fluid is rotated by external torque rise in pressure head takes place.
- Conversion of energy occur by virtue of two main parts of the pump:
  a) Impeller
  b) Casing.
- Impeller converts driver energy into the kinetic energy & diffuser converts the kinetic energy into pressure energy.

COMPONENTS

- Impeller
- Casing
- Suction pipe
- Foot valve and strainer
- Delivery pipe



COMPONENTS

1.IMPELLER:

The rotating part of the 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:

Casing of centrifugal pump is similar to that of reaction turbine. Function of casing is kinetic energy of the water discharged at the outlet of the impeller is converted into pressure energy.

COMPONENTS

3. 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.

Foot value which is non return valve or one way type of valve is fitted at the lower end of the suction pipe. The foot valve opens only in the upward direction.

Strainer is fitted at the lower end of suction pipe

COMPONENTS

4.DELIVERY PIPE:

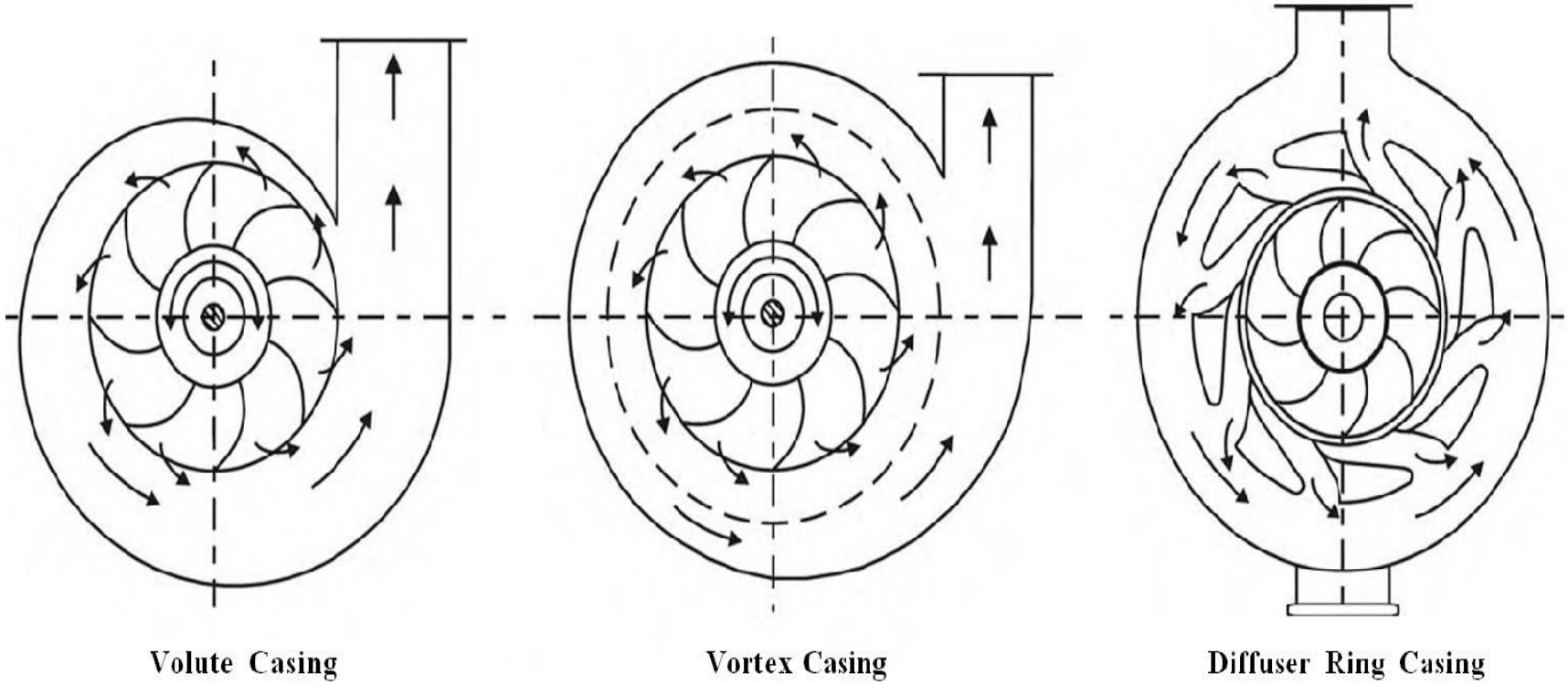
A pipe whose one end is connected to the outlet of pump and other end delivers water at a required height is known as delivery pipe.

COMPONENTS

IMPELLER

COMPONENTS

- Types of casing:



COMPONENTS

TYPES OF CASING :

1.VOLUTE CASING:

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. The efficiency of the pump increases slightly as a large amount of energy is lost due to the formation of eddies in this type of casing

COMPONENTS

2. VORTEX CASING:

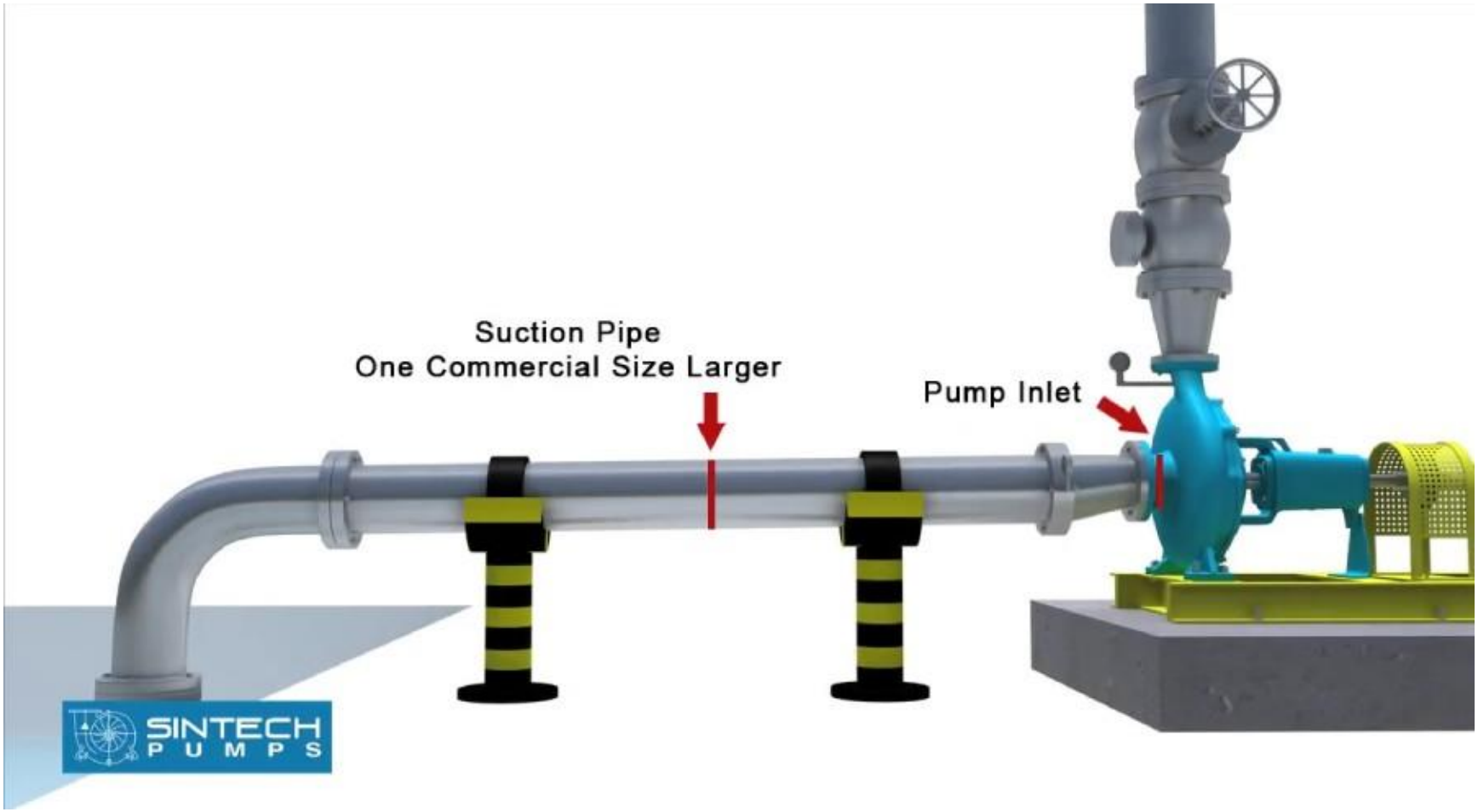
If a circular chamber is introduced between the casing and the impeller, the casing is known as vortex casing. By introducing the circular chamber, the loss of energy due to formation of eddies is reduced to a considerable extent Thus the efficiency of the pump is more than the efficiency when the volute casing is provided.

COMPONENTS

3. CASING WITH GUIDE BLADES:

In this casing the impeller is surrounded by a series of guide blades mounted on a ring which is known as diffuser. The guide vanes are designed in such a way that the water from the impeller enters the guide vanes without stock. Also the area of the guide vanes increases, thus reducing the velocity of flow through guide vanes and consequently the pressure of water the water from the guides vanes then passes through the surrounding casing which is in most of the cases concentric with the impeller.

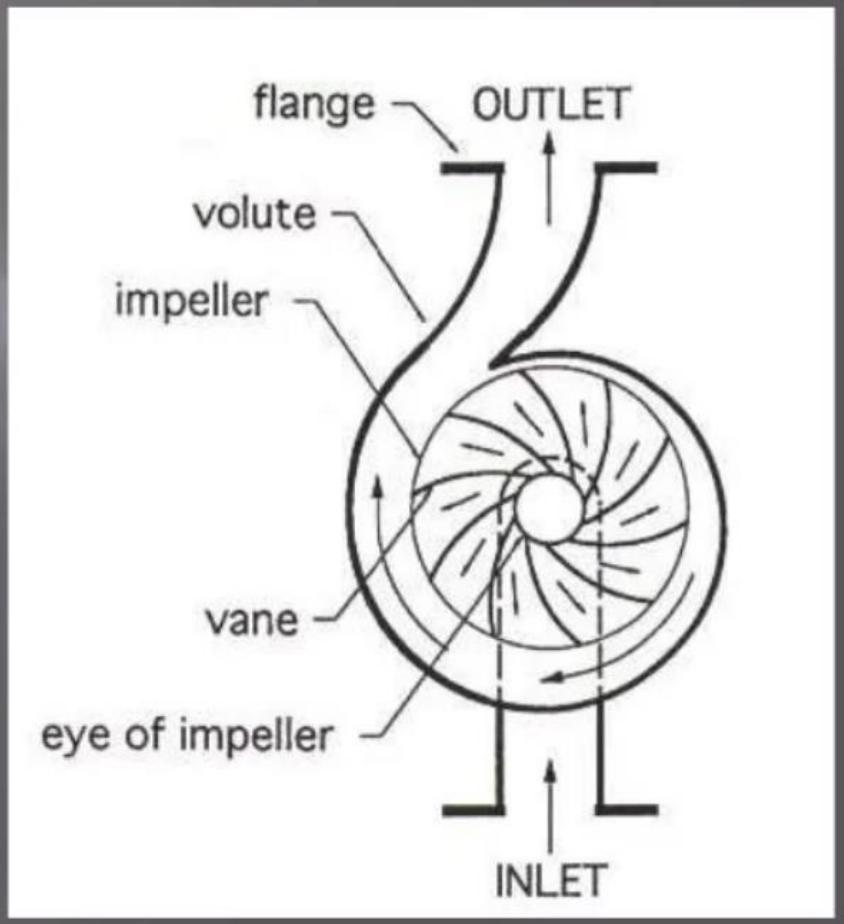
COMPONENTS



SUCTION PIPE

How do they work?

- Liquid forced into impeller
- Vanes pass kinetic energy to liquid: liquid rotates and leaves impeller
- Volute casing converts kinetic energy into pressure energy



- A centrifugal pump has two main components:
  I. A rotating component comprised of an impeller and a shaft.
  II. A stationary component comprised of a casing, casing cover, and bearings.

WORK DONE

- Work is done by the impeller on the water

$$W=[V_{w2}U_2-V_{w1}U_1]/g$$

where,

W=work done per unit wg. of water per sec.

V_{w2}=whirl component of absolute vel. of jet at outlet.

U_2=tangential vel. of impeller at outlet.

V_{w1}=whirl component of absolute vel. of jet at inlet.

U_1=tangential vel. of impeller at inlet.

- As water comes radially :

  Guide blade angle at inlet $\alpha = 90^0$

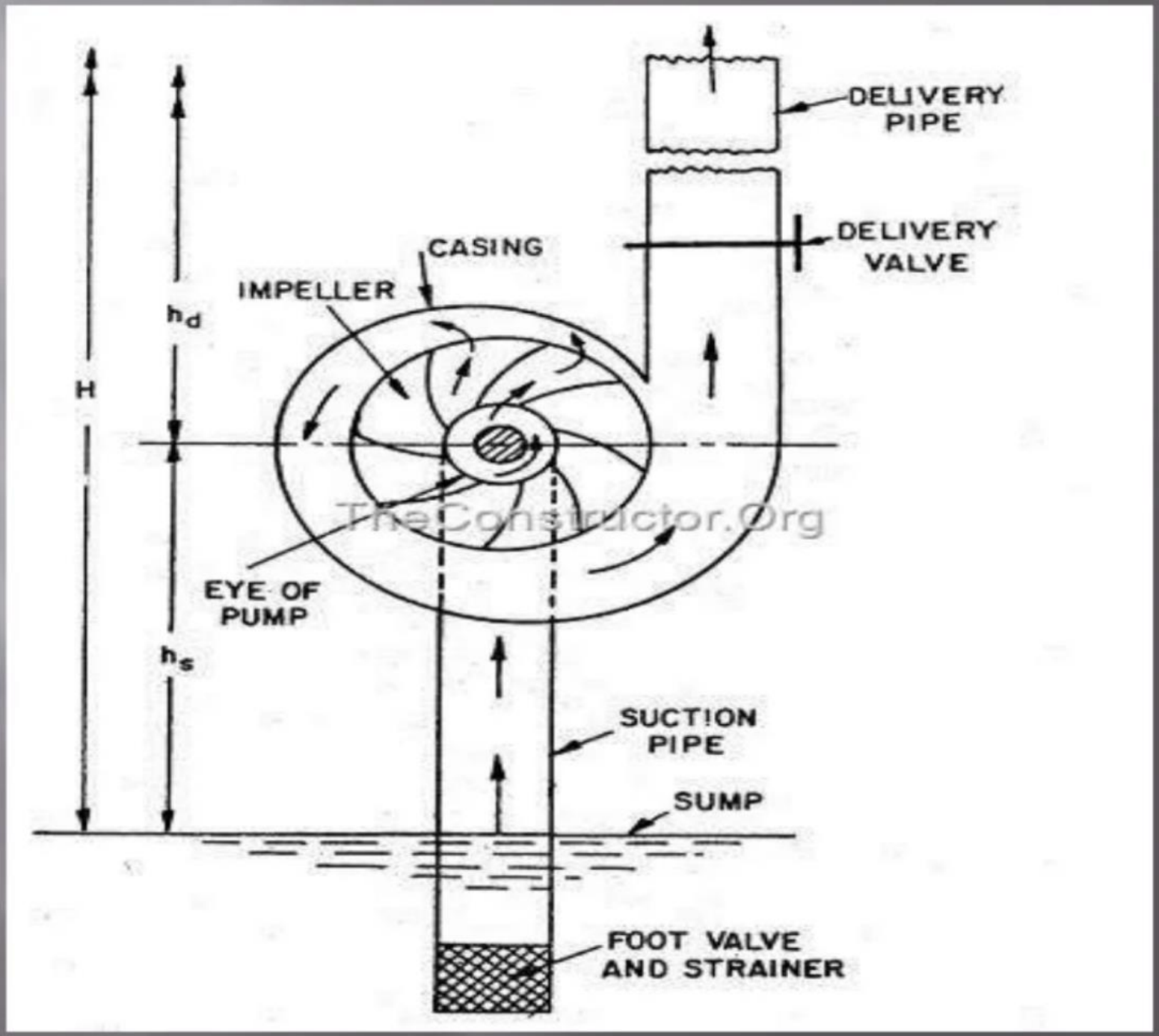
  $V_{W1} = 0$

  then

  $$W = V_{w2} U_2 / g$$

HEADS IN CENTRIFUGAL PUMP

- Suction Head:- Vertical height of center line of centrifugal pump above the water surface to the pump from which water to be lifted.
- Delivery Head:- Vertical distance between center line of the pump and the water surface in the tank to which water is delivered.
- Static Head:- Sum of suction head and delivery head.
- Manometric Head:- The head against which a centrifugal pump has to work.
- $H_m=h_s+h_d+h_{fs}+h_{fd}+(V_d*V_d)/2g$



EFFICIENCES

- Manometric efficiency:-The ratio of manometric head to the head imparted by impeller.

$$=H_m/(V_{w2}\,u_2/g)$$

- Mechanical efficiency :-The ratio of power delivered by the impeller to the liquid to the power input to the shaft.

$$=(WV_{w2}u_2/g)/(\text{power input to the pump shaft})$$

- Overall Efficiency:-Ratio of power output of the pump to power input to the pump or shaft.

$= wQH_m/P$

$=WH_m/P$

LOSSES

Centrifugal pump encounters various losses during its operation. They are

1.HYDRAULIC LOSSES.

2.MECHANICAL LOSSES

3.LEAKAGE LOSSES.

LOSSES

1.HYRAULIC LOSSES:

Losses within the pump consists of shock at entry or exit of impeller, friction in impeller, friction in guide Vanes and casing.

2.MECHANICAL LOSSES:

Friction between main bearings and the glands.

Friction between impeller and liquid which tills Space between impeller and casing

LOSSES

3.LEAKAGE LOSSES:

It is impossible to construct complete water tight Sealing at suction and delivery pipes. Thus, liquid at high pressure slips into low pressure Zone. Thus it never passes through delivery pipe. Thus energy possessed by the liquid at high pressure zone is wasted due to leakage losses. This loss of energy is mainly due leakage impossible to control.

Minimum speed for starting a centrifugal pump

- When a centrifugal pump is started, it will start delivering liquid only if the pressure rise in the impeller is more than or equal to the manometric head.

$$\frac{V_2^2 - V_1^2}{2g} + \frac{u_2^2 - u_1^2}{2g} + \frac{V_{r1}^2 - V_{r2}^2}{2g}$$

$$= \frac{u_2^2 - u_1^2}{2g}$$

- Flow will commence only if $\frac{u_2^2 - u_1^2}{2g} \geq H_{mano}$
- *For minimum speed ,we must have*

$$\frac{u_2^2 - u_1^2}{2g} = H_{mano} \quad \ldots\ldots\ldots\ldots(1)$$

also ,

$$\eta_{mano} = \frac{H_{mano}}{\left(\frac{V_{W2}u_2}{g}\right)} = \frac{gH_{mano}}{V_{w2}u_2}$$

$$H_{mano} = \eta_{mano} \times \left(\frac{V_{w2} u_2}{g} \right)$$

$$u_1 = \frac{\pi D_1 N}{60} \qquad u_2 = \frac{\pi D_2 N}{60}$$

- Substitute the value in eqn. 1

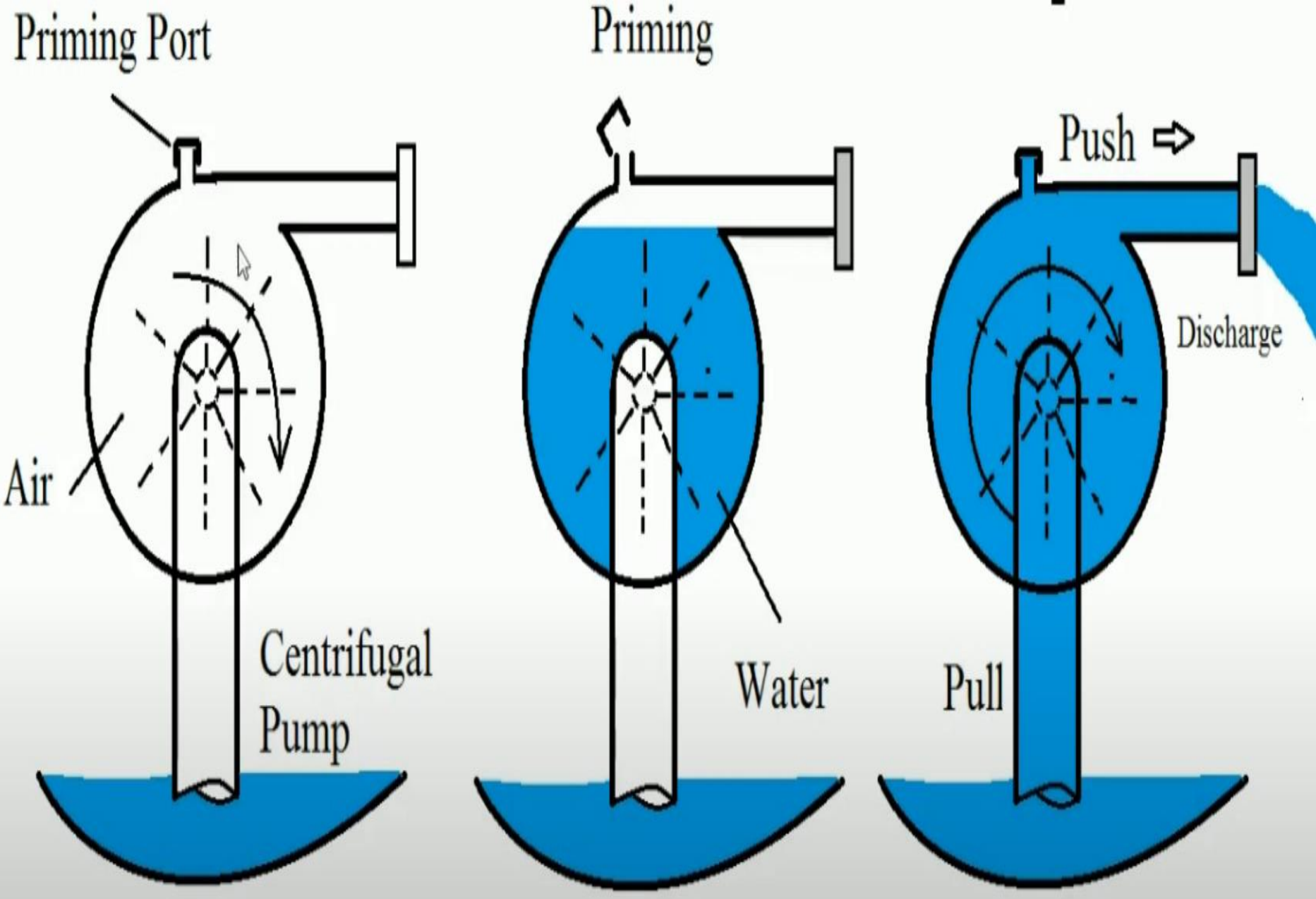
$$\frac{1}{2g}\left[\left(\frac{\pi D_2 N}{60}\right)^2 - \left(\frac{\pi D_1 N}{60}\right)^2\right] = \eta_{mano} \times \frac{V_{w2}}{g} \times \left(\frac{\pi D_2 N}{60}\right)$$

$$\frac{\pi N}{120}\left(D_2^2 - D_1^2\right) = \eta_{mano} \times \left(V_{w2} \times D_2\right)$$

$$N_{\min} = \frac{120 \times \eta_{mano} \times V_{w2} \times D_2}{\pi\left(D_2^2 - D_1^2\right)}$$

PRIMING

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 value is completely filled up from outside source with the liquid to be raised by the pump before starting the these parts of the pump is pump. Thus the air from these removed and these parts are filled with the liquid to be Pumped.


Priming Port
Air
Centrifugal
Pump
Priming
Water
Push
Discharge
Pull

Specific speed

- The specific speed of a centrifugal pump is defined as the speed of a geometrically similar pump which would deliver unit quantity(one cubic meter of liquid per second) against a unit head (one meter). It is denoted by Ns. The specific speed is a characteristic of a pumps which can be used as a basis for comparing the performance of different pumps.

The discharge through impeller is given by=area×velocity of flow

$$Q = \pi D_1 B_1 V_{f1} = \pi D_2 B_2 V_{f2}$$

$$Q \propto DBV_f \ , \ Q \propto D^2 V_f \quad (\text{Q} B \propto D) \ldots\ldots\ldots\ldots\ldots\ldots\text{(i)}$$

The tangential speed of impeller is given by

$$u = \frac{\pi DN}{60} \quad \because \quad u \propto DN \ldots\ldots\ldots\ldots\ldots\ldots\text{(ii)}$$

$$\text{but } u = K_u\sqrt{2gH_m} \quad \because u \propto \sqrt{H_m} \quad \ldots\ldots\ldots\ldots\text{(iii)}$$

and $V_f = K_f\sqrt{2gH_m}$ $\therefore V_f \propto \sqrt{H_m}$ .....(iv)

From eqn. (ii) and (iii) we get

$$DN \propto \sqrt{H_m} \quad \therefore D \propto \frac{\sqrt{H_m}}{N} \text{.....(v)}$$

Putting eqn. (iv) and (v) in eqn. (i)

$$Q \propto \left(\frac{\sqrt{H_m}}{N}\right)^2 \sqrt{H_m} \quad \therefore Q \propto \frac{(H_m)^{\frac{3}{2}}}{N^2} \quad \therefore N^2 \propto \frac{(H_m)^{3/2}}{Q}$$

$$\therefore N = C\frac{(H_m)^{3/4}}{\sqrt{Q}}$$ where C is constant.

When Q=1m3/s, H_m= 1m then C=N which is known as specific speed Ns

$$N_s = \frac{N\sqrt{Q}}{(H_m)^{3/4}}$$

NPSH

- Net positive suction head defined as "the difference between the net inlet head and the head corresponding to the vapour pressure of the liquid.
- NPSH may also be defined as the net head(in metres of liquid) that is required to make the liquid flow through the suction from the sump to the impeller.
- NPSH=(absolute pressure head at inlet of pump)-(vapour pressure head)+(velocity head at inlet of pump)

$$= \frac{p_1}{\rho g} - \frac{p_v}{\rho g} + \frac{V_S^2}{2g} \quad \text{but}$$

$$\text{NPSH} = \frac{p_{atm}}{\rho g} - \left(\frac{V_s^2}{2g} + h_s + h_{fs} \right) - \frac{p_v}{\rho g} + \frac{V_S^2}{2g}$$

$$\text{NPSH} = H_{atm} - h_s - h_{fs} - H_v$$

NPSH= Total suction Head

NPSH is total suction head and it is given by the manufacturer. For any pump installation , distinction need to be made between the required NPSH and available NPSH. The required NPSH varies with the pump design , speed and capacity of pump. When the pump is installed , the available NPSH is calculated from the eqn.

$$h_s = H_{atm} - H_s - h_{fs} - \frac{V_s^2}{2g}$$

In order to have cavitation free operation of centrifugal pump, **available NPSH > required NPSH**

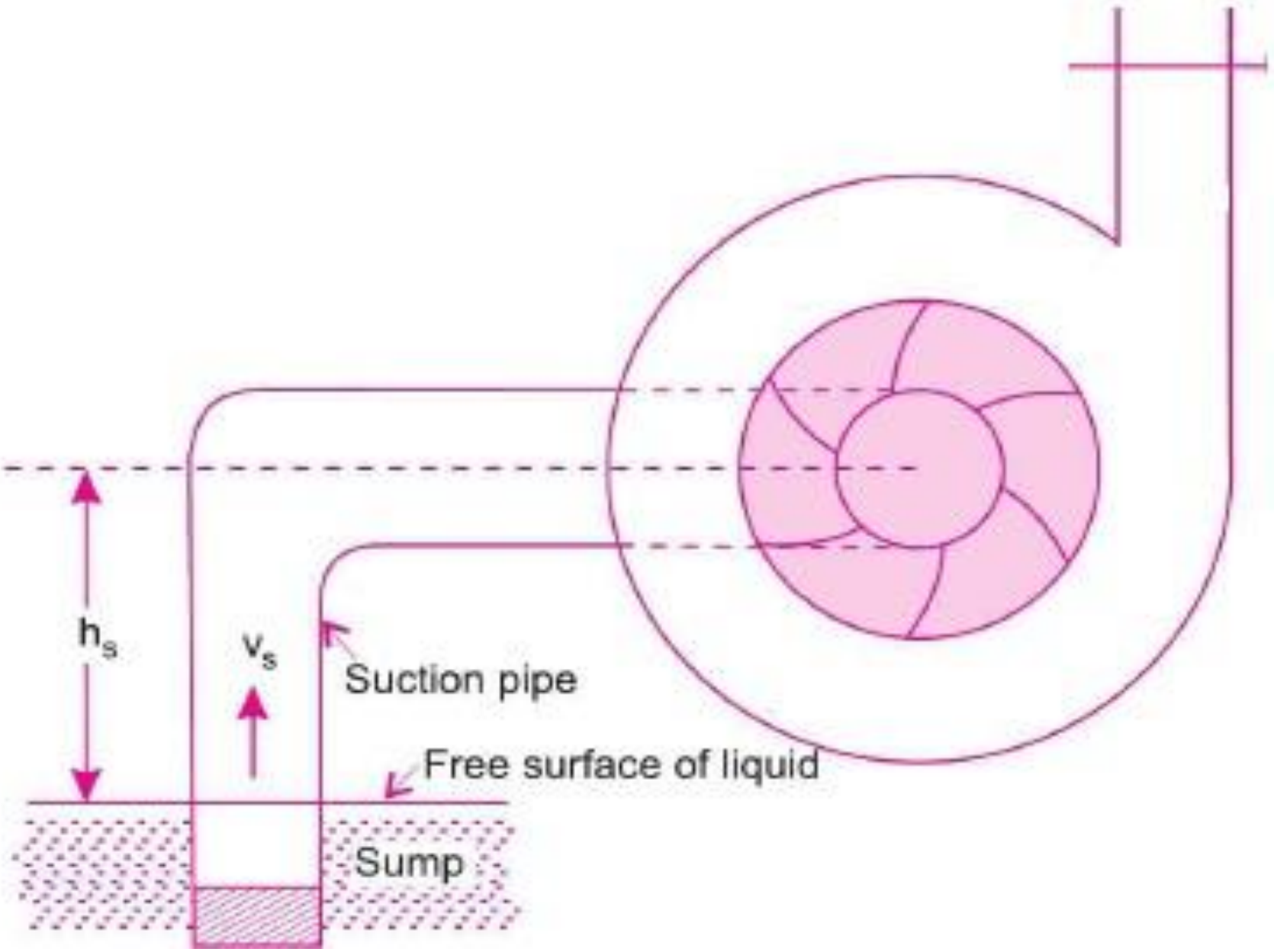
SUCTION LIFT

The centrifugal pump lifts a liquid from a sump. The free surface of liquid is at a depth of h_s below the pump axis. The liquid is flowing with a velocity v_s in the suction pipe. Let hs in the figure be the suction lift.

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

Where, H_a=Atmospheric head=$p_a/\rho g$

H_v= Vapour pressure head=$p_v/\rho g$


h_s
v_s
Suction pipe
Free surface of liquid
Sump

CHARACTERISTIC CURVES

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 and necessary to predict the behavior and performance of the Pump when the pump is working under different flow rate, head and speed.

1. Main characteristic curve.
2. Operating characteristic curves.
3. Constant efficiency curves.

CHARACTERISTIC CURVES

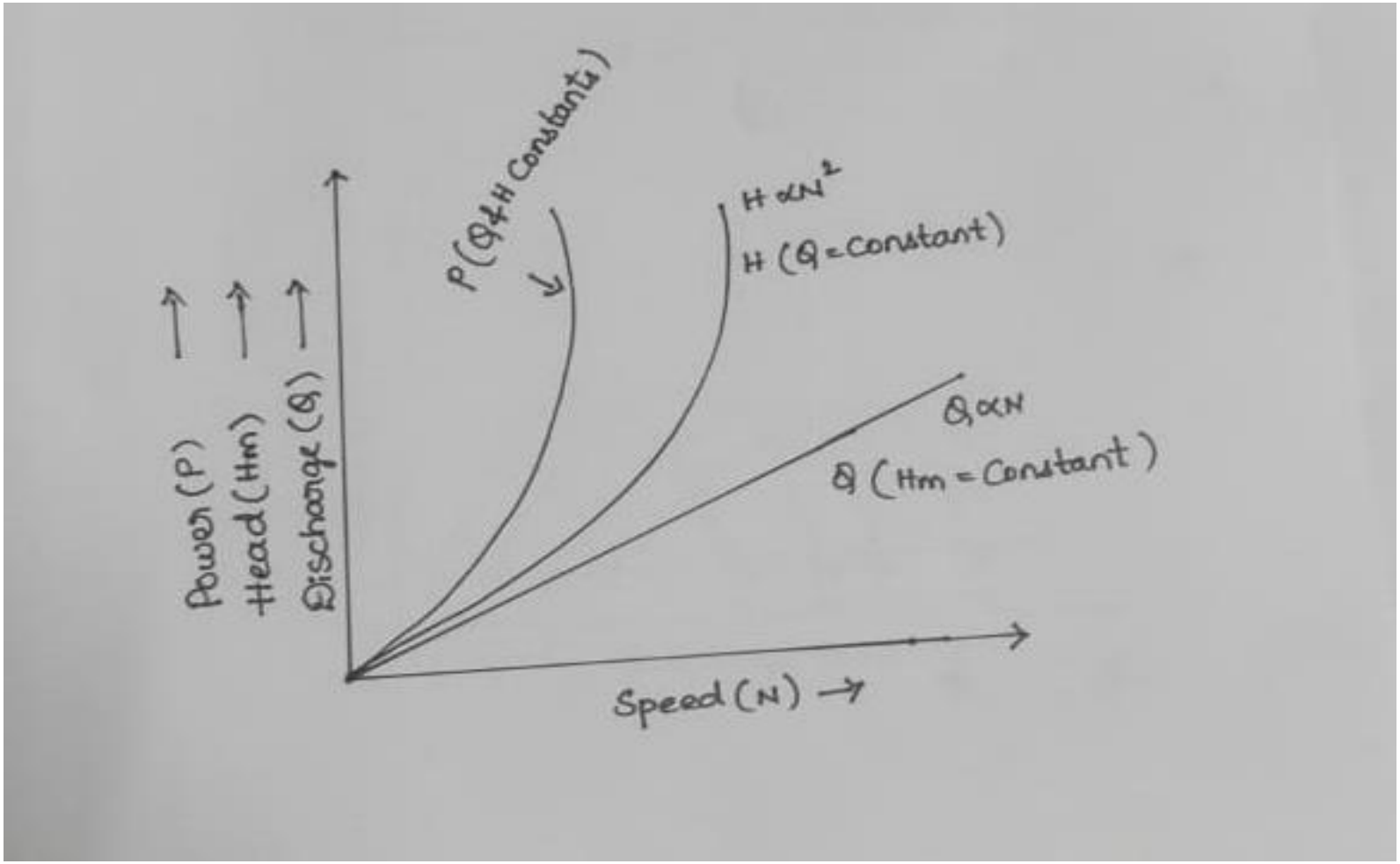
1.Main characteristic curve:

The main characteristic Curves of a centrifugal pump Consists of variation of head (manometric head, Hm.) Power and discharge with respect to speed.

2. Operating characteristic curves:

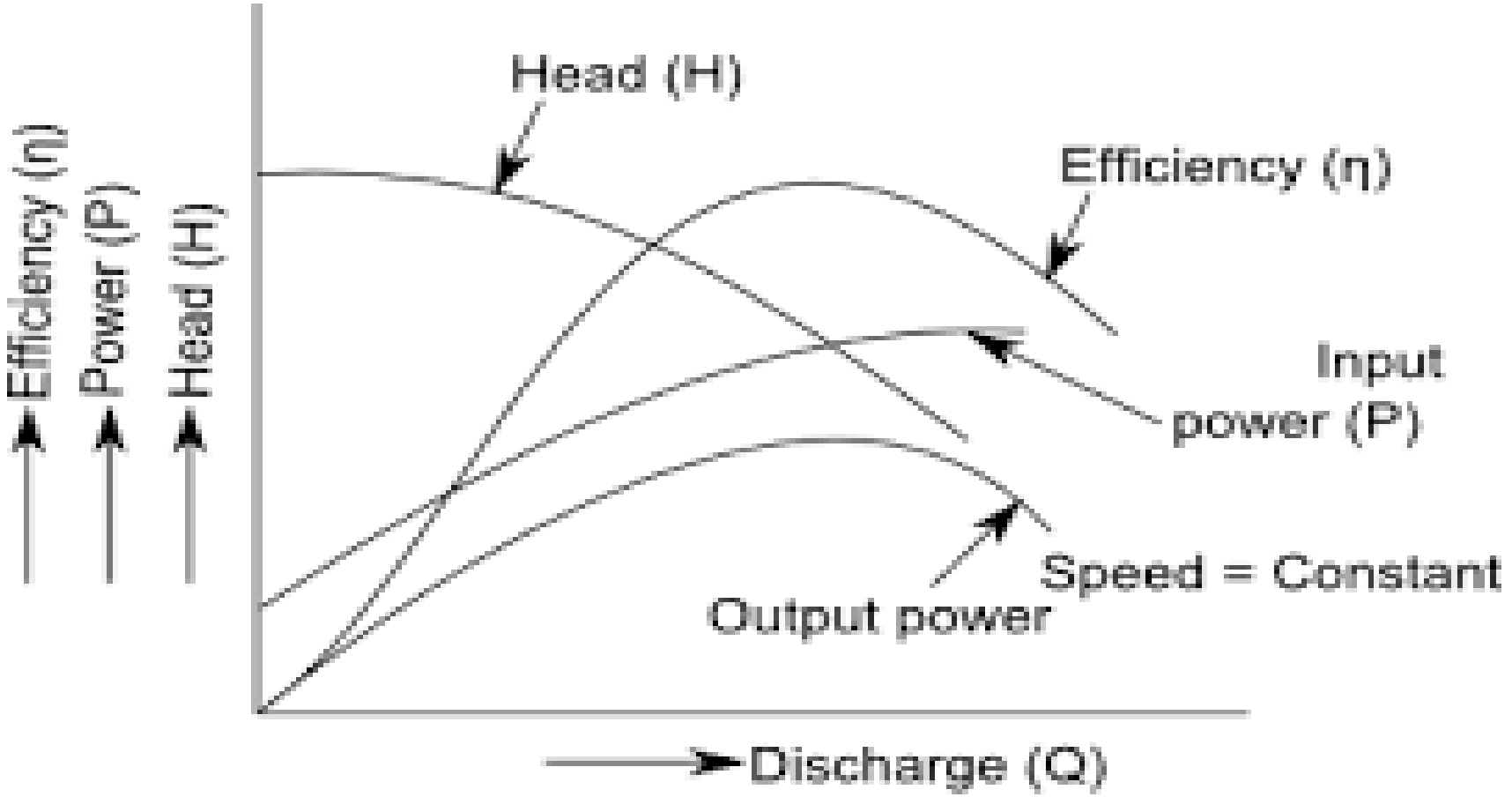
If the speed is kept constant, the variation of manometric head, power and efficiency with respect to discharge gives the operating characteristic of the Pump

CHARACTERISTIC CURVES



Main characteristic curve

CHARACTERISTIC CURVES



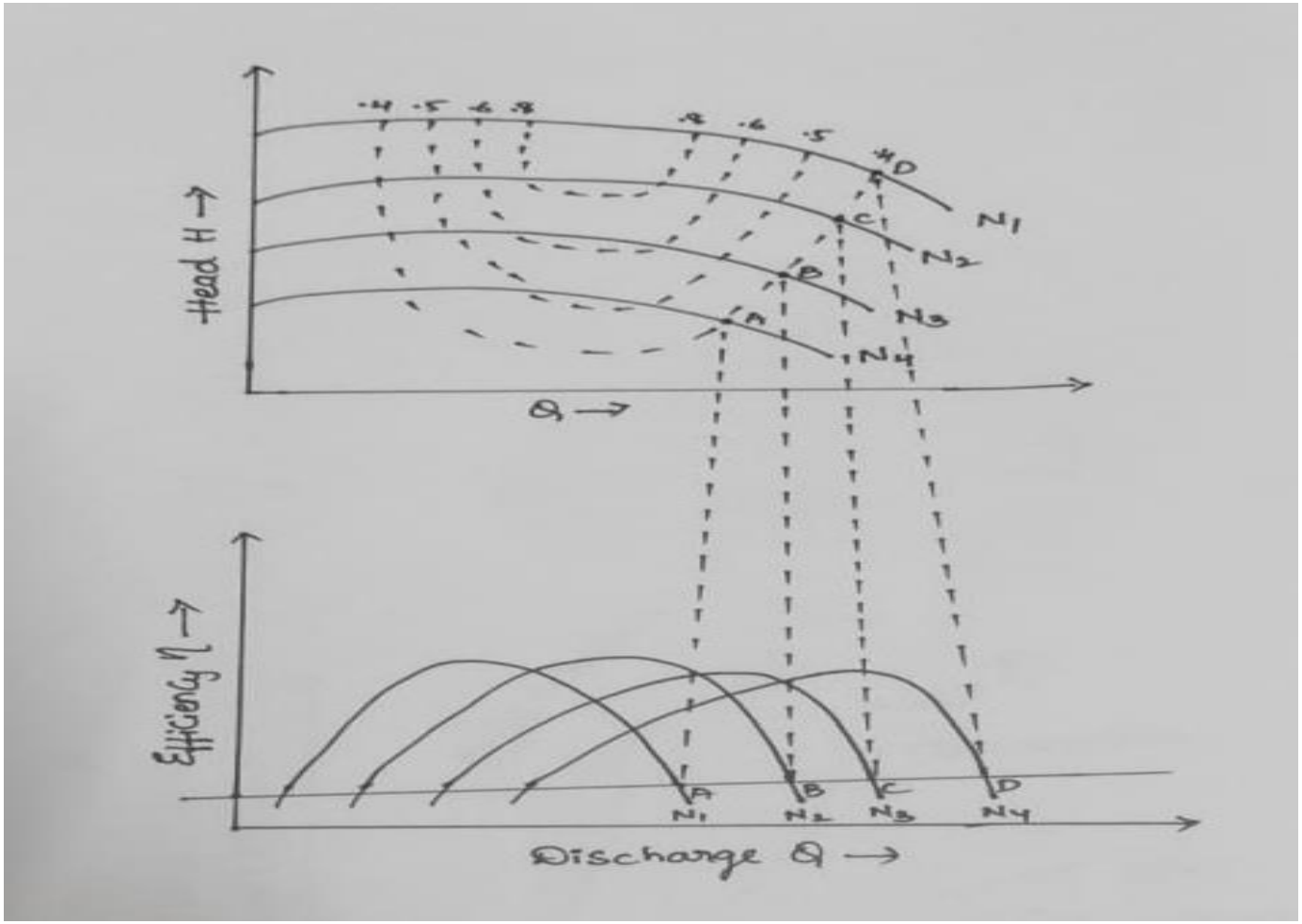
Operating characteristic surves of a pump.

CHARACTERISTIC CURVES

3. Constant efficiency curves:

For obtaining constant efficiency curves for a pump, the head verses discharge curves and efficiency verses discharge curves for different speed are used.

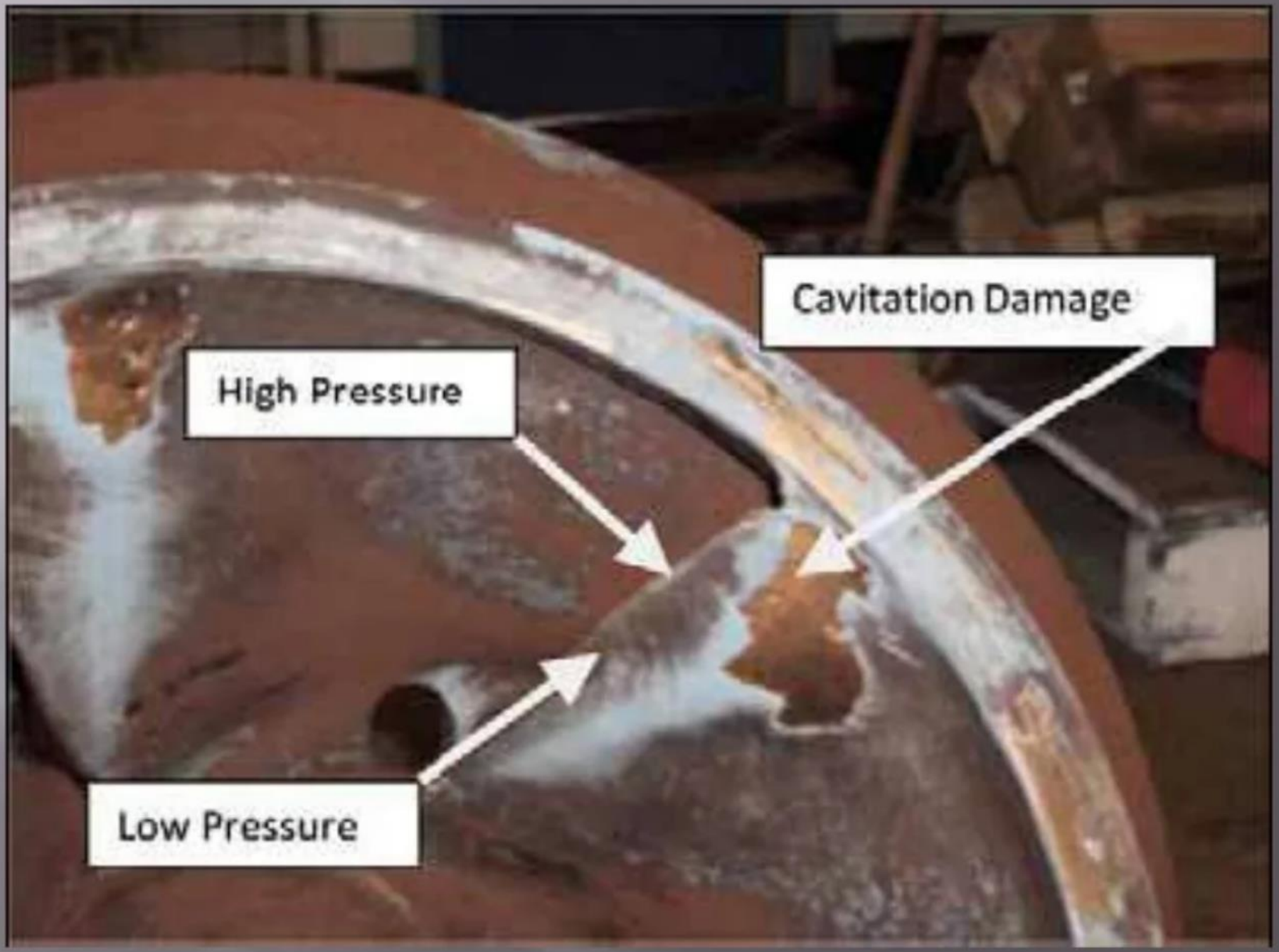
CHARACTERISTIC CURVES



Constant efficiency curves

CAVITATION

- It is a phenomena of formation of vapour bubble where the pressure falls below the vapour pressure of flowing liquid .
- Collapsing of vapour bubble causes high pressure results in pitting action on metallic surface.
- Erosion, noise & vibration are produced.


Cavitation Damage
High Pressure
Low Pressure

EFFECT OF CAVITATION

- Metallic surface are damaged & cavities are formed.
- Efficiency of pump decreases.
- Unwanted noise and vibrations are produced.

MULTISTAGE CENTRIFUGAL PUMP

For a centrifugal pump consists of two or more impellers, the pump is called a multistage centrifugal pump The impellers may be mounted on the same shaft or on different shafts. A multistage pump is having the following two important functions.

1. To produce a high head.
2. To discharge a large quantity of liquid.

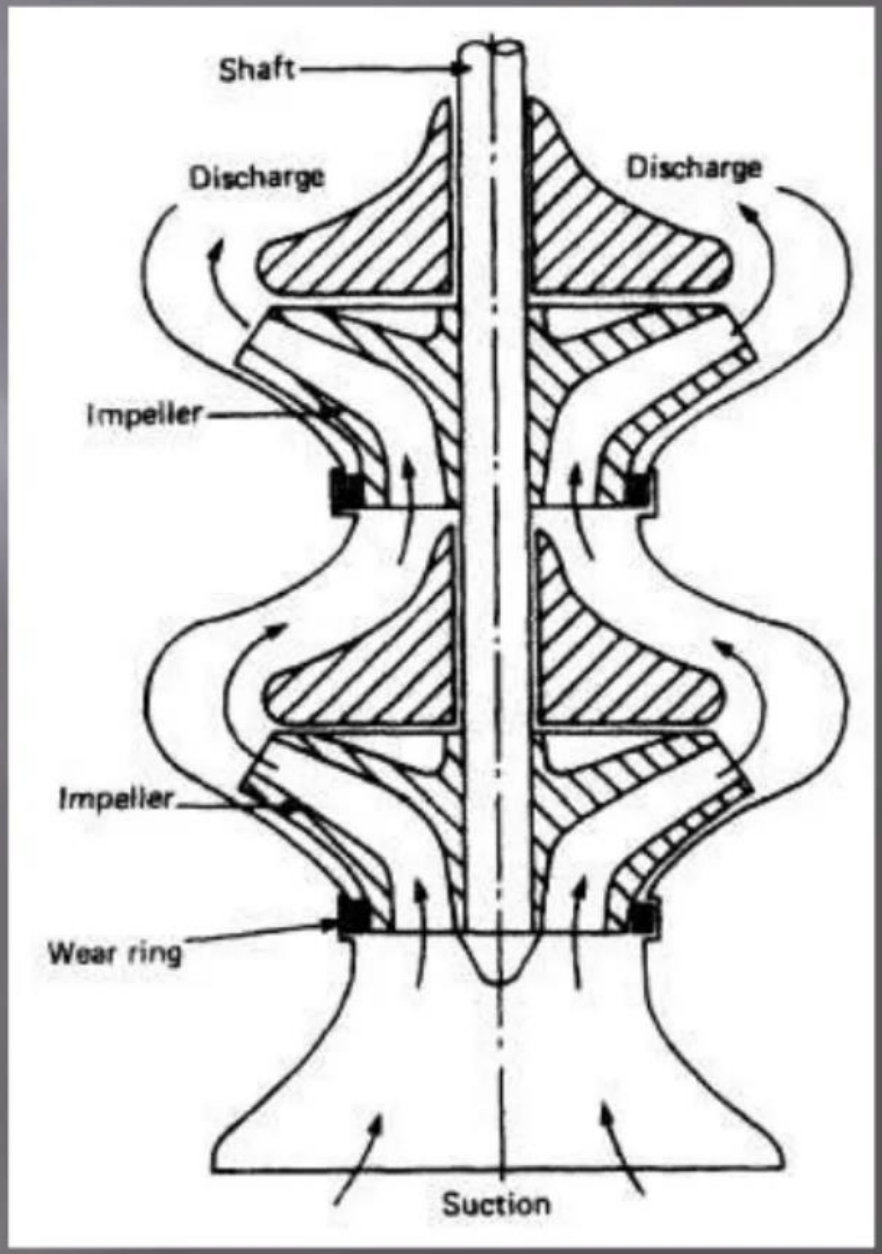
MULTISTAGE CENTRIFUGAL PUMP

1.Multistage centrifugal Pumps for High Heads :

For developing a high head, a number of impellers are mounted in Series or on the same shaft as shown in figure.

The water from the suction pipe enters the 1st impeller at inlet and is discharged at outlet with increased pressure. The water with increased pressure from the outlet of the 1st impeller is taken to the inlet of the 2nd impeller with the help of a connecting pipe. At the outlet of the 2nd impeller, the pressure of water will be more than the pressure of water at the outlet of the 1st impeller. Thus if more impellers are mounted on the same shaft, the pressure at the outlet will be increased further.

Series combination for high head



MULTISTAGE CENTRIFUGAL PUMP

2.Multistage centrifugal pumps for high discharge:

For obtaining high discharge, the pumps should be connected in parallel. Each of the pumps lifts the water from a Common pump and discharges water to a common pipe to which the delivery, pipes of each pump is connected. Each of the pump is working against the same head.

Total discharge=n x Q

Parallel combination for high discharge

TROUBLES AND LOSSES

S.NO	TROUBLES	REMEDIES
1.	Lack of prime	Fill pump and suction pipe completely with liquid.
2.	Loss of prime	Check for leaks in suction pipe joints and fittings; vent casing to remove accumulated air.
3.	Discharge system head too high	Check pipe friction losses. Larger discharge piping may correct condition. Check that valves are wide open.
4.	Wrong direction of rotation	Check motor rotation with directional arrow on pump casing, wrong rotation will cause pump damage.
5.	Impeller completely plugged	Dismantle pump or use piping hand hole to clean impeller.

TROUBLES AND LOSSES

S.NO	TROUBLES	REMEDIES
6.	Suction lift too high	If no obstruction at inlet, check for pipe friction losses. However ,static lift may be too great. Measure with mercury column or vacuum gauge while pump operates. If static lift is too high, liquid to be pumped must be raised or pump lowered.
7.	Speed too low	Check whether motor is directly across the line and receiving full voltage. Alternatively, frequency may be too low, motor may have an open phase.

RECIPROCATING PUMP

INTRODUCTION

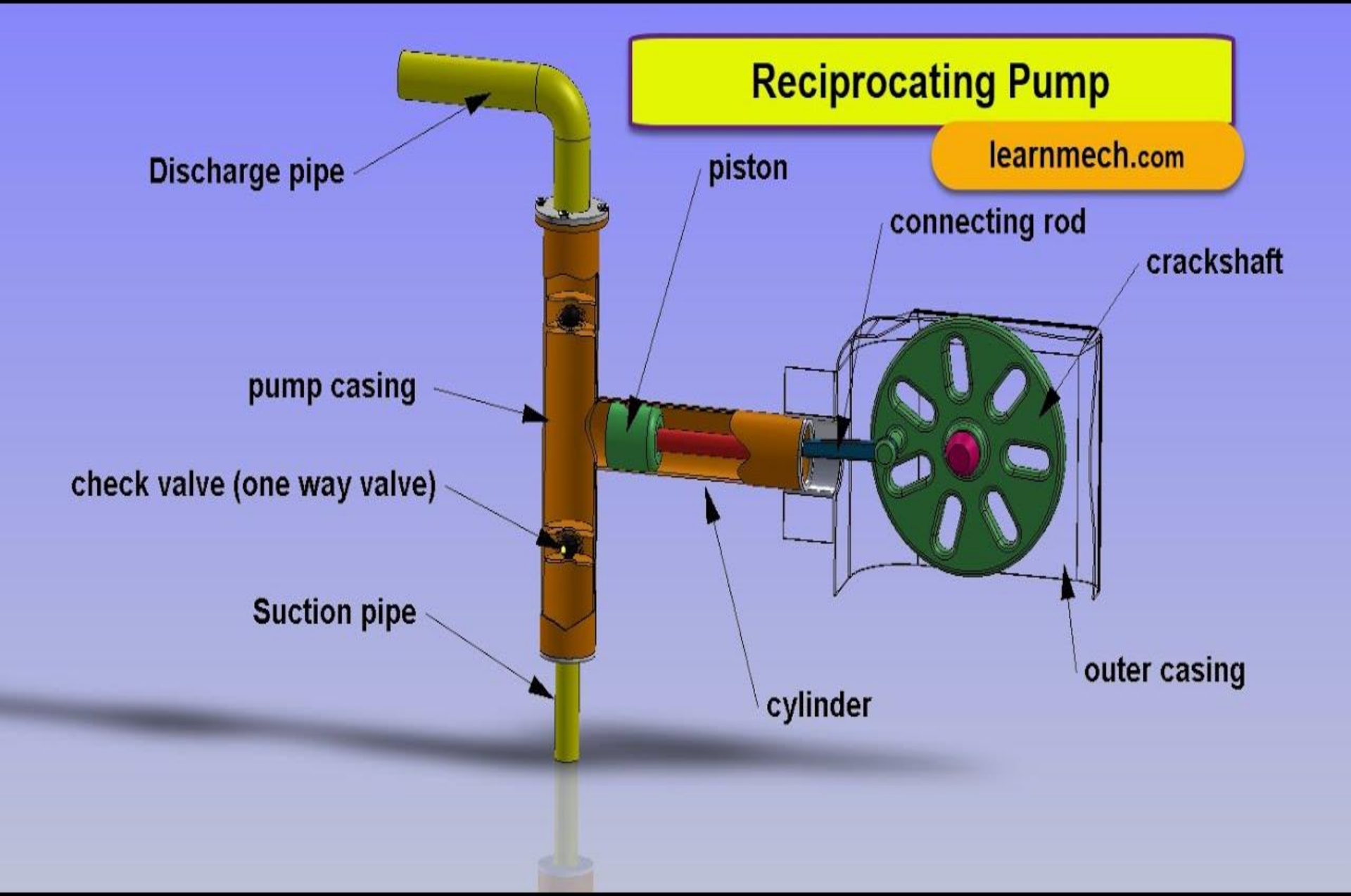
- Pumps are used to increase the energy level of water by virtue of which it can be raised to a higher level.
- Reciprocating pumps are positive displacement pump, i.e. initially, a small quantity of liquid is taken into a chamber and is physically displaced and forced out with pressure by a moving mechanical elements.
- The use of reciprocating pumps is being limited these days and being replaced by centrifugal pumps.

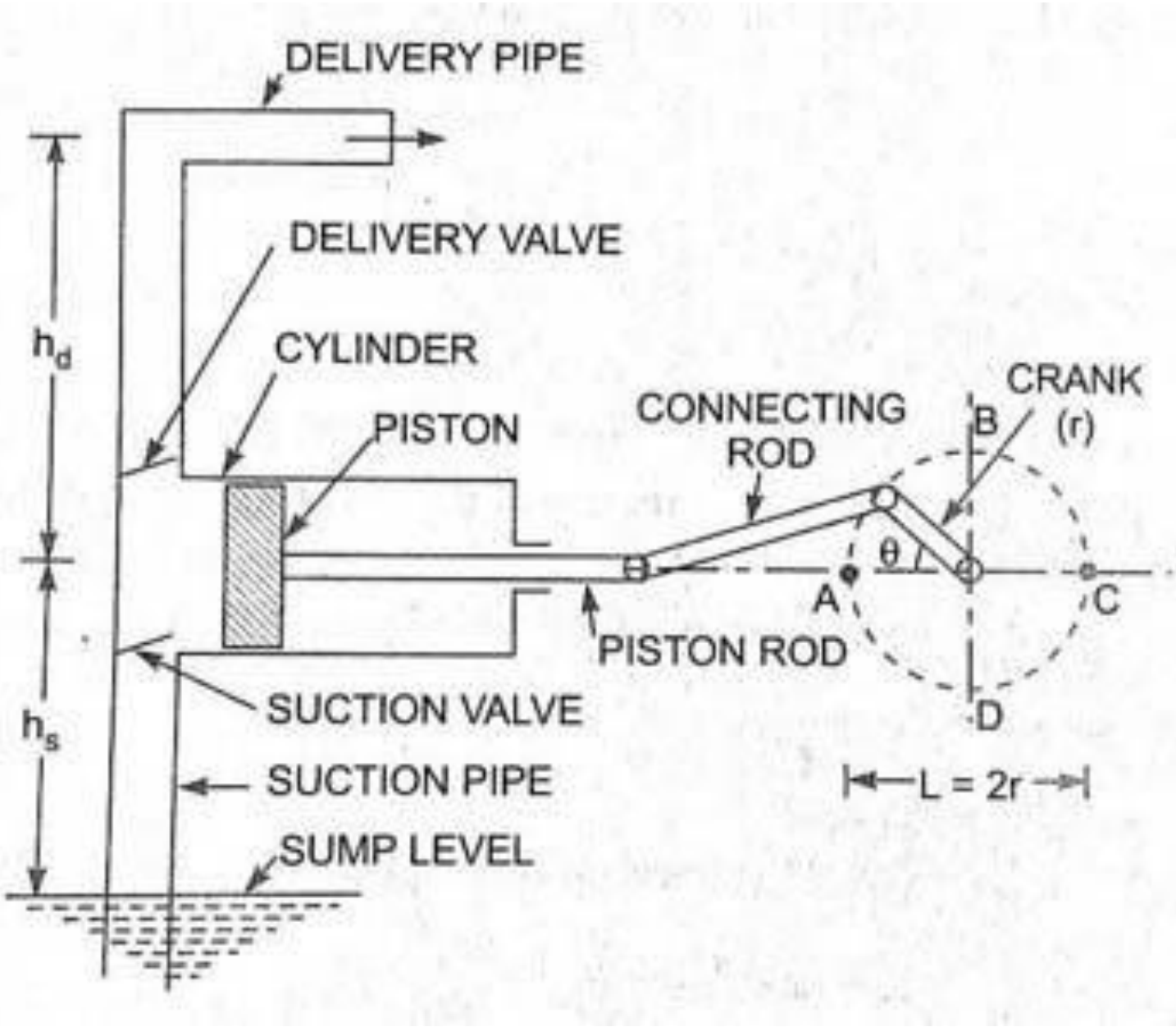
INTRODUCTION

- For industrial purposes, they have become obsolete due to their high initial and maintenance costs as compared to centrifugal pumps.
- Small hand operated pumps are still in use that include well pumps, etc.
- These are also useful where high heads are required with small discharge, as oil drilling operations.

Main components

- A reciprocation pumps consists of a plunger or a piston that moves forward and backward inside a cylinder with the help of a connecting rod and a crank. The crank is rotated by an external source of power.
- The cylinder is connected to the sump by a suction pipe and to the delivery tank by a delivery pipe.
- At the cylinder ends of these pipes, non-return valves are provided. A non-return valve allows the liquid to pass in only one direction.
- Through suction valve, liquid can only be admitted into the cylinder and through the delivery valve, liquid can only be discharged into the delivery pipe.


Reciprocating Pump
learnmech.com
Discharge pipe
piston
connecting rod
crackshaft
pump casing
check valve (one way valve)
Suction pipe
cylinder
outer casing


DELIVERY PIPE
DELIVERY VALVE
CYLINDER
PISTON
CONNECTING ROD
CRANK (r)
B
θ
A
C
D
PISTON ROD
SUCTION VALVE
SUCTION PIPE
SUMP LEVEL
h_d
h_s
L = 2r

Working of Reciprocating Pump

- When the piston moves from the left to the right, a suction pressure is produced in the cylinder. If the pump is started for the first time or after a long period, air from the suction pipe is sucked during the suction stroke, while the delivery valve is closed. Liquid rises into the suction pipe by a small height due to atmospheric pressure on the sump liquid.
- During the delivery stroke, air in the cylinder is pushed out into the delivery pipe by the thrust of the piston, while the suction valve is closed. When all the air from the suction pipe has been exhausted, the liquid from the sump is able to rise and enter the cylinder.

Working of Reciprocating Pump

- During the delivery stroke it is displaced into the delivery pipe. Thus the liquid is delivered into the delivery tank intermittently, i.e. during the delivery stroke only.

ADVANTAGES

- High delivery head
- High viscosity
- Solids handle capability
- High pressure
- Efficiency 90%

DISADVANTAGES

- Pulsation flow
- Low discharging capacity
- High Maintenance
- Short Life


Thank
you!!