Module 7
PUMP

Centrifugal pumps

- Rotation increase centrifugal head
- The centrifugal head converted to static head
- The outlet is radially outward
- Pumping is lift of water vertically or built energy by or static pressure

CENTRIFUGAL PUMP
(radial flow pump)

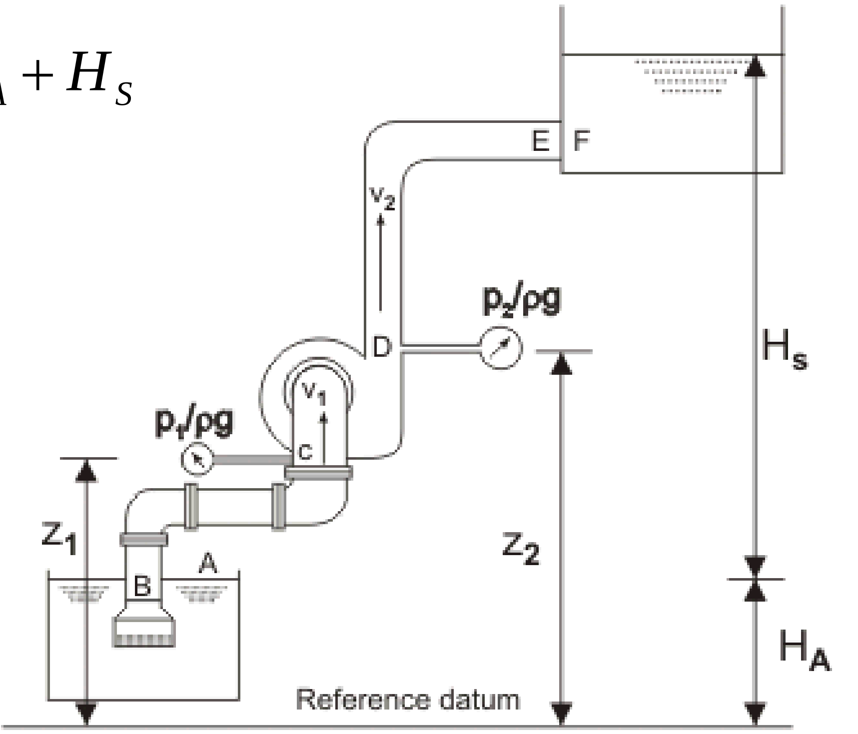
$$total\_head\_at\_A = H_A$$

$$total\_head\_at\_B(freesurface) = H_A + H_S$$

$$H_S = static\_head / lift$$

$$inlet\_head = H_1 = \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1$$

$$outlet\_head = H_2 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2$$



- Total or net head developed is (H2 - H1)
- Bernouli's equn between A & C and D & E

$$H_1 = \frac{p_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = H_A - h_{in} - h_{f1}$$

$$H_2 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + z_2 = H_A + H_S + h_{f2} + h_E$$

$$\therefore H_2 - H_1 = H_S + h_{in} + h_{f1} + h_{f2} + h_E$$

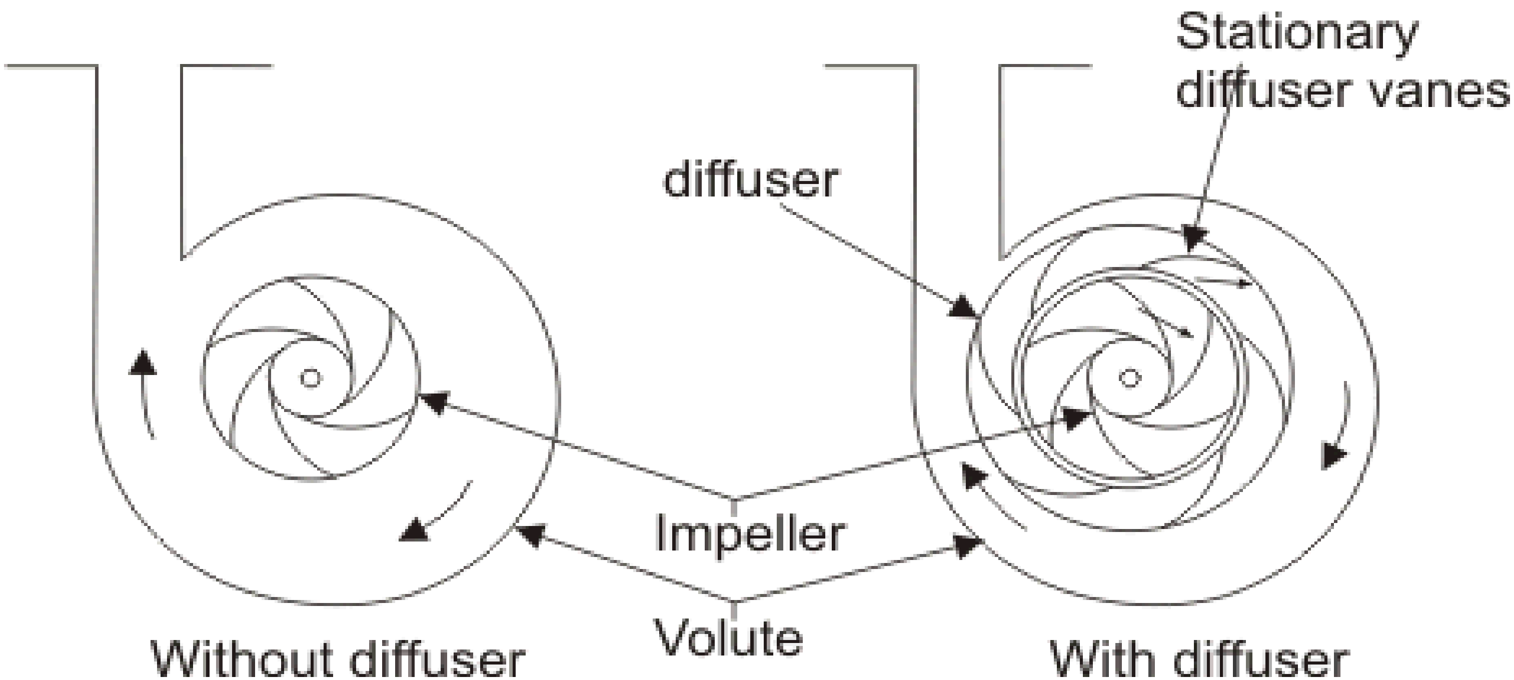
- Net head

$$H = H_2 - H_1 = \frac{p_2 - p_1}{\rho g} + (z_2 - z_1) = \left(\frac{p_2}{\rho g} + z_2\right) - \left(\frac{p_1}{\rho g} + z_1\right)$$

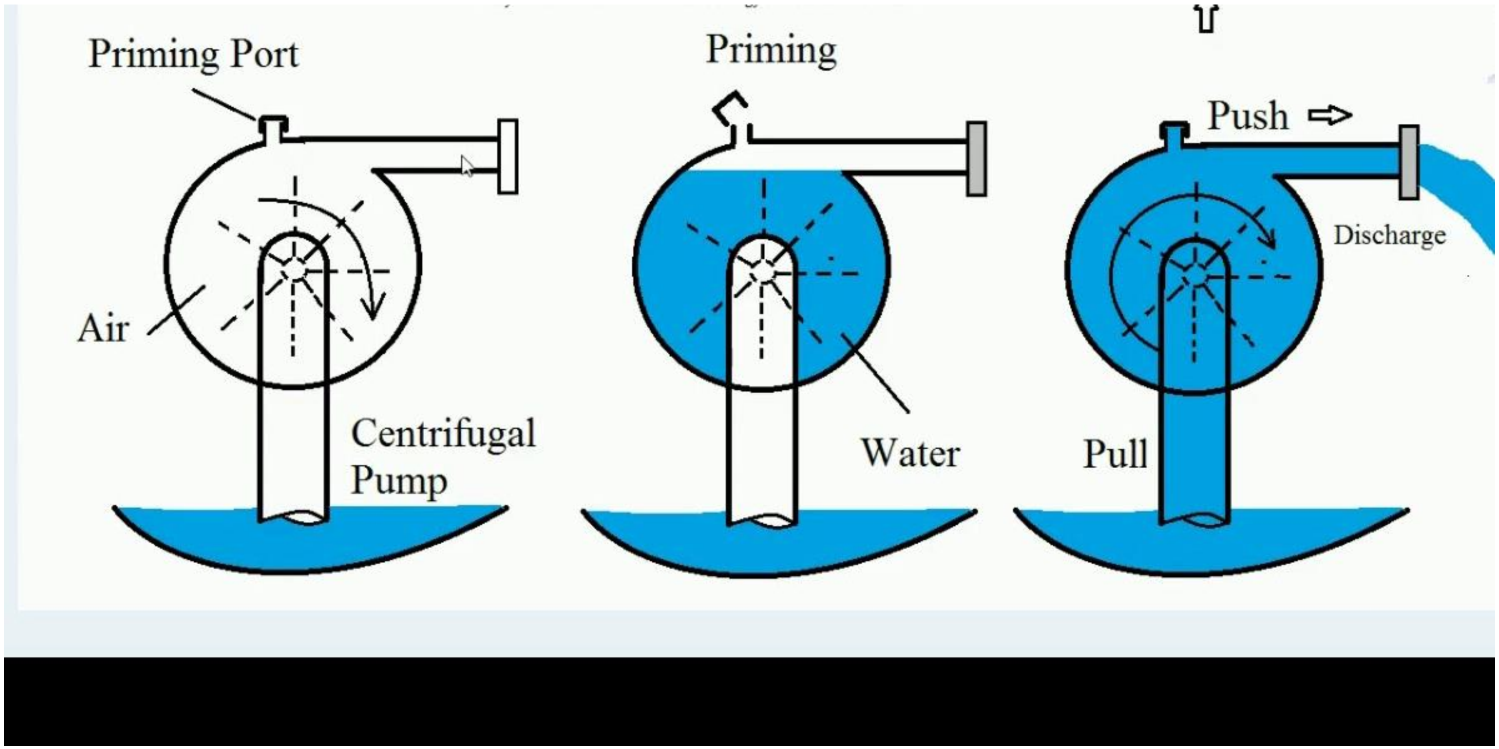
The above head is measured using piezometric manometer

CENTRIFUGAL PUMP

- Components: impeller, diffuser ring and volute

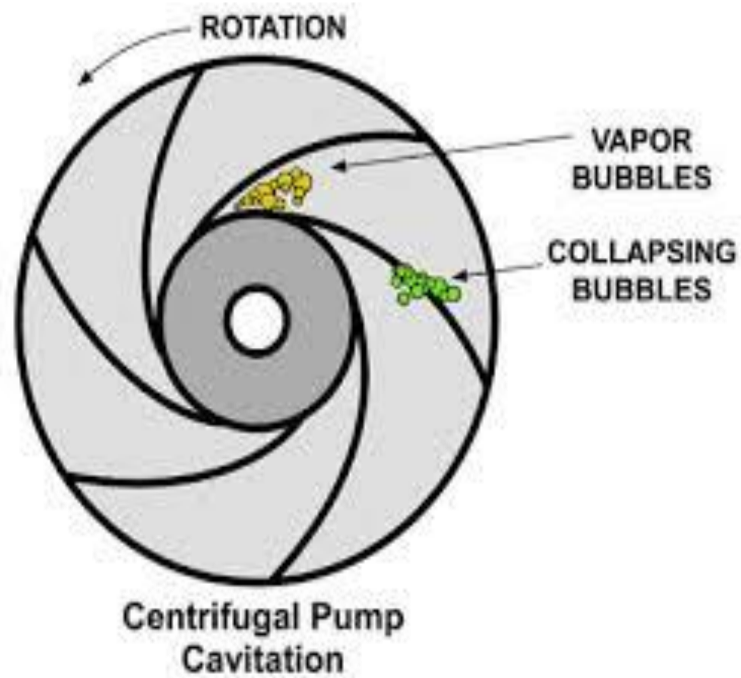


Priming in centrifugal pump

- 

Cavitation in centrifugal pump

- **cavitation** occurs when the liquid pressure at a given location is reduced to the vapor pressure of the liquid.
- For a piping system that includes a pump, **cavitation** occurs when the absolute pressure at the inlet falls below the vapor pressure of the water.
- This phenomenon may occur at the inlet to a pump and on the impeller blades, particularly if the pump is mounted above the level in the suction reservoir.



Effect of Cavitation in centrifugal pump

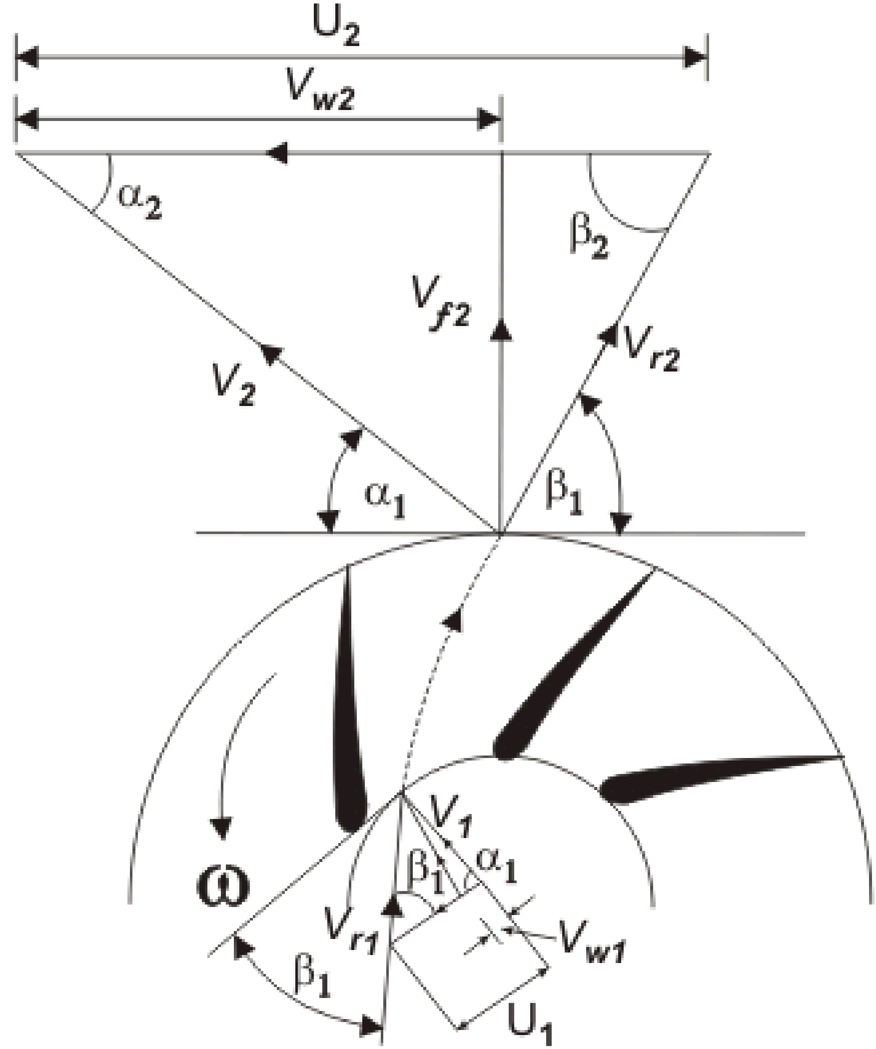
- Under this condition, vapor bubbles form (water starts to boil) at the impeller inlet and when these bubbles are carried into a zone of higher pressure, they collapse abruptly and hit the vanes of the impeller (near the tips of the impeller vanes).
- This results in

1. Damage to the pump (pump impeller)
2. vibrations (and noise).
3. Reduce pump capacity.
4. Reduce pump efficiency

Flow path of water through centrifugal pump

- The impeller rotates and the fluid is drawn into the blade passage at the impeller eye, the centre of the impeller.
- The inlet pipe is axial and therefore fluid enters the impeller with very little whirl or tangential component of velocity and flows outwards in the direction of the blades.
- The fluid receives energy from the impeller while flowing through it and is discharged with increased pressure and velocity into the casing. To convert
- the kinetic energy or fluid at the impeller outlet gradually into pressure energy using diffuser blades mounted on a diffuser ring are used.
- The stationary blade passages so formed have an increasing cross-sectional area which reduces the flow velocity and hence increases the static pressure of the fluid.
- Finally, the fluid moves from the diffuser blades into the volute casing which is a passage of gradually increasing cross-section and also serves to reduce the velocity of fluid and to convert some of the velocity head into static head. Sometimes pumps have only volute casing without any diffuser.

- β_1 is the angle made by the blade at inlet, with the tangent to the inlet radius.
- β_2 is the blade angle with the tangent at outlet.
- V_1 & V_2 are the absolute velocities of fluid at inlet an outlet respectively
- V_{r1} & V_{r2} are the relative velocities (with respect to blade velocity) at inlet and outlet respectively



- Work done on the fluid per unit weight

$$=\frac{\left(V_{w2}U_2 - V_{w1}U_1\right)}{g}$$

- A centrifugal pump rarely has any sort of guide vanes at inlet. The fluid therefore approaches the impeller without appreciable whirl and so the inlet angle of the blades is designed to produce a right-angled velocity triangle at inlet.
- Work done on the fluid per unit weight $=\frac{V_{w2}U_2}{g}$
- the manometric head $<= \frac{V_{w2}U_2}{g}$
- because of the energy dissipated in eddies due to friction.

- Manometric efficiency $\eta_m = \frac{gH}{V_{w2}U_2}$
- Overall efficiency $\eta_o = \frac{\rho QgH}{P}$
- Q is the volume flow rate of the fluid through the pump, and *P* is the shaft power, i.e. the input power to the shaft.
- The energy required at the shaft exceeds $\frac{V_{w2}U_2}{g}$

because of friction in the bearings and other mechanical parts. Thus a mechanical efficiency is defined as

$$\eta_{mech} = \frac{\rho QV_{w2}U_2}{P}$$

$$\therefore \eta_o = \eta_m \times \eta_{mech}$$

Net positive – suction head (NPSH)

- NPSH is defined as the net head developed at the suction port of the pump, in excess of the head due to the vapor pressure of the liquid at the temperature in the pump.
- NPSH must be positive for preventing the liquid from boiling.
- Boiling or cavitations may damage the pump.

$$NPSH = \left(\frac{P}{\rho g} + \frac{V^2}{2g} + z \right)_{suction} - \frac{P_v}{\rho g}$$