Hydraulic Machine:

Hydraulic machine are defined as those machines which converts either hydraulic energy (energy possed by water) into mechanical energy (which is further converted into electrical energy) or mechanical energy into hydraulic energy.

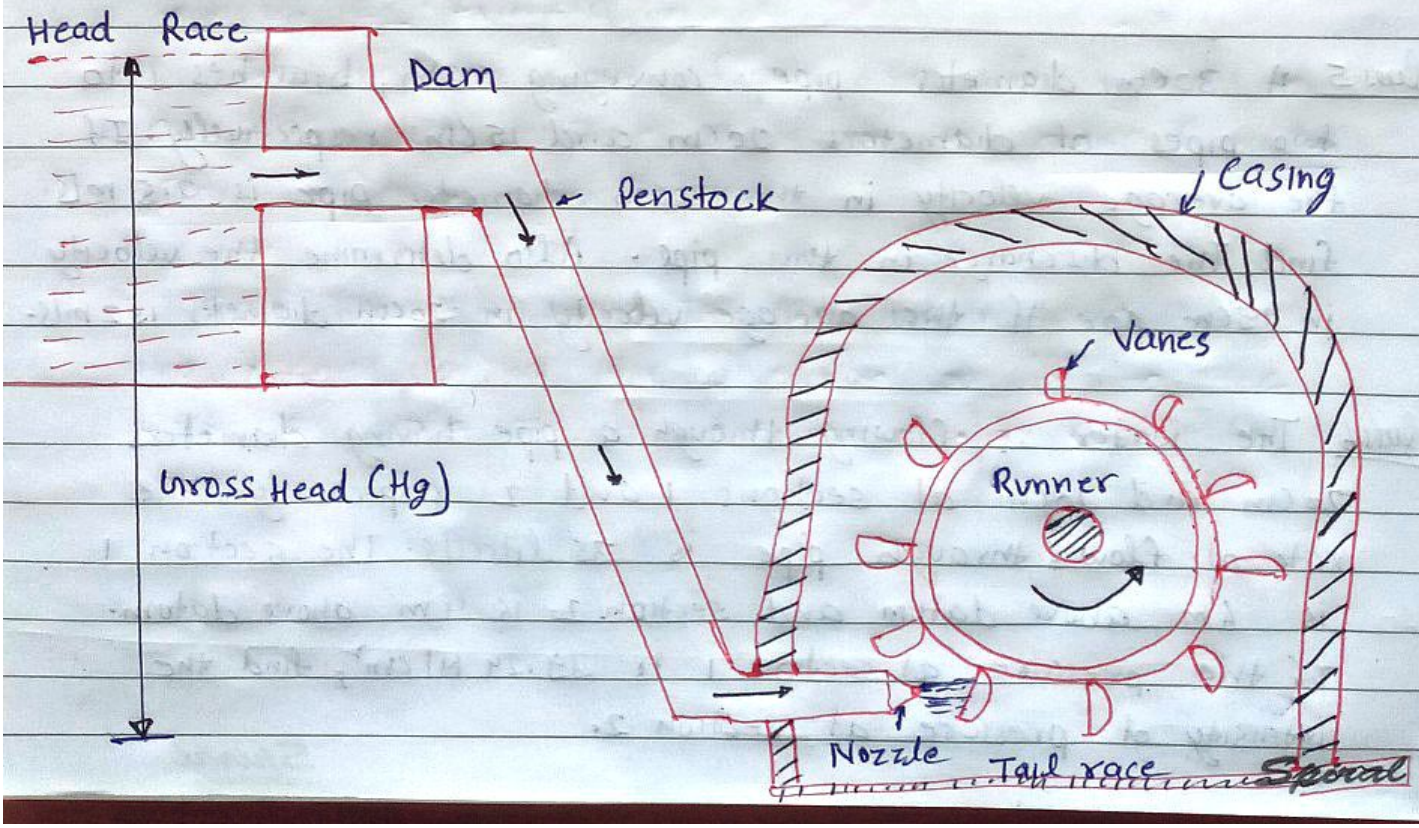
Turbines converts hydraulic energy into mechanical energy.

Pumps converts mechanical energy into hydraulic energy.

Turbines: Turbines are defined as the hydraulic machines which convert hydraulic energy into mechanical energy which is further converted into electrical energy.

The electric power which is obtained from the hydraulic energy (energy of water) is known as Hydro-electric power.

- Construction & working principle of turbine:



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Hydro-electric power plant consists of

(i) A dam constructed across a river to store water.

(ii) Pipes of large diameter called penstocks, which carry water under pressure from the storage reservoir to the turbines.

(iii) Turbines having different types of vanes fitted to the wheels.

(iv) Tail race, which is a channel carries water away from the turbines after the water has worked on the turbines.

Working Principle:

The liquid comes out in the form of a jet from the outlet of a nozzle through penstock, which is fitted to the dam through which the liquid is flowing under pressure. ~~Nozzle is fitted at the~~ vanes of the wheel are placed in the path of the jet, a force is exerted by the jet on the plate. This force is obtained from Newton's second law of motion or from impulse-momentum equation.

If the vanes or wheel is stationary then work done by the jet is zero ie no work done on the vanes.

If wheel is moving then the work done on the wheel rotate it which is coupled with shaft. Thus hydraulic energy is converted into mechanical energy.

The force exerted by the jet on the vanes.

F = Rate of change of momentum in the direction of force.

$$\boxed{F = \rho A V^2}$$

Work done per second by the jet on the vanes

$$\boxed{W = \rho A V^2 \cdot u}$$

Classification of Hydraulic turbines:

The following are the important classification of the turbines:

1- According to type of energy at inlet:

(a) Impulse turbine: Only kinetic energy available at the inlet of the turbine. Ex- Pelton wheel.

(b) Reaction turbine: If kinetic energy as well as pressure energy available at the inlet of the turbine. Ex - francis turbine, kaplan turbine

2- According to the direction of flow through runner:

(a) Tangential flow turbine: Water is flowing along the tangent of the runner.

(b) Radial flow turbine: If the water flows in the radial direction through the runner.

If the water is flows from outwards to inwards radially, the turbine is known as inward radial flow turbine. Ex: francis turbine.

If the water is flows radially inwards to outwards, the turbine is known as outward radial flow turbine.

(c) Axial flow turbine: If the water flow through the runner along the direction parallel to the axis of rotation of the runner. Ex: Kaplan turbine.

3- According to the head at the inlet of turbine:

(a) High head turbine: Above 250m. Ex: Pelton

(b) Medium head turbine: 60m – 250m. Ex: Francis

(c) Low head turbine: Below 60m. Ex: Kaplan

4- According to the specific speed of the turbine:

(a) Low specific speed turbine: Below 50, Ex - Pelton

(b) Medium specific speed turbine: 50 – 300, Ex - Francis

(c) High specific speed turbine: Above 300, Ex - Kaplan.

Efficiency:

Turbine converts hydraulic energy into mechanical energy.

Power supplied at inlet [Hydraulic power or water power]
(W.P.)

→ Hydraulic efficiency $(\eta_h) = \frac{R.P.}{W.P.}$

Power delivered to runner [Runner power]
(R.P.)

→ Mechanical efficiency $(\eta_m) = \frac{S.P.}{R.P.}$

Power at the shaft of the turbine [Shaft power]
(S.P.)

$\eta_o = \eta_m \times \eta_h = \frac{S.P.}{W.P.}$

Electric power

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Pumps:

The hydraulic machines which convert the mechanical energy into hydraulic energy [Pressure energy] are called pumps.

Pumps converts mechanical energy [shaft power] into impeller power, this impeller power is converted into manometric head ie water power.

Power is decreases from shaft of the pump to impeller and then to the water.

E.P. → S.P. → I.P. → W.P. (Head)

S.P. → mechanical efficiency (η_m)

I.P. → Manometric efficiency (η_{man})

$$\eta_{man} = \frac{W.P.}{I.P.}$$

$$\eta_m = \frac{I.P.}{S.P.}$$

$$\eta_o = \frac{W.P.}{S.P.}$$

NOTE:

(i) for high head pumps are connected in series.

(ii) For obtaining high discharge the pump should be connected in parallel.

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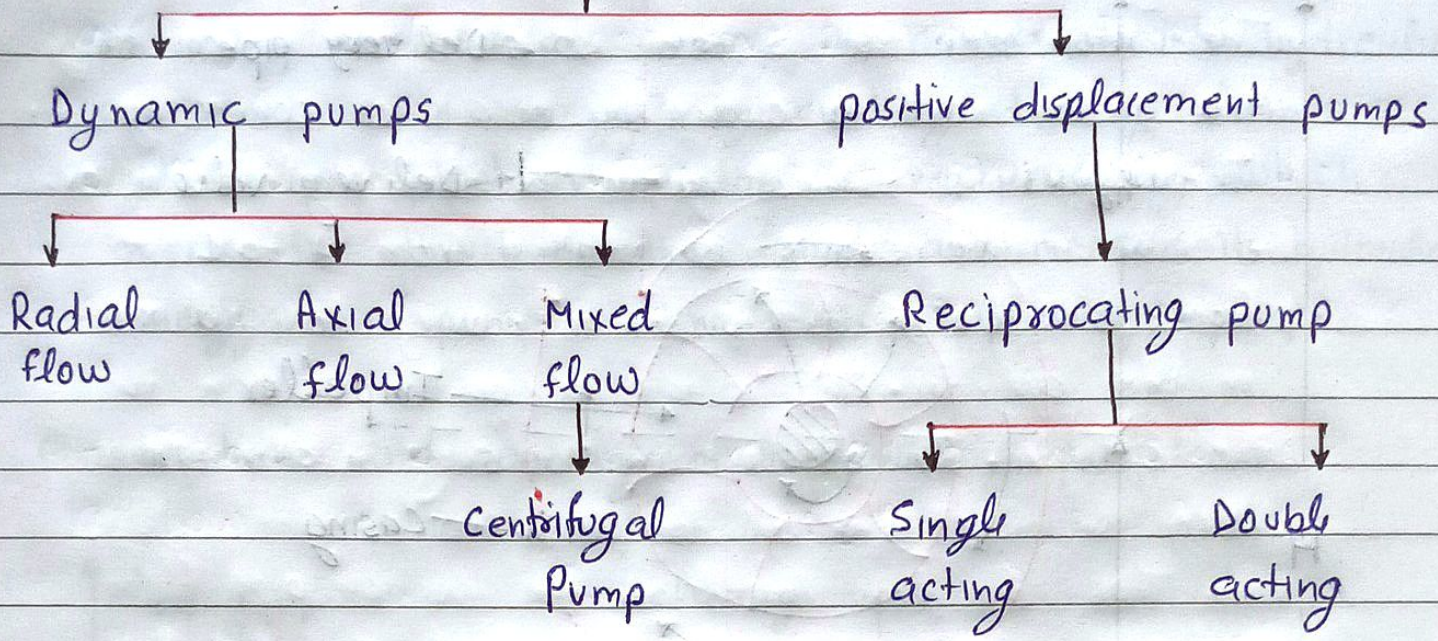
Classification of pumps:



Here we discuss in detail construction and working principle of centrifugal pump and reciprocating pump.

Centrifugal pump:

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

Working principle:

Centrifugal pump acts as a reverse of inward flow reaction turbine. The centrifugal pump works on 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 $\frac{r^2\omega^2}{2g}$.

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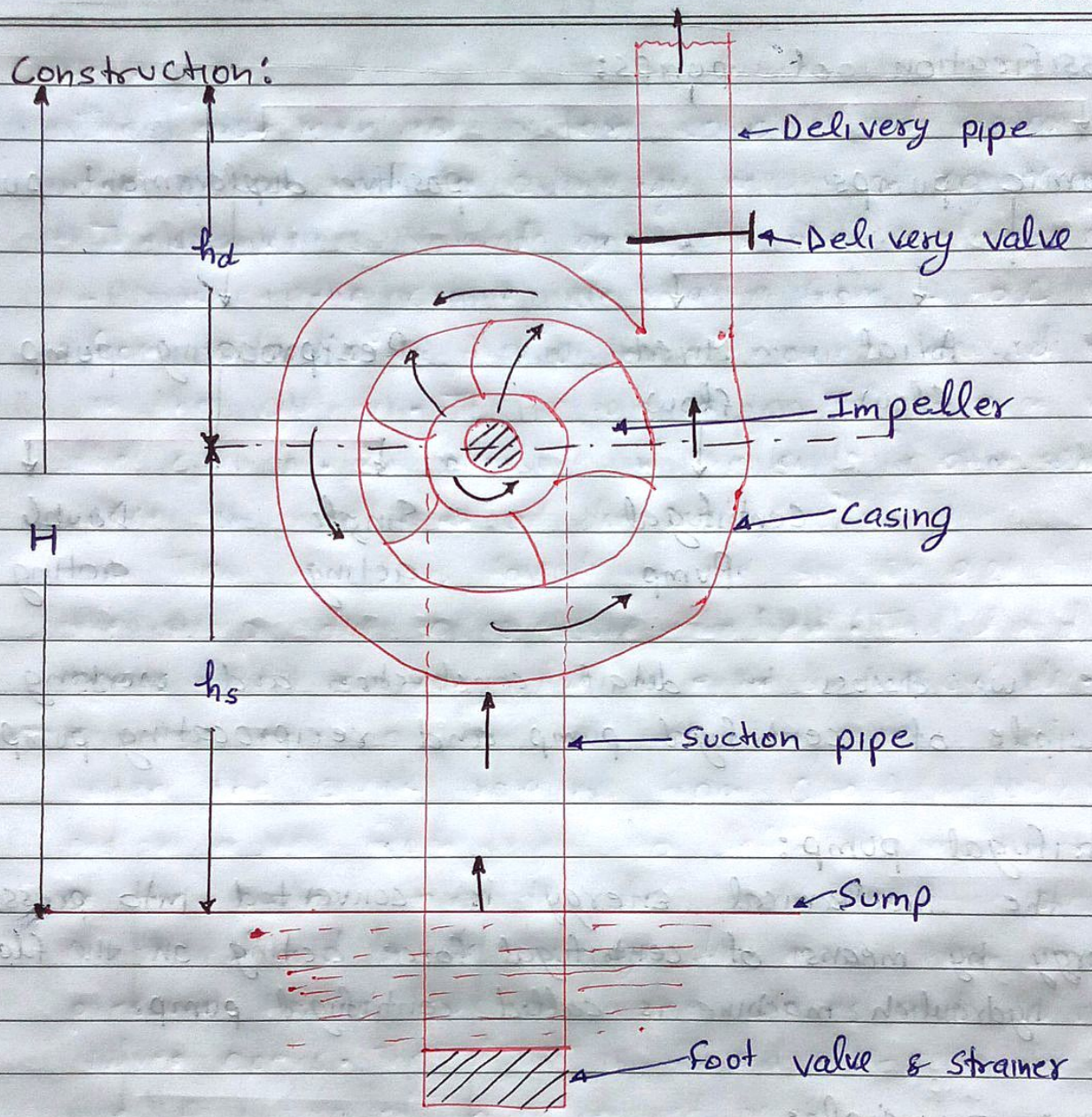
Construction:



The main part of a centrifugal pump are:

1- Impeller: It is the rotating part which consists of a series of curved vanes.

2- Casing: It is an air tight passage surrounding the impeller & designed in such a way that kinetic energy is converted into pressure energy.

3- Suction pipe with a foot valve and a strainer:
Suction pipe is connect inlet of the pump to water sump.
A foot valve opens only in the upward direction (one way valve)

4- Delivery pipe: One end is connected to the outlet of the pump and other end dulivers the water at a required height.

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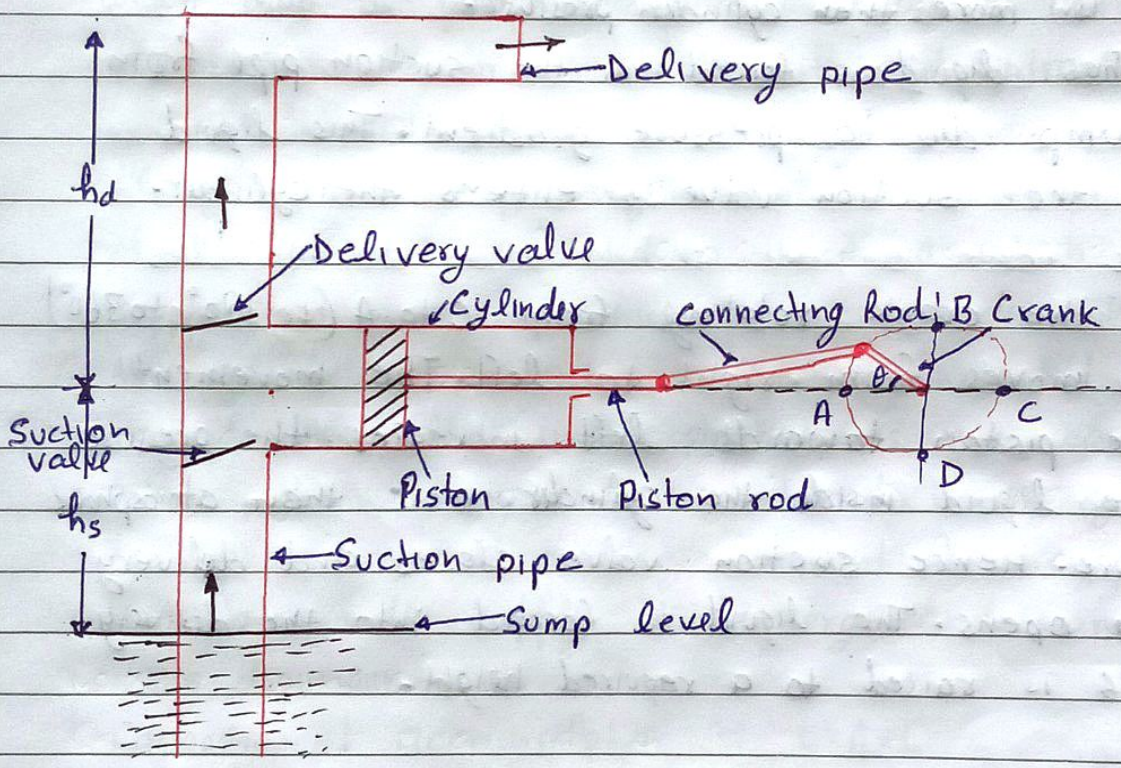
Reciprocating pump:

If the mechanical energy is converted into hydraulic energy [pressure energy] by sucking the liquid into a cylinder in which a piston is reciprocating, which exerts the thrust on the liquid and increase its hydraulic energy, the pump is known as reciprocating pump.

Constouction and working of Reciprocating pump:



Main parts of the reciprocating pump

1- A cylinder with a piston, piston rod, connecting rod and a crank.
2- Suction pipe: Connected between sump to cylinder.
3- Delivery pipe: Conected between cylinder & delivery point.
4- Suction valve: fitted in suction pipe
5- Delivery valve.: fitted in delivery pipe
valves are one way value which allowed water only upward direction.

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Working:

The movement of piston is obtained by connecting the piston rod to crank by means of connecting rod. The crank is rotated by means of an electric motor.

When the crank is rotating from A to C (ie from 0 to 180°), the piston is moving toward right in the cylinder. This creates a partial vacuum in the cylinder. But pressure in the sump is atmospheric which is more than cylinder pressure.

Thus liquid is forced in the suction pipe from the sump due to pressure gradient. This liquid opens the suction valve & enters the cylinder.

When the crank rotating from C to A (ie 180° to 360°) piston moves from right to left. The movement of the piston towards left increases the pressure of the liquid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. The liquid is forced into the delivery pipe & is raised to a required height.

Weight of the water delivered per second

$$W = sg\,Q = \frac{sg\,ALN}{60}$$

Work done per second $= \frac{sg\,ALN}{60} \times (hs + hd)$

Power required to drive the pump in KW

$$P = \frac{sg\,ALN(hs+hd)}{60 \times 1000} \text{ KW}$$

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Fluid System:

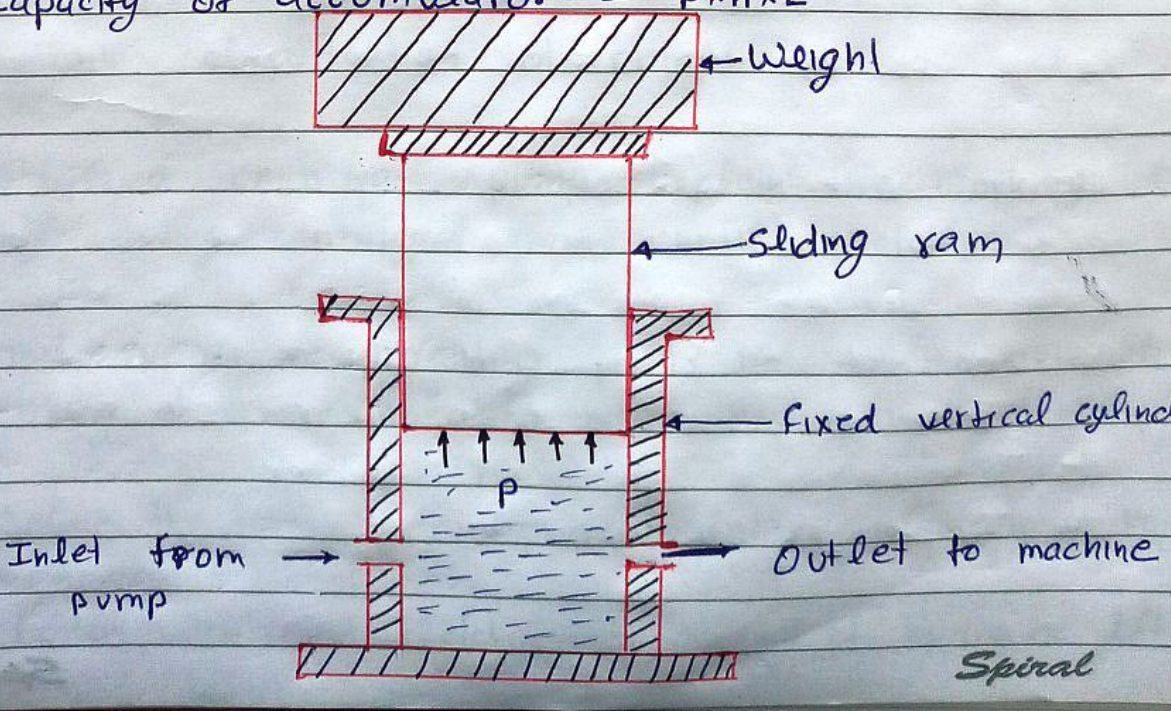
Fluid system is defined as the device in which power is transmitted with the help of a fluid [liquid or gas] under pressure. These devices are based on the principles of fluid statics and fluid kinematics.

Hydraulic accumulator: It is a device used for storing the energy of a liquid in the form of pressure energy which may be supplied for any sudden or intermittent requirement. Ex for hydraulic lift and hydraulic crane.

It consists of a fixed vertical cylinder containing a sliding ram. A heavy weigh is placed on the ram. The inlet of the cylinder is connected to the pump, which continuously supply fluid under pressure to the cylinder. The outlet of the cylinder is connected to the machine (lift or crane).

If the fluid under pressure is not required by the machine, the energy will be stored in the cylinder. When the machine required a large amount of energy, the hydraulic accumulator will supply this energy and ram will move in the downward direction.

Capacity of accumulator = $p \times A \times L$



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Hydraulic lift: It is a device used for carrying passenger or goods from one floor to another in multistoreyed building.

Hydraulic lifts are of two types:

1- Direct acting hydraulic lift
2- Suspended hydraulic lift.

Direct acting hydraulic lift consists of a ram, sliding in fixed cylinder. 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 & thus raises the cage to the required height.

The cage is moved downward direction, by removing the liquid from the fixed cylinder.

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Q.1 Define the following fluid properties:
Density, weight density & specific gravity of a fluid

Q.2 Explain the terms: Dynamic viscosity and kinematic viscosity. Give their dimension.

Q.3 Define Newtonian and non-Newtonian fluid.

Q.4 Define pressure. State the pascal's law.

Q.5 Define the equation of continuity. Also derive its expression.

Q.6 What is Euler's equation of motion? How will you obtain Bernoulli's equation from it?

Q.7 Define the terms: Hydraulic machines, turbines and pumps.

Q.8 How will you classify the turbines.

Q.9 Explain construction and working of turbine [Pelton turbine]

Q.10 Explain classification of pumps.

Q.11 Define a centrifugal pump. Explain the working of a single acting centrifugal pump with sketch.

Q.12 What is a reciprocating pump? Describe the principle and working of a reciprocating pump with a neat sketch.

Q.13 Define the term hydraulic accumulator. Explain its working.

Q.14 Explain with neat sketch, the working of hydraulic lift.

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