Program : **B.Tech**

Subject Name: **Basic Mechanical Engineering**

Subject Code: **BT-203**

Semester: **2nd**

UNIT III

Fluids: Fluid properties pressure, density and viscosity etc, Types of fluids, Newton’s law of viscosity, Pascal’s law, Bernoulli’s equation for incompressible fluids, only working principle of Hydraulic machines, pumps, turbines, Reciprocating pumps.

Fluid: - A fluid is a substance that continually deforms under an applied load. Fluids are liquids, gases, plasmas, and to some extent, plastic solids. Fluids are substances that have zero shear modulus, or, in simpler terms, a fluid is a substance which cannot resist any shear force applied to it.

Branches of Fluid Mechanics:-

1. Fluid Statics: - The study of mechanics of fluids at rest is called Fluid Statics. The fluid statics is also study of incompressible fluid under static conditions.

2. Fluid Dynamics: - The study of mechanics of fluid in motion under the influence of forces is called Fluid Dynamics.

3. Fluid Kinematics: - The fluid kinematics deals with translational, rotation and deformation of fluid without considering the forces. The study of fluid in motion due to its energy without considering forces is called Fluid Kinematics.

4. Fluid Kinetics: - Fluid Kinetics deals with the relation between velocities, acceleration and the forces which are exerted by or upon the moving fluid.

5. Hydraulics: - Hydraulics is the branch of Fluid Mechanics which deals with behavior of water (incompressible fluid) either in motion or at rest.

6. Pneumatics: - Pneumatics is the branch of Fluid Mechanics, which deals with behavior of compressible fluid either at rest or in motion.

Types of Fluid:-

1. Ideal Fluid: - An Ideal Fluid is one which has no properties other than its density. Such type of fluids is theoretical fluids and doesn't exist in nature. These fluids are based on assumptions for simplification of calculations, or we can say that “The fluid which is having zero viscosity is known as Ideal Fluid.”

2. Real Fluid: - All fluids are Real Fluids. They have viscosity, surface tension, compressibility and density. Means “The Fluid which has some viscosity, it is known as Real Fluid”

3. Newtonian Fluid: - The Fluid which obeys the Newton's Law of Viscosity is known as Newtonian Fluid. If for a fluid the shear stress is directly proportional to the rate of shear strain than such fluids are known as Newtonian Fluid.

4. Non - Newtonian Fluid: - The fluids which doesn't obeys Newton's Law of Viscosity, is known as Non – Newtonian Fluid.

5. Ideal Plastic Fluid:- A fluid, in which shear stress is more than the yield value and the shear stress is directly proportional to the rate of shear strain is known as Ideal Plastic Fluid.

Properties of Fluids:-

1. Density: - It is also known as Specific Mass or Mass Density of Fluid. Density or Mass Density of Fluid is defined as the ratio of mass and its volume. Thus Mass per unit Volume is called Density. It is denoted by symbol **'ρ'** (Rho).

$$\rho = \text{Mass} / \text{Volume} \ (kg/m^3)$$

2. Specific Weight or Weight Density: - Specific Weight or Weight Density of a fluid is the ratio between the Weight of the fluid and its volume. Thus Weight per unit Volume of a fluid is known as the Weight Density. It is denoted by **'ϒ'** (Gamma).

Thus,

Υ = (Mass of Fluid X Acceleration due to Gravity) / Volume of Fluid
$\Upsilon = (m \times g) / V$ N/m^3

3. Specific Gravity: - The specific Gravity is defined as the ratio of density of a substance (ρ) to the density of water at 4° C (ρ_{water} = 1000 kg/m3). It is denoted by S and it is a dimensionless quantity.
$S = \rho / \rho_{water}$
So the density of fluid, $\rho = S \times \rho_{water} = S \times 1000$ (kg/m^3)
The weight density of a fluid $\Upsilon = (S \times \rho_{water}) \times g = S \times 1000 \times 9.81$ (N/m^3)

4. Dynamic Viscosity: - The dynamic viscosity or simply 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. It is denoted by mu,

$$\mu = \tau / (du/dy)$$

The viscosity is measured in poise, or in centi-poise.
1 Poise = 1000 centi-poise
1 N-s/m^2 = 10 Poise
The viscosity of water at 20° C is 0.01 poise or centi-poise.

5. 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,

$$\nu = \text{Viscosity} / \text{Density} = \mu / \rho$$

The kinematic viscosity is measured in m^2/sec; In C.G.S. units it is measured in stoke (cm^2/sec).
1 Stoke = 10^{-4} m^2/sec

Newton's Law of Viscosity:-
It states that the Shear Stress is directly proportional to the rate of Shear strain or Velocity Gradient. i. e.

$$\tau \propto du / dy$$

$$\text{Or, } \tau = \mu (du / dy)$$

Whereμ is the constant of proportionality, called Coefficient of Viscosity or Dynamic Viscosity.

Pressure:-
The pressure or intensity of pressure is defined as normal force exerted by a fluid per unit area. Pressure is considered only in case of Liquid and Gases, while in case of Solid it is Stress.

$$P = F / A \ (N / m^2)$$

Where, Force, F = mass (m) X Acceleration due to gravity (g)
Mass, m = Volume X Density = Area (A) X Depth (h) X Density (ρ)
So, $F = A \times h \times \rho \times g$
And Now Pressure, $P = (A \times h \times \rho \times g) / A = \rho \times g \times h$ (N / m^2)

Units of Pressure: - The pressure is measured in N/m^2, which is called Pascal (Pa).

1 kPa = 10^3 Pa
1 MPa =10^6 Pa = 10^3 kPa
1 bar = 100 kPa = 10^5 Pa
1 atm = 101325 Pa = 101.325 kPa

Pascal's Law:-
Pascal's law (also Pascal's principle or the principle of transmission of fluid-pressure) is a principle in fluid mechanics which states that a pressure change occurring anywhere in a confined incompressible fluid is transmitted throughout the fluid with the same intensity in all directions.
Or Pascal's law states that when there is an increase in pressure at any point in a confined fluid, there is an equal increase at every other point in the container.

This principle is stated mathematically as:

$$\Delta P = h \times \rho \times \Delta h$$

Where

ΔP = hydrostatic pressure

Δh = the height of fluid above the point of measurement

Bernoulli equation

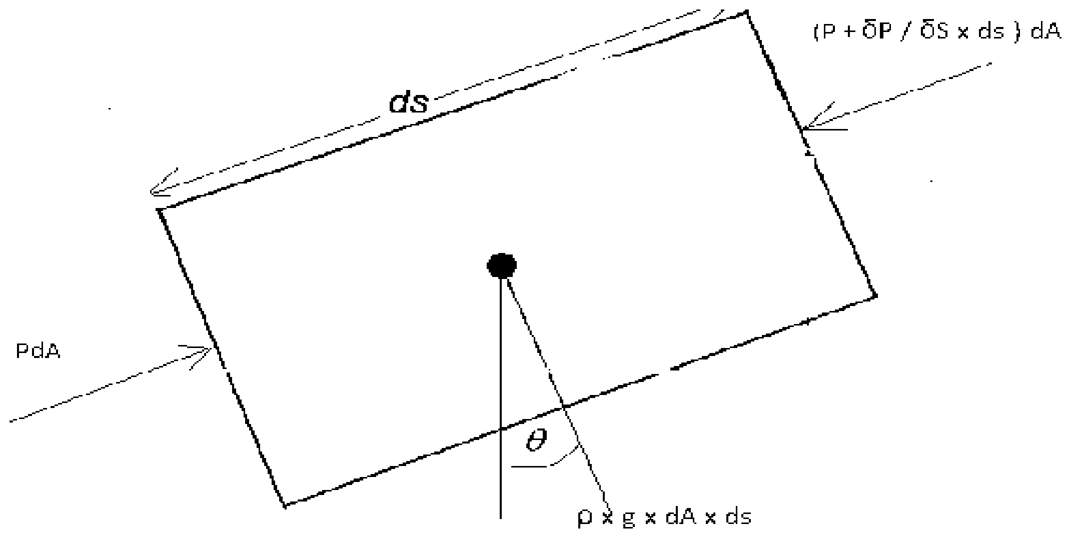
Euler's Equation of Motion

This is the equation of motion in which forces due to gravity and pressure are taken in to consideration. Considering a stream line flow in which flow is in s–direction, Consider a cylindrical element of cross sectional area dA and length ds

The forces acting on the cylindrical element are

1. Pressure force PdA in the direction of flow
2. Pressure force $(P + \delta P/ \delta S)$ dA opposite to the direction of flow
3. Weight of element $\rho \times g \times dA \times ds$

Let θ is the angle between the direction of flow and line of action of the weight of element.



The resultant force on the fluid element in the direction of flow must be equal to the mass of fluid element multiplied wit acceleration in the direction.

$$PdA - (P + \delta P/ \delta S \times ds)\, dA - \rho \times g \times dA \times ds \times \cos\theta = \rho \times dA \times ds \times a_s \quad \text{-----(1)}$$

Where term a_s is the acceleration in the direction of flow

Now $a_s = dv / dt$ where v is the function of s and t. -----(2)

So $a_s = (\delta v/\delta s) \times (\delta v/\delta t) + \delta v/\delta t$

If the flow is steady,

$$\delta v / \delta t = 0$$

Now equation no (2) will be

$$a_s = v\, (\delta v/\delta s)$$

Putting the values in equation no (1)

$$-\ (\delta P/ \delta S \times ds)\, dA - \rho \times g \times dA \times ds \times \cos\theta = \rho \times dA \times ds \times v\, (\delta v/\delta s)$$

On dividing by $\rho \times dA \times ds$ to the above equation

$$-\quad (\delta P/\rho\, ds) - g \times \cos\theta = v\,(\delta v/\delta s)$$

$$(\delta P/\rho\, \delta s) + g \times \cos\theta + v\,(\delta v/\delta s) = 0$$

$$(1/\rho) \times (\delta P/\delta s) + g\,(dz/ds) + v\,(\delta v/\delta s) = 0$$

$$(dP/\rho) + g\,dz + v\,dv = 0$$

This equation is known as Euler's equation of motion.

Bernoulli Theorem:-

It states that in a steady, ideal flow of an incompressible fluid, the total energy at any point of the fluid is constant. The total energy consists of pressure energy, kinetic energy, and Potential Energy.

Assumptions of Theorem:-

1. Flow is steady
2. The fluid is ideal
3. The flow is incompressible
4. The flow is along a stream line

Now on integration of Euler's equation

$$\int (dP/\rho) + \int (g\,dz) + \int v\,dv = \text{Constant}$$

If flow is incompressible then ρ is constant and equation will be

$$(P/\rho g) + Z + (V^2/2g) = \text{constant}$$

The above equation is known as Bernoulli equation.

Hydraulic Machines

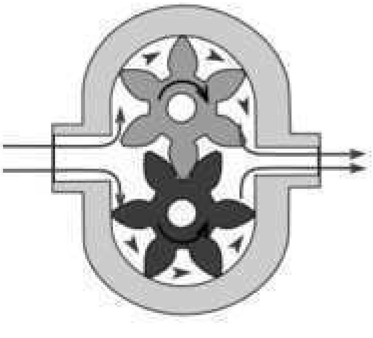
The basic rule of hydraulic machines is Pascal's Principle.

Pascal's Principle: pressure exerted on a fluid is distributed equally throughout the fluid. Hydraulics uses incompressible liquids so the applied pressure from one end is equal to the desired pressure on the other end.

Pump:-

A fluid or hydraulic pump is a machine that transfers energy from its moving parts to the fluid passing through the pump. The energy transferred from the pump to the fluid appears as the pressure and velocity of the fluid. Or a hydraulic pump is a mechanical source of power that converts mechanical power into hydraulic energy.

When a hydraulic pump operates, it creates a vacuum at the pump inlet, which forces liquid from the reservoir into the inlet line to the pump and by mechanical action delivers this liquid to the pump outlet and forces it into the hydraulic system.

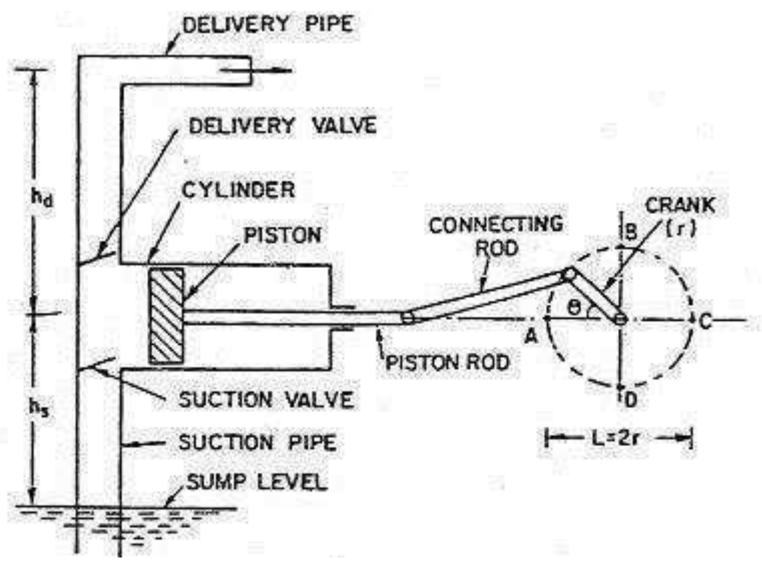


Hydraulic pump types
1.1 Gear pumps
1.2 Rotary vane pumps
1.3 Screw pumps

TURBINES
Turbines are used to convert freely available energy from rivers and wind into useful mechanical work, usually through a rotating shaft. The **hydraulic turbine** is a mechanical device that converts the potential energy contained in an elevated body of water (a river or reservoir) into rotational mechanical energy. Which can be further used to generate electricity.

Classification of Hydraulic Turbines: Based on flow path
Water can pass through the Hydraulic Turbines in different flow paths. Based on the flow path of the liquid Hydraulic Turbines can be categorized into three types.
1. Axial Flow Hydraulic Turbines: This category of Hydraulic Turbines has the flow path of the liquid mainly parallel to the axis of rotation. Kaplan Turbines has liquid flow mainly in axial direction.
2. Radial Flow Hydraulic Turbines: Such Hydraulic Turbines has the liquid flowing mainly in a plane perpendicular to the axis of rotation.
3. Mixed Flow Hydraulic Turbines: Most of the Hydraulic Turbines used there is a significant component of both axial and radial flows. Such types of Hydraulic Turbines are called as Mixed Flow Turbines. Francis Turbine is an example of mixed flow type, in Francis Turbine water enters in radial direction and exits in axial direction.
None of the Hydraulic Turbines are purely axial flow or purely radial flow. There is always a component of radial flow in axial flow turbines and of axial flow in radial flow turbines.

Reciprocating Pump
A reciprocating pump is a class of pump which includes the piston, plunger and diaphragm. It is often used where a relatively small quantity of liquid is to be handled and where delivery pressure is quite large. In reciprocating pumps, the chamber in which the liquid is trapped, is a stationary cylinder that contains the piston or plunger.



The Main Parts of Reciprocating Pump are:
1. CYLINDER- It is made of cast iron or steel alloy. The piston reciprocates inside the cylinder. The movement of piston is obtained by a connecting rod which connects piston and rotating crank.
2. SUCTION PIPE- It connects the source of water and cylinder, the water is sucked.
3. DELIVERY PIPE- Water sucked by pump is discharged into delivery pipe.

4. SUCTION VALVE- It adjusts the flow from the suction pipe into delivery pipe.
5. DELIVERY VALVE- It admits the flow from the cylinder in to delivery pipe.
6. AIR VESSEL- It is a cast iron closed chamber having an opening at its pass through which the water flows into vessel.

WORKING:

During the suction stroke the piston moves left thus creating vacuum in the Cylinder. This vacuum causes the suction valve to open and water enters the Cylinder. During the delivery stroke the piston moves towards right. This increasing pressure in the cylinder causes the suction valve to close and delivery to open and water is forced in the delivery pipe. The air vessel is used to get uniform discharge.

Describe the construction and working of Pelton turbine. **[RGPV Dec 2010]**

Or

Draw a neat sketch of Pelton turbine and explain its working. **[RGPV Dec 2014]**

Or

Describe the construction and working of any one hydraulic turbine. **[RGPV June 2011]**

Or

Write a short note on hydraulic turbine and fluid coupling explaining their working with the help of neat sketches. **[RGPV Dec 2011]**

Construction of the Pelton turbine are as follows :

1. **Nozzle and flow regulating arrangement :** The amount of water striking the buckets (vanes) of the runner is controlled by providing a spear in the nozzle.

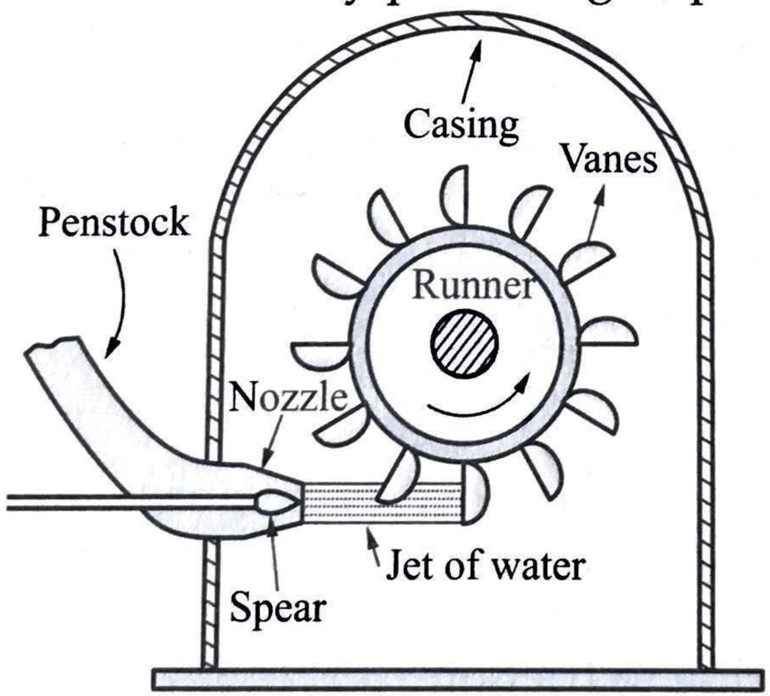


Fig. Pelton turbine

2. **Runner with buckets :** 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.
3. **Casing :** The function of the casing is to prevent the splashing of the water and to discharge water to tail race.
4. **Breaking jet :** 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.

The working principle of Pelton turbine are as follows :

- A Pelton turbine is a tangential flow impulse turbine.
- When water is transferred from a high head source through a penstock which is fitted with a nozzle. Through the nozzle, the water flows out as a high speed jet.
- A needle spear moving inside the nozzle controls the flow of water through the nozzle and at the same time provides a smooth flow with a negligible energy loss.
- The available potential energy of water is thus converted into kinetic energy before the jet strikes the buckets.
- The pressure of wheel is atmospheric and constant so that energy transfer occurs due to purely impulse action. Thus the wheel rotates in the direction of jet producing mechanical work.
- Speed of the turbine is kept constant by a governing mechanism that automatically regulate the quantity of water flowing through the runner in accordance with any variation of load.

Explain the construction and working of a radial flow reaction turbine or Francis turbine.

Radial flow reaction turbine : This type of turbines in which the water flows in the radi direction and at the same time water at the inlet of the turbine possesses kinetic energy well as pressure energy.

Construction of the radial flow reaction turbine are as follows :

1. **Casing :** 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.
2. **Guide mechanism :** 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.

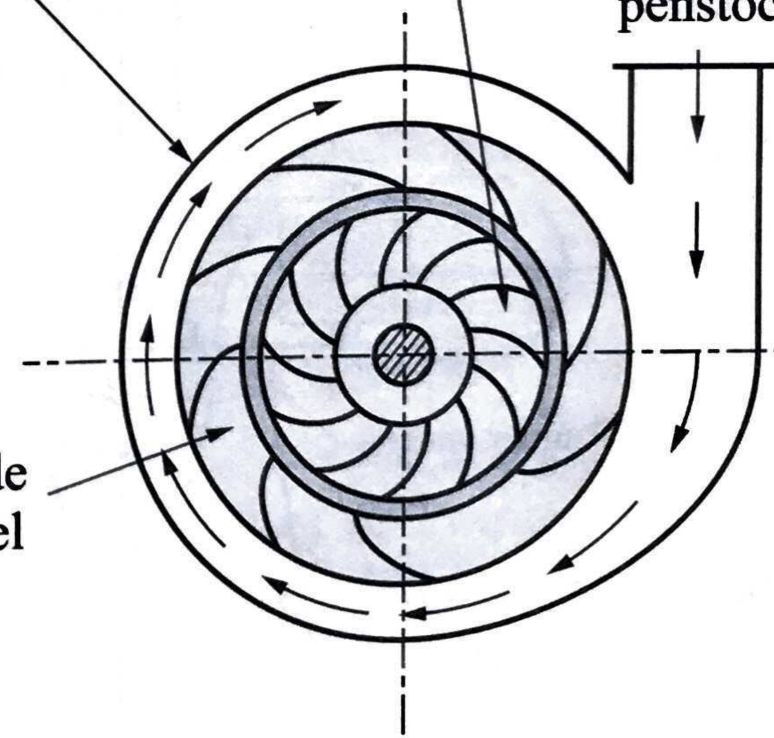


Fig. Radial flow reaction turbine (Francis turbine)

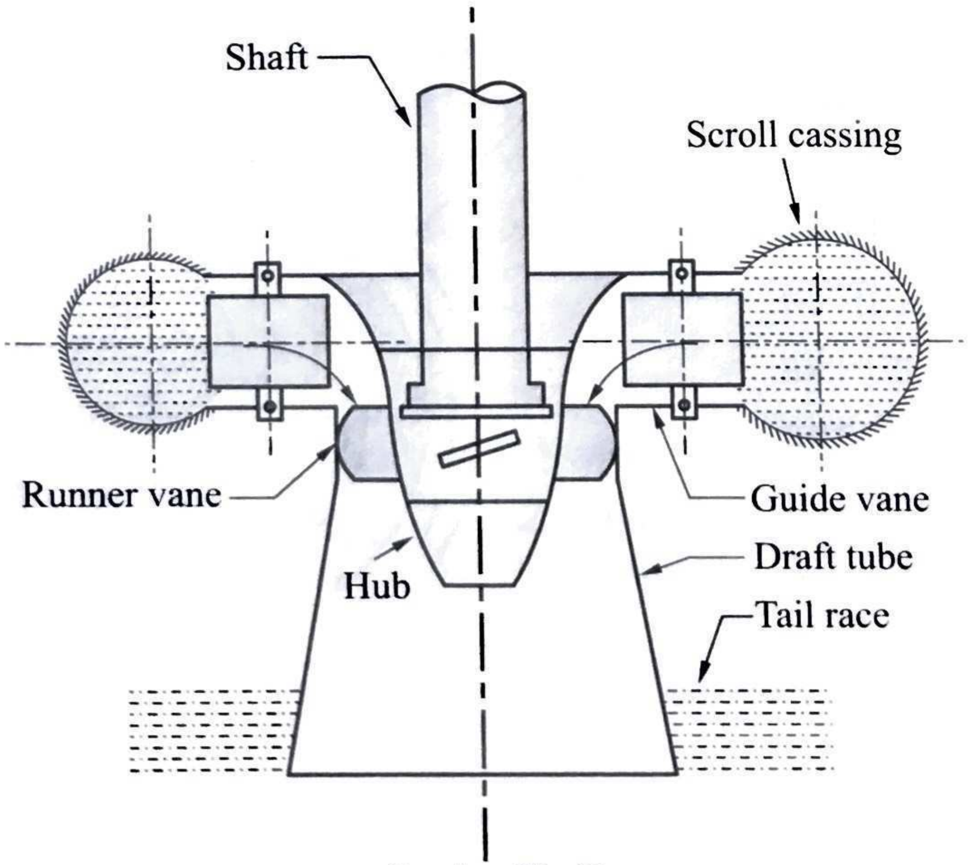
3. **Runner** : It is a circular wheel on which a series of radial curved vanes are fixed. They are keyed to the shaft.
4. **Draft tube** : The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. A tube or pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race.

The working principle of radial flow reaction turbine are as follows :

- The Francis turbine is example of radial flow turbine flow turbine. The Frances turbines is a medium head reaction turbine in which water flow radially inwards.
- It consists of a spiral casing enclosing a number of stationary guide blades fixed all around the circumference of inner ring of moving vanes forming the runner which is keyed to the turbine shaft.
- Water at high pressure enters through the inlet in the casing and flows radially inwards to the outer periphery of the runner through the guide blades.
- During its flow over the moving blades it imparts kinetic energy to the runner to set it into rotational motion.
- To enable the discharge of water at lower pressure, a diverging conical tube called draft tube is fitted at the center of the runner.

Describe with sketch construction and working of Kaplan turbine. [RGPV June 2010]

Ans. **Working principle of Kaplan turbine :** In a Kaplan turbine the runner blades are adjustable and can be rotated about pivots fixed to the boss of the runner. The blades are adjusted automatically by servomechanism so that at all loads the flow enters them without shock. Thus a high efficiency is maintain even at part load.



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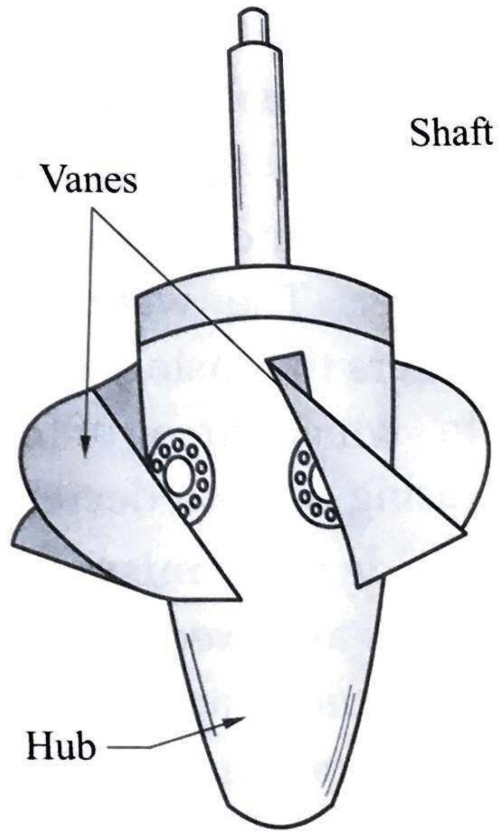

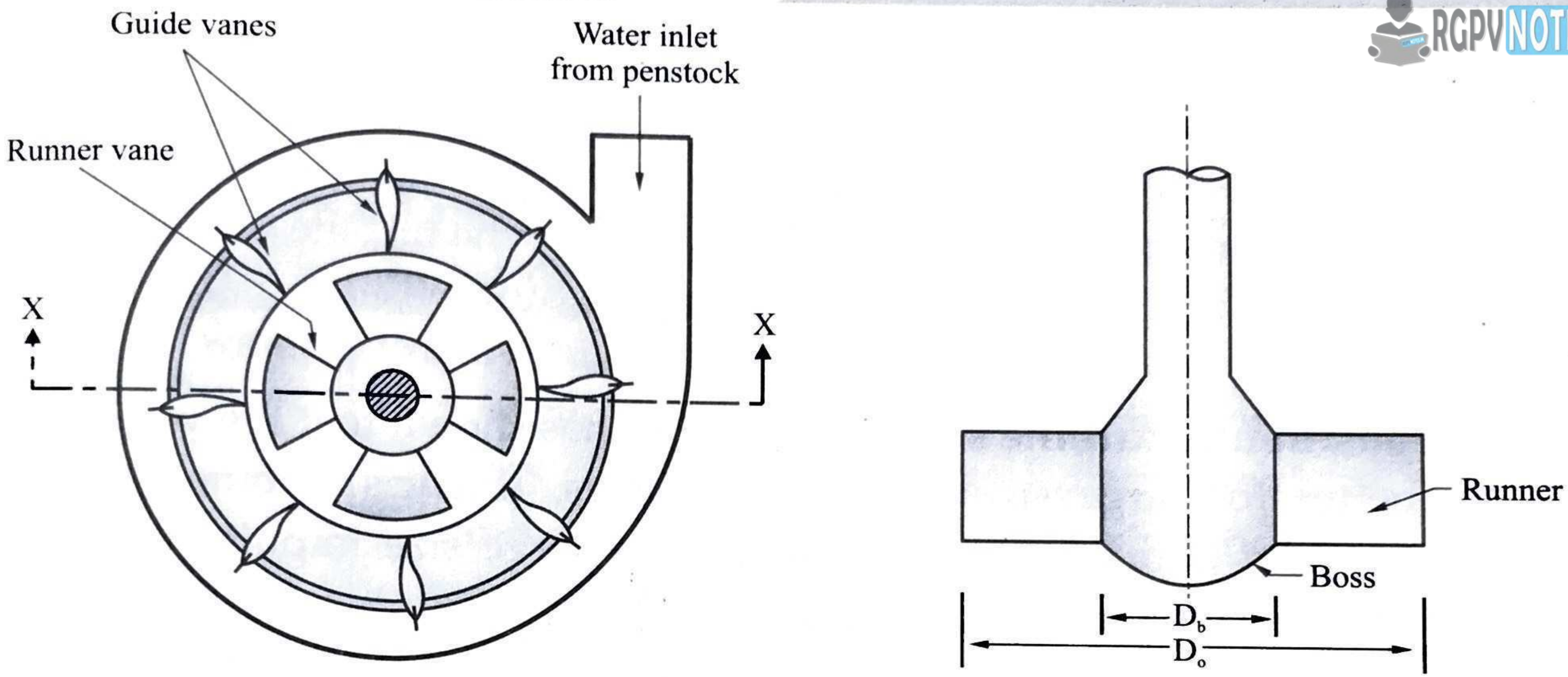

Fig. Main components of Kaplan turbine

Construction of Kaplan turbine are as follows :

1. Scroll casing
2. Guide vanes mechanism
3. Hub with vanes or runner of the turbine
4. Draft tube.

The scroll casing, guide mechanism and draft tube are similar to that in the Francis tur The shape of runner blades is different from that of Francis turbine. The blades of Ka turbine are made of stainless steel.

The water from penstock enters the scroll casing and then moves to the guide. From the g vanes, the water turns through 90^0 and flows axially through the runner.

