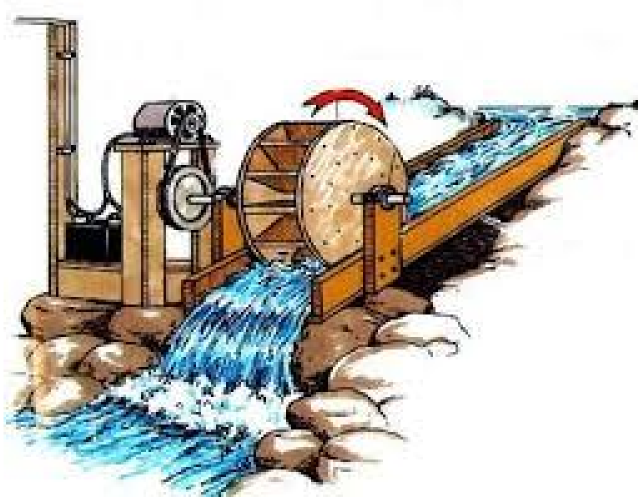
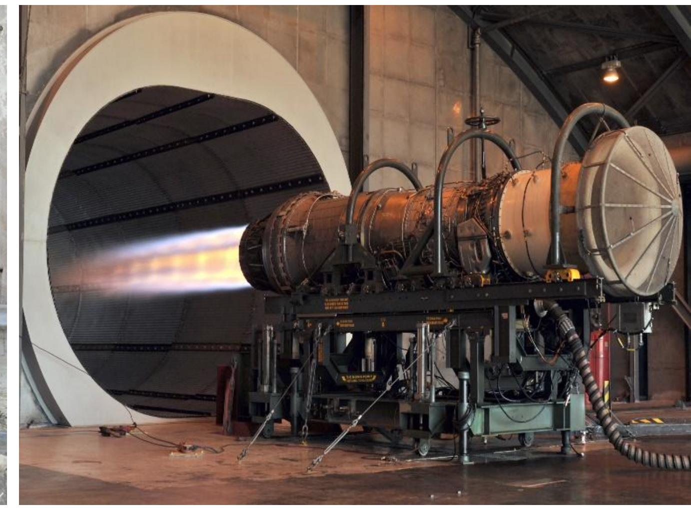
RME 1102

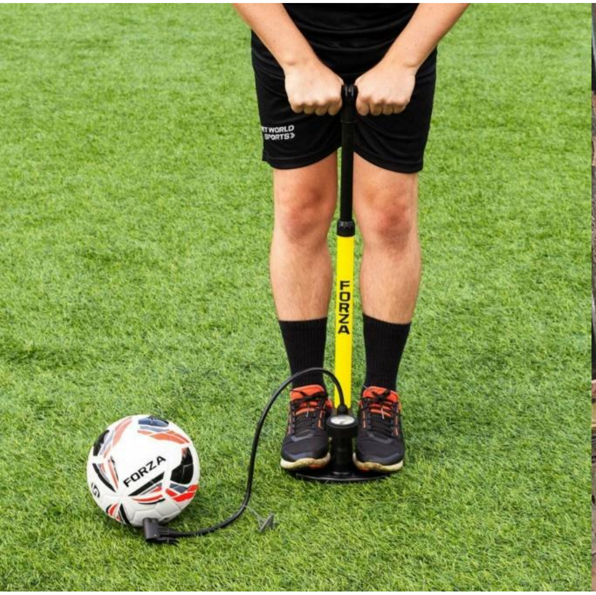




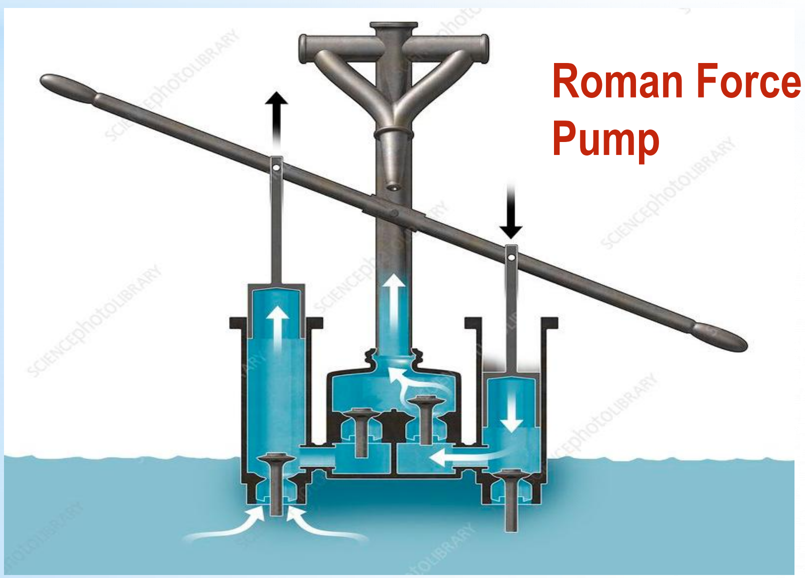
Fluid Machinery: From River Currents to Modern Turbomachines

Dr. Abdul Aziz Shuvo
ME, BUET, Dhaka-1000

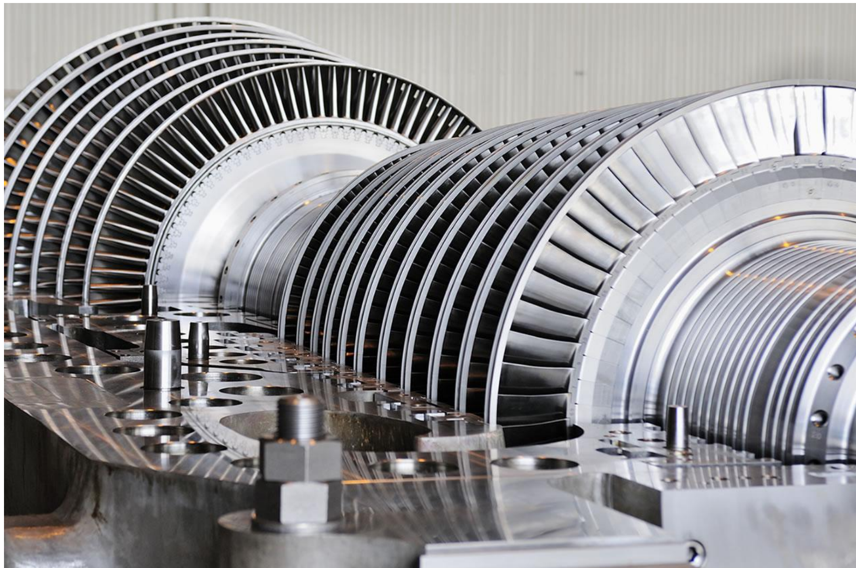
Fluid Machinery in our daily life



Ancient Fluid Machinery



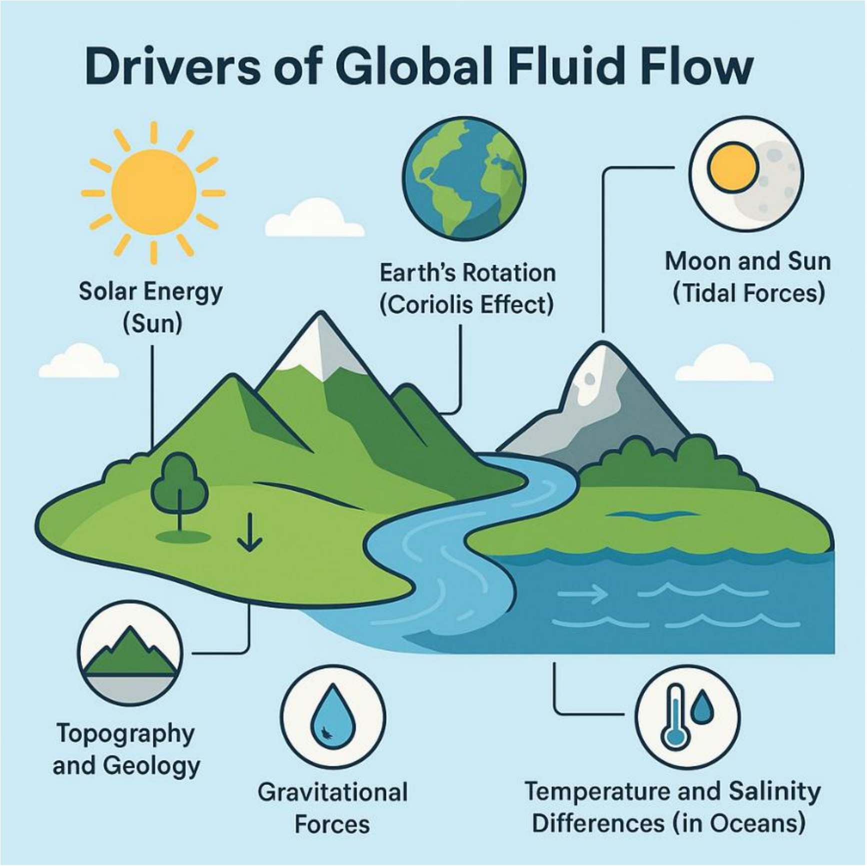
Advanced Fluid Machinery




Global Fluid Energy: Drivers

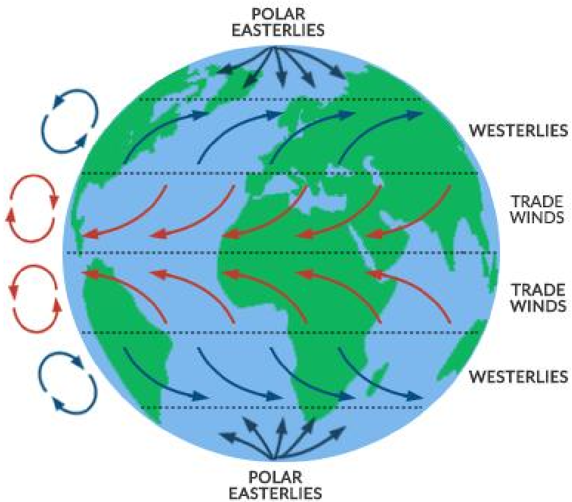
- **Solar Energy (SUN)**
  - Primary source of energy driving most atmospheric and hydrospheric movements
  - Causes uneven heating of the Earth's surface- creates temperature and pressure gradients
  - Drives wind circulation, ocean currents, evaporation- precipitation cycles (Water Cycle)

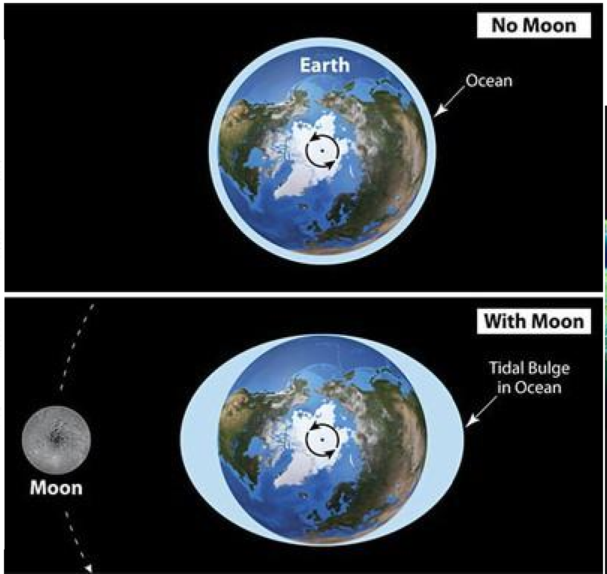
- **Gravitational Forces**
  - Mainly due to the Earth's gravity, influencing all downward and slope-based fluid movements
  - Drives-
    - River water flow from highlands to oceans.
    - Tidal movements, along with moon's gravitational pull



Global Fluid Energy: Drivers and Potentials

- **Earth's Rotation (Coriolis Effect)**
  - Deflects moving fluids (air and water) to the right in the Northern Hemisphere and to the left in the Southern Hemisphere
  - Influences global wind patterns, ocean gyres
- **Moon and Sun (Tidal Effect)**
  - The gravitational interaction with the Moon (main driver) and Sun (secondary) causes tidal bulges
  - Responsible for tidal flows and cyclic ocean level changes (high and low tides).
- **Topography and Geology**
  - Mountain ranges, valleys, sea floor features, and riverbeds guide and restrict fluid paths
  - Impacts river flow speed, wind tunnel effects, and subsurface water movement





Global Fluid Energy: Potentials

- **Global Energy requirement: 20 TW (20 $\times 10^{12}$ Watt)**

  $1\ TW = 10^{12}\ W = 10^{6}\ MW$

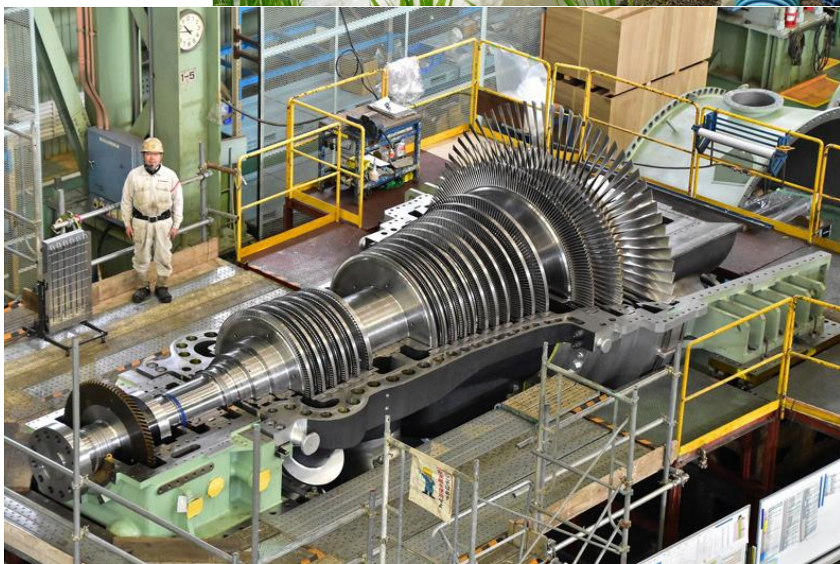
  - Electricity accounts for ~25% of total demand
  - The rest is used in transport, heating, industrial processes, etc.
- **Incoming Solar Power to Earth: 1,74,000 TW**
  - Reflected- 30%
  - Absorbed by Atmosphere-20%; by land and Ocean-50%
  - **70% of Absorbed Solar Energy is Radiated from Earth** while remaining 30% contributed to
    - ✓ Evaporation and Water Cycle (23%)
    - ✓ Wind and Ocean Currents (7%)
- **Global Fluid Energy Potential Distribution:**
  - Wind Energy Potential: 870 TW
  - Ocean Energy Potential: 1 TW
  - Tidal and Wave Energy Potential: 6 TW
  - River Flow Potential: 15 TW

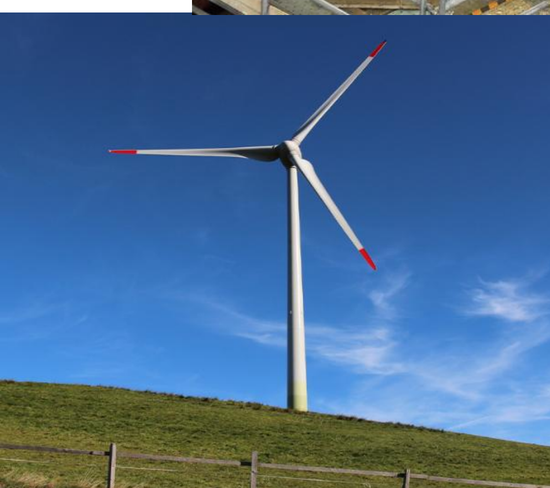
- **Global Fluid Energy Potential**
  - Theoretical: 900 TW (Extractable- 120 TW)
  - Technically Feasible with current technology: 15-20 TW; Currently extracted: 2.8 TW (Wind Energy- 1.2 TW, River Energy: 1.6 TW)
- Huge Global Fluid Energy Potential is **unutilized**
- Research and Development of Future Fluid Machines focus on greater utilization of global Fluid Energy (Wind, Wave, tidal etc.) in efficient way that will **reduce carbon foot print of conventional fossil fuel based fluid machines (Steam Turbine, Gas Turbine etc) leading to sustainable earth.**

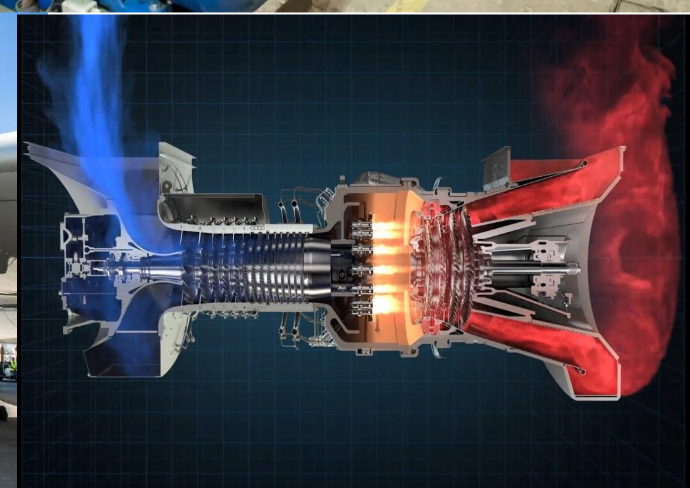
Fluid Machinery

- **Fluid machinery** refers to mechanical devices that utilize fluids (liquids or gases) to transfer energy. These machines either impart energy to a fluid (such as **pumps and compressors**) or extract energy from a fluid (such as **turbines**) .
- Fluid machinery operates based on the principles of fluid dynamics and thermodynamics.
- Fluid machinery is very important in modern civilization in:
  - **Energy Conversion/Power Generation:** Fluid machines like hydraulic and steam turbines play a central role in power generation by converting the energy of flowing fluids into mechanical energy.
  - **Power Transmission:** Fluid Machines like Hydraulic Coupling is used to transmit rotational power from one shaft to another using a fluid medium
  - **Fluid Transport:** Pumps and blowers are vital in moving water, oil, air, and gases in industries, water supply systems, HVAC and irrigation
  - **Industrial Processes:** Fluid machines like compressor are crucial for various industrious processes such as refrigeration, air conditioning, chemical/food processing, pneumatic control systems etc. where pressurized gases are needed
  - **Renewable Energy:** Fluid machinery underpins systems like wind turbines and micro-hydro plants, supporting sustainable power production
  - **Automotive and Aerospace Applications:** Fuel pumps, turbochargers, and jet engines all rely on fluid machines to enhance efficiency and performance
  - **Disaster Response and Safety:** Flood control pumps, firefighting systems, and emergency drainage units protect communities from natural and man-made hazards



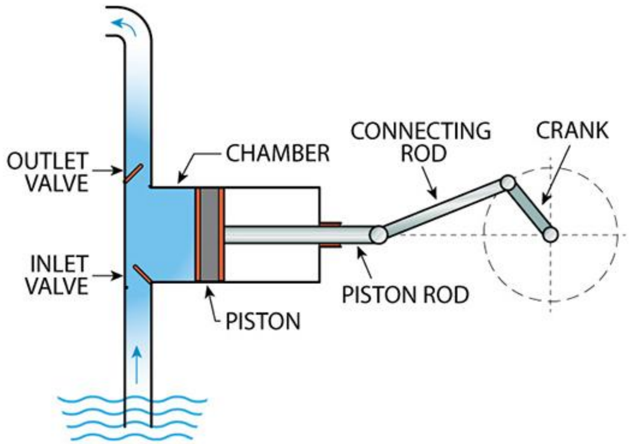






Fluid Machinery: Classification

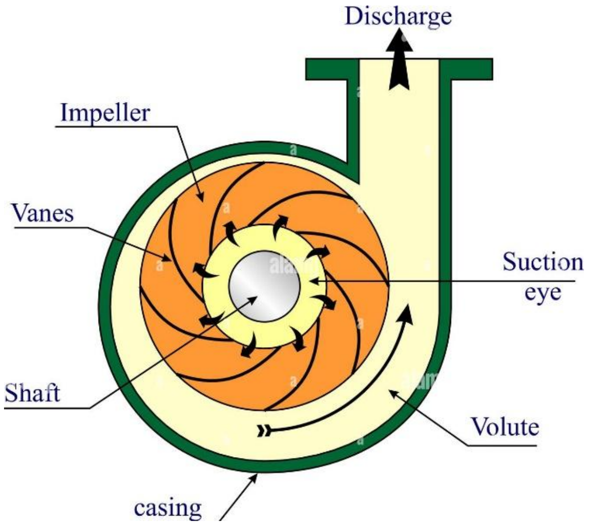
- Based on the **mode of energy transfer** between the machine and the fluid, fluid machines can be broadly classified as:
  - **Turbomachines**
  - **Positive Displacement Machines**



Fluid Machinery: Classification

Turbomachines

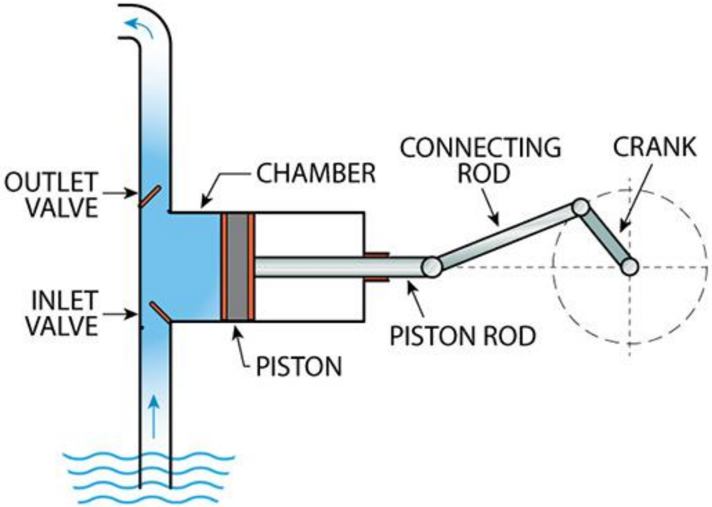
- Turbomachines are dynamic fluid machines that transfer energy **continuously between the fluid and rotating components** (usually rotors or impellers). They are also termed as **"Rotodynamic Machines"** also.
- Energy transfer occurs due to the **change in angular momentum** of the fluid passing through the rotating blades or vanes.
- Features:
  - **Continuous flow of fluid**
  - **High-speed operation**
  - **Suitable for large flow rates**
  - **Less efficient at handling viscous or sludgy fluids**
  - **Example includes:**
    - ✓ **Pumps**: Centrifugal pump, axial-flow pump
    - ✓ **Turbines**: Pelton turbine, Francis turbine, Kaplan turbine
    - ✓ **Compressors**: Centrifugal compressor, axial compressor
    - ✓ **Fans/Blowers:**

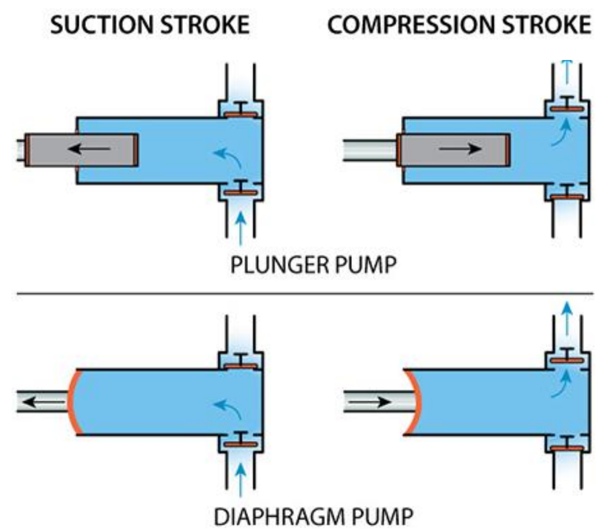


Fluid Machine: Classification

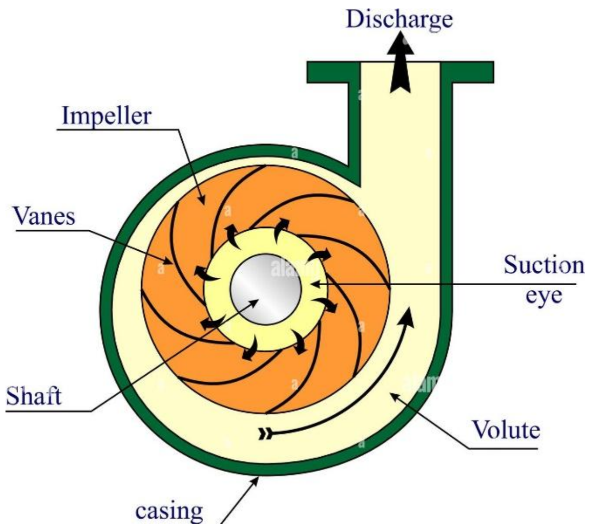
Positive Displacement Machines

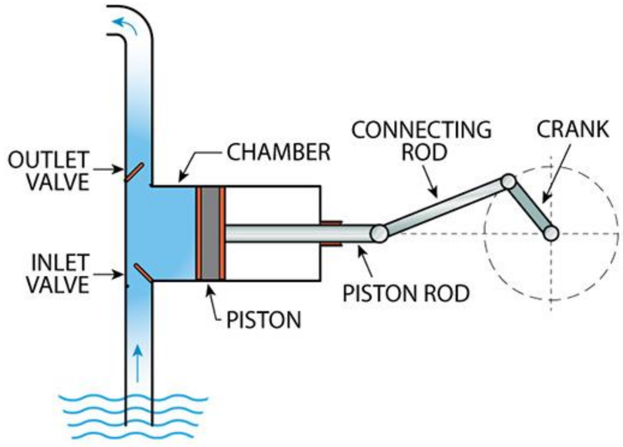
- These machines transfer energy to or from a fluid by **trapping a fixed volume of fluid** and then moving it mechanically through the machine.
- The fluid is displaced by a piston or diaphragm or rotary element, and **pressure is developed by reducing the volume** of the fluid chamber at some stage of the process.
- Features:
  - Intermittent flow (but can be smoothed with multi-cylinder designs)
  - Capable of high pressures
  - Ideal for small flow rates and viscous fluids
  - **Low/Medium speed operation**
  - **Example includes:**
    - ✓ **Reciprocating Pumps**: Piston pump, Plunger Pump, Diaphragm pump
    - ✓ **Rotary Pumps** : Gear Pump, Lobe Pump, Vane Pump, Screw Pump
    - ✓ **Compressors**: Reciprocating Compressor, Rotary Screw compressor, Vane Compressor





Turbo Machine vs. Positive Displacement Machine



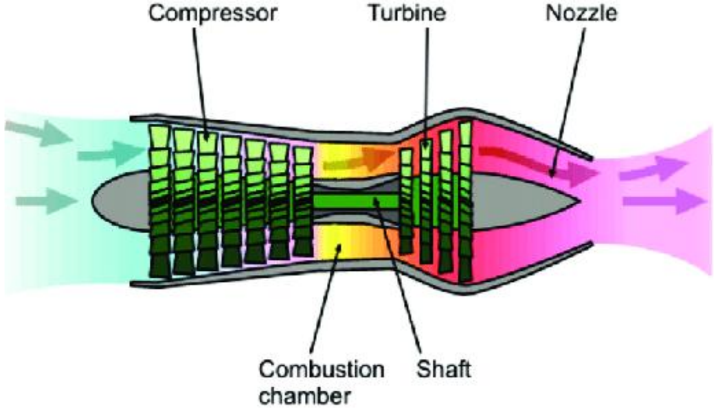


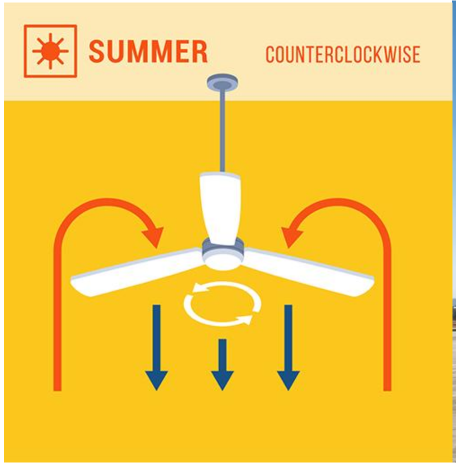
Feature	Turbomachines	Positive Displacement Machines
Energy Transfer Mechanism	Dynamic (via velocity change)	Mechanical (via displacement/volume change)
Flow Type	Continuous	Intermittent
Pressure Range	Moderate	High
Volume Range	High	Low
Efficiency	High for large volumes	High for low flow
Fluid Type	Ideal for clean fluids	Suitable for viscous/slurry fluids

Fluid Machinery: Classification

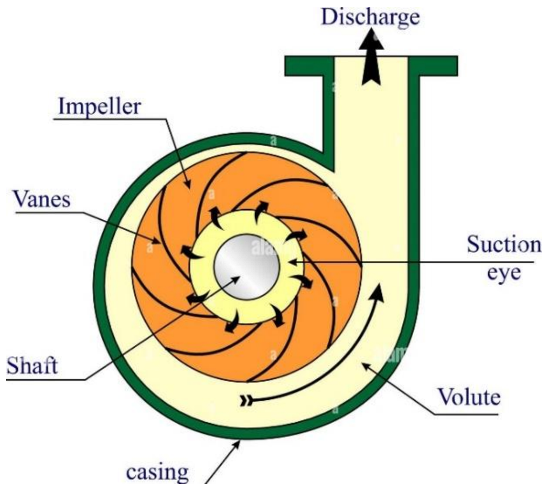
- Based on the **direction of fluid flow relative to the axis of fluid machines:**
  - **Axial Flow Machines:** When fluid flow is parallel to the axis of rotation-Ex.: Ceiling Fan, Horizontal Wind Turbine, Axial Turbo-compressor of Jet Engine
  - **Radial Flow Machines:** When fluid flow is perpendicular to the axis of rotation. Ex.-Centrifugal pumps
  - **Mixed Flow Machines:** When fluid flow has both radial and axial velocity components in the fluid machines. Ex.-Mixed Flow Turbine

Axial Flow Machines

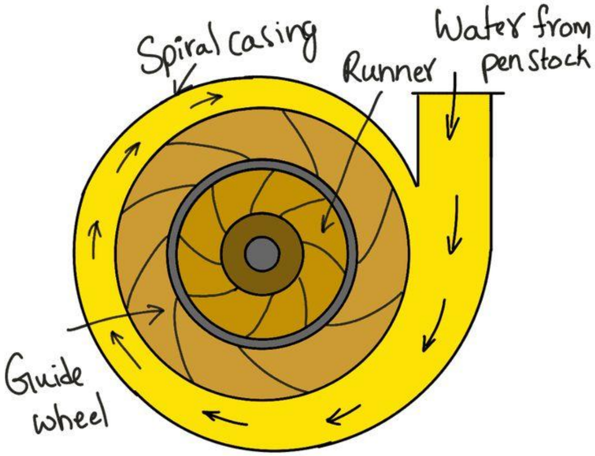




Radial Flow Machines

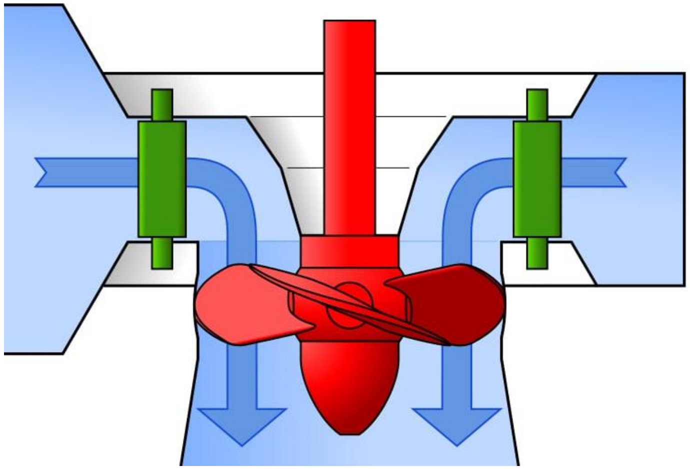


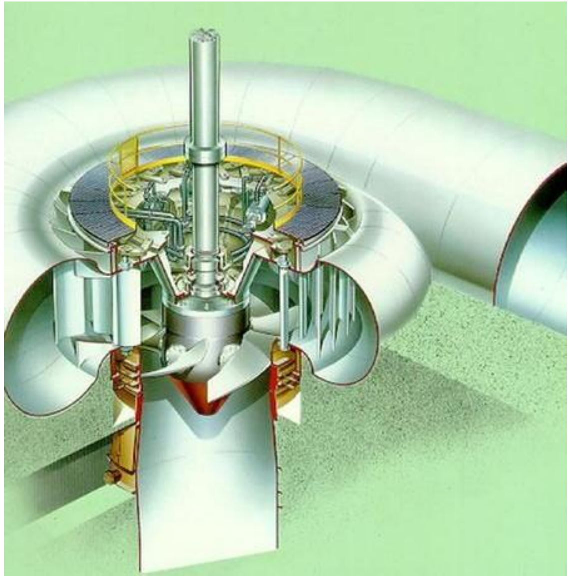
Centrifugal Pump



Radial Flow Hydraulic Turbine

Mixed Flow Machines

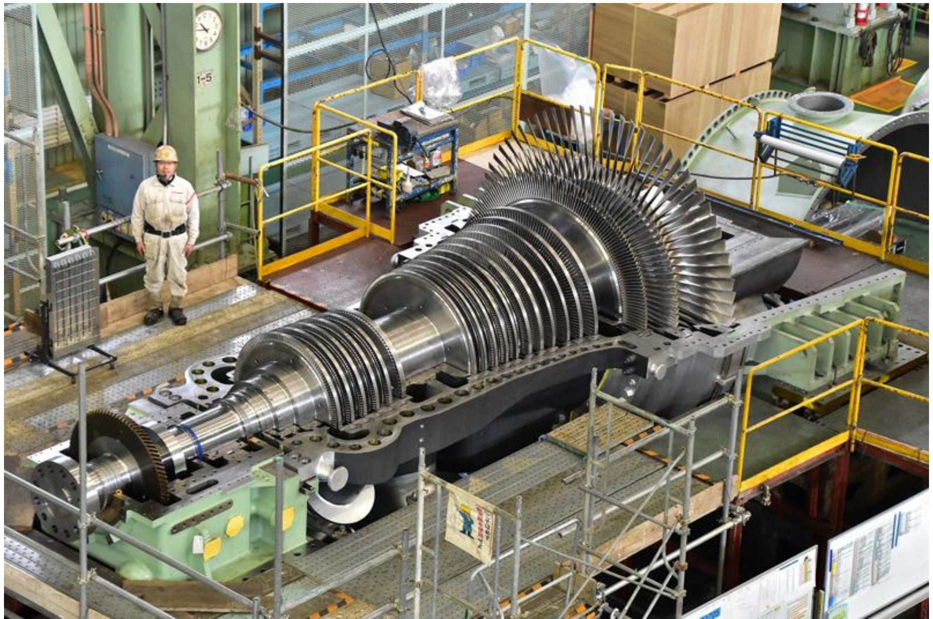




Kaplan Turbine

Fluid Machinery: Classification

- Fluid Machinery can be classified according to the direction of energy transfer between Fluid and Machine
- Those that **extract and convert fluid energy to mechanical energy** (either by momentum transfer or by expansion from high pressure to lower pressure) are called "**Turbine**"
- May be classified based on working fluids as:
  - *Wind Turbine*
  - *Hydraulic Turbine*
  - *Steam Turbine*
  - *Gas Turbine*



Fluid Machinery: Classification

- Those that deliver mechanical energy to fluids. Examples include:
  - Pumps (Deals with liquids)
  - Fans, Blowers and Compressor (Deals with gases)

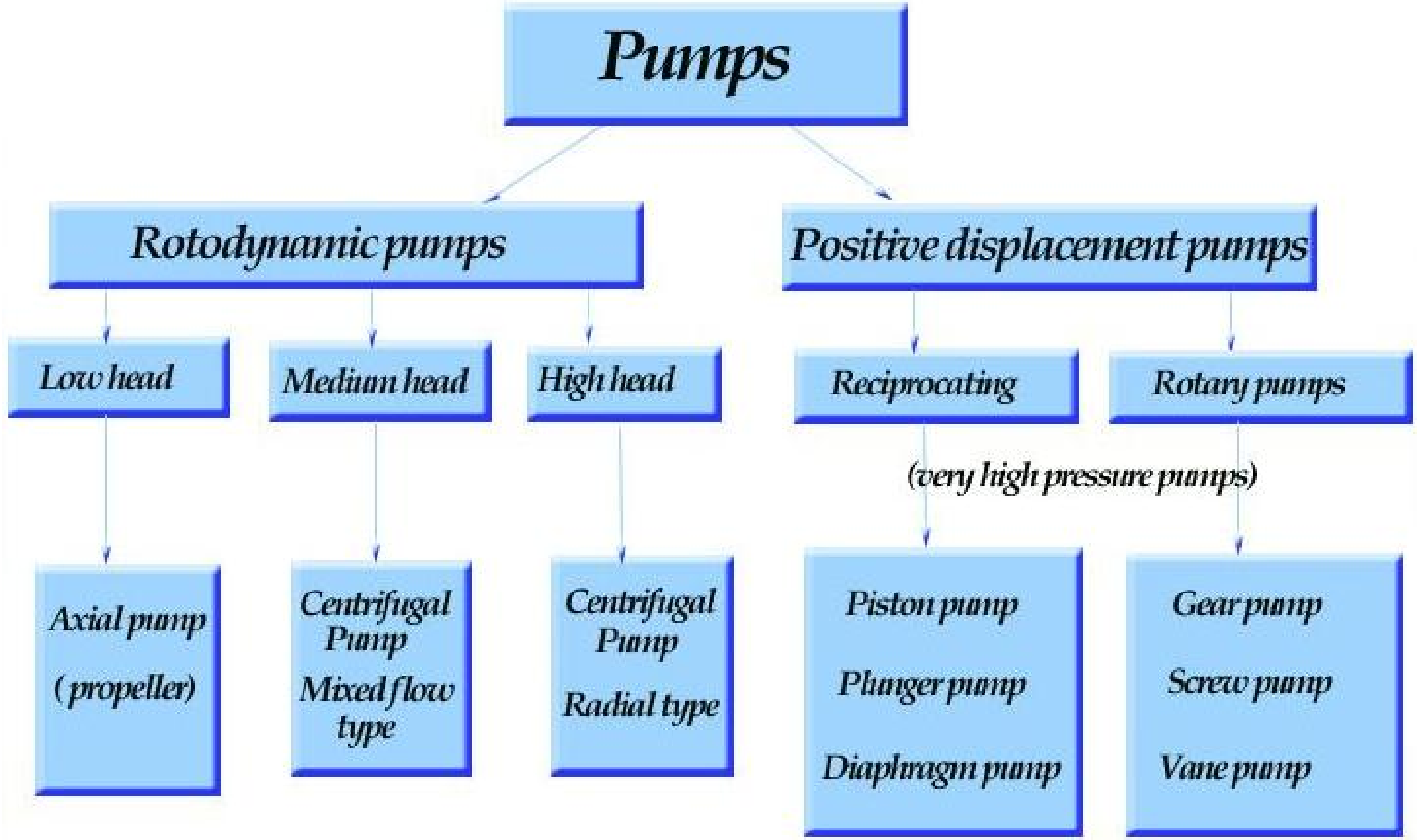




Pumps

- As mentioned earlier, liquids are moved by pumps; gases are moved by fans, blowers, and compressors.
- Pumps are fluid machines which increase the pressure of a liquid, to enable the fluid to be moved from one location (High pressure) to another (Low pressure).
- Pumps are typically used to overcome losses due to friction in pipes over long distances, losses due to fittings, losses due to components, and elevation differences. Typical applications includes:
  - To deliver fluid at a higher elevation or at a long distance.
  - To deliver fluid at a pressurized device
  - For the control of hydraulic systems
  - For drainage system, removing slurries, mud, water
  - For irrigation systems

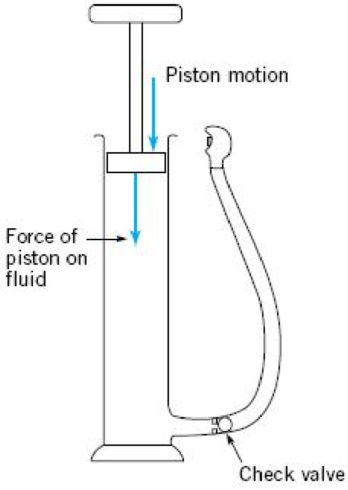
Pumps: Classification



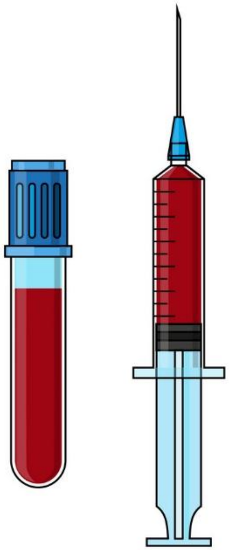
Pumps in daily Life

Centrifugal pump

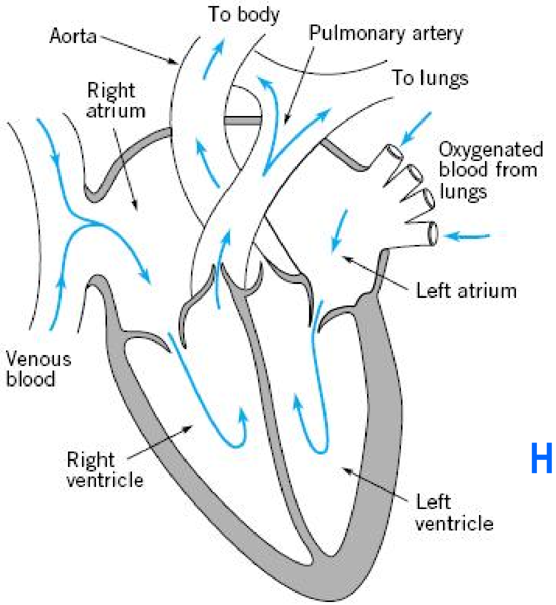
Fuel pump



Plunger/Tire pump



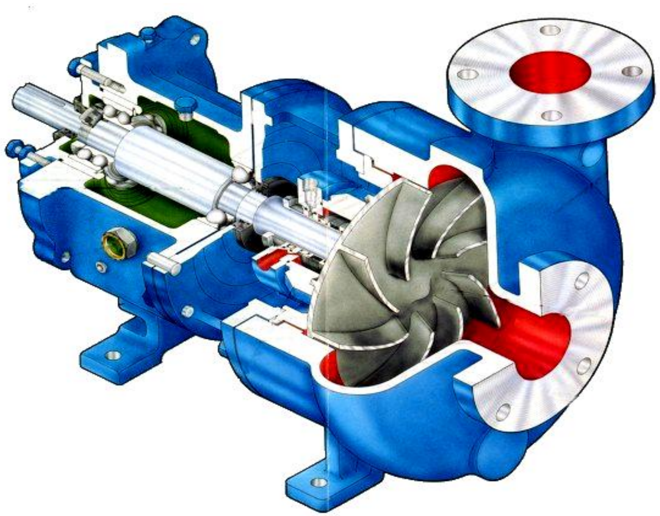
Blood Syringe pump



Human heart

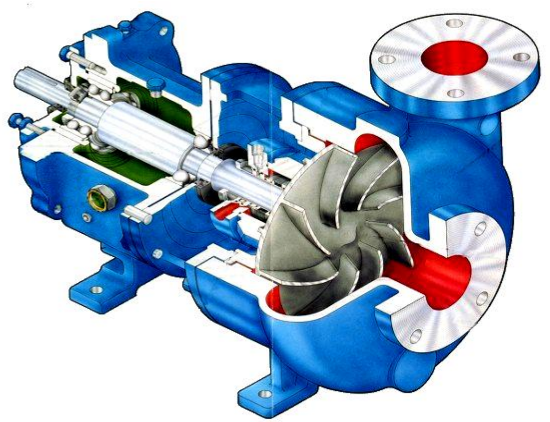
Rotodynamic Pumps

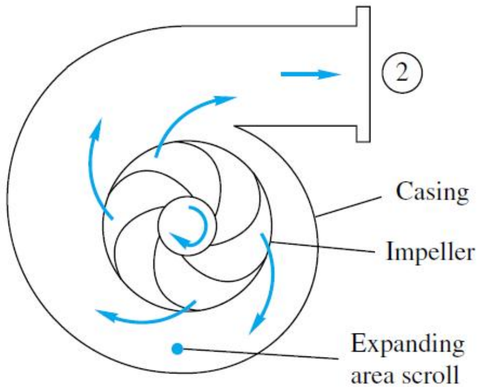
- A **rotodynamic pump** is a type of pump in which energy is continuously added to the fluid by **rotating impellers**, increasing the fluid's velocity and pressure. Unlike positive displacement pumps, they do **not trap** a fixed volume of fluid.
- It is essentially a turbine in reverse.
- Typical examples of Rotodynamic pumps include **Centrifugal pump, Turbine pump and Submersible pump.**
- **Common Features:**
  - Operates at **high speed** with continuous fluid flow.
  - Converts **mechanical energy** (from a motor or engine) into **kinetic and pressure energy** of the fluid.
  - Best suited for **large volume flow rates** with **low to moderate pressure**.
  - Commonly used for **water supply, irrigation, cooling systems, and process industries**.

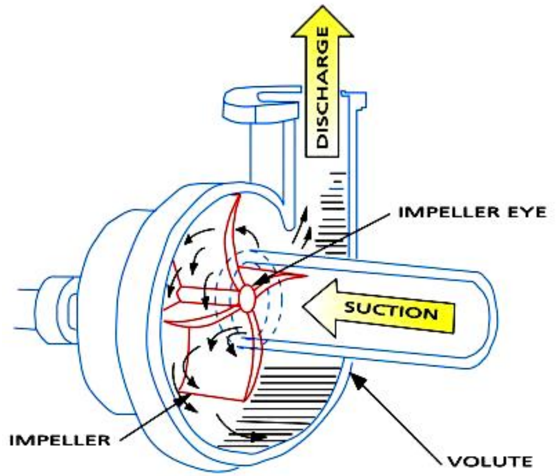


CENTRIFUGAL PUMPS

- Converts kinetic energy to pressure energy employing centrifugal effects.
- These pumps are in use for more than a century.
- Because of certain inherent advantages, such as compactness, smooth and uniform flow, low initial cost and high efficiency, centrifugal pumps are used in almost all pumping systems.
- The impeller is attached to a shaft which is mounted on bearings and is coupled to a motor.
- The fluid enters the pump impeller along or near to the rotating axis through a hole called impeller eye.
- The kinetic energy of the impeller is transmitted to the fluid and its velocity increases.
- So, the fluid is accelerated by the impeller rotation. Fluid flows radially outward into a diffuser or volute chamber.
- By the virtue of its shape, the volute casing converts the kinetic energy of the fluid to pressure energy.
- The high pressure fluid is delivered through the delivery pipe (discharge side).

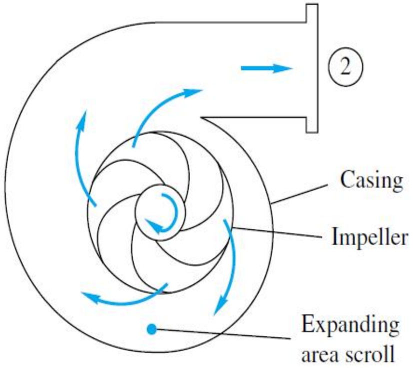






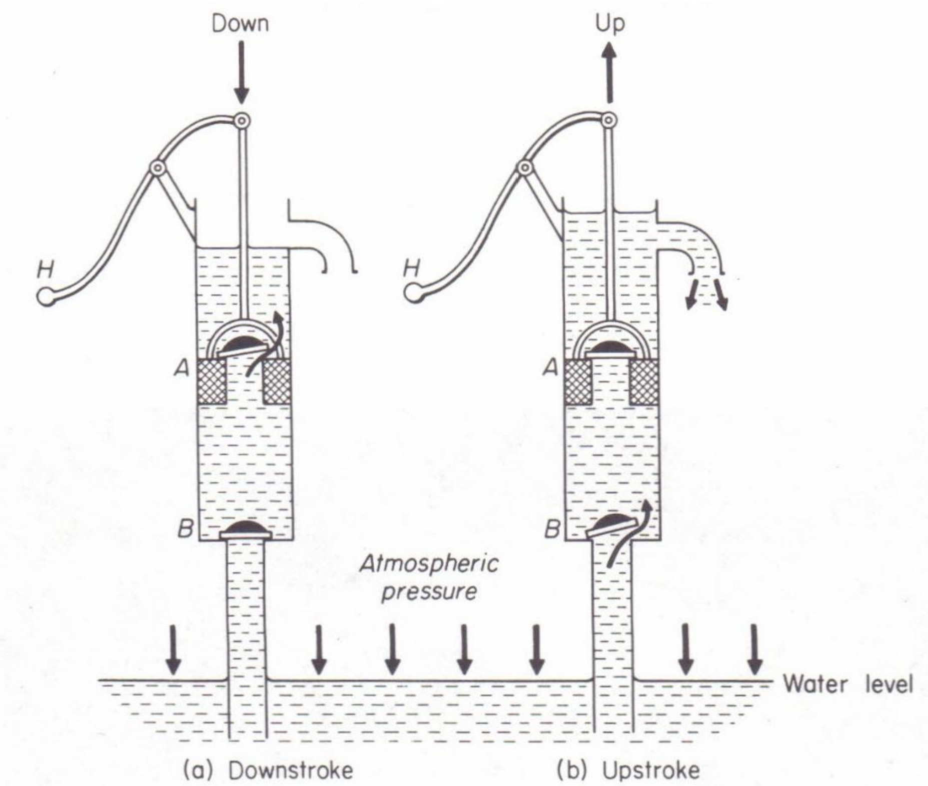
CASING/VOLUTE CHAMBER

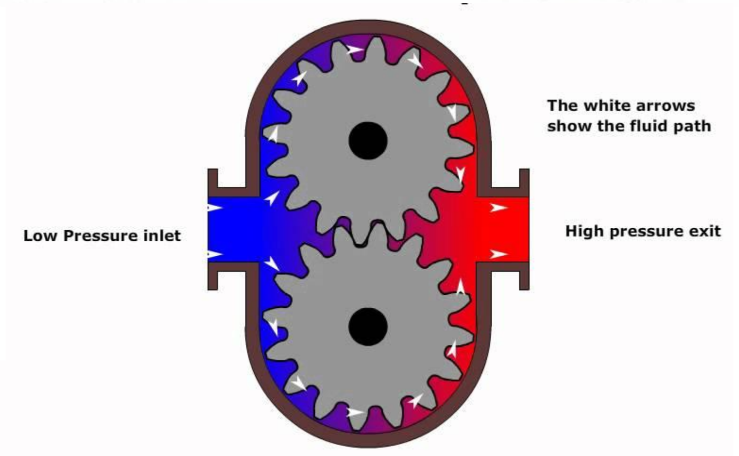
- **Casing (volute chamber)** is an airtight passage surrounding the impeller which **converts the kinetic energy of the fluid into pressure energy.**
  - Water can be raised from one level to a higher level in two ways -
    - **High pressure**
    - **High velocity**
  - **High velocity method is very inefficient** since the friction increases proportionally to the square of the velocity.
  - **High pressure method is efficient** because of low velocity and friction.
  - Volute/Diffuser (Velocity to Pressure Conversion) serve similar to Transformer in Electrical Power Transmission (Current to Voltage conversion)



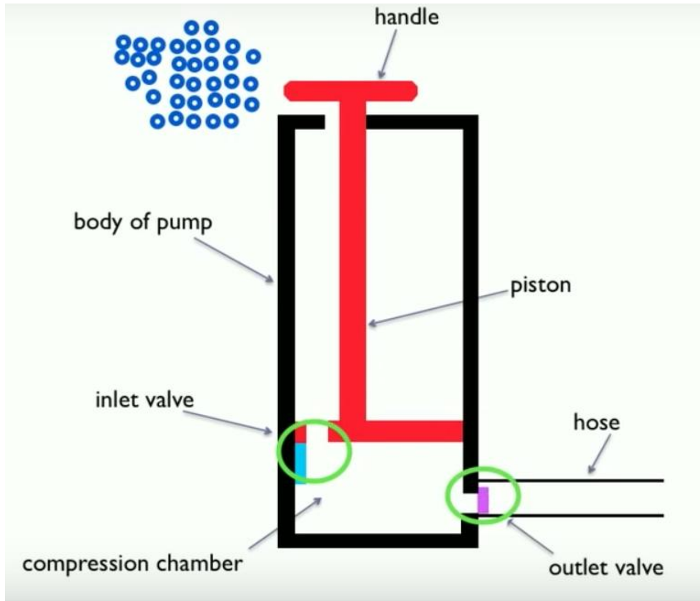
POSITIVE DISPLACEMENT PUMPS

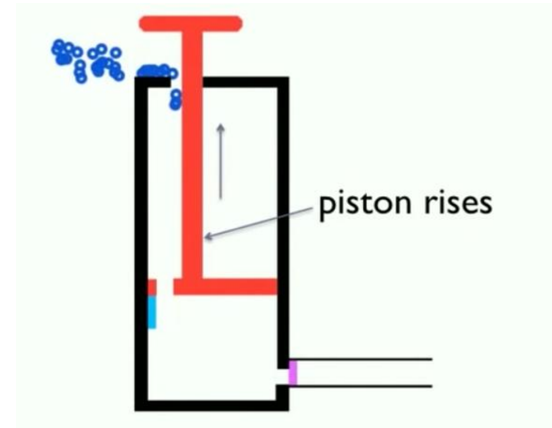
- **Positive displacement** uses **the reciprocating action of one or several pistons**, or **a squeezing action of meshing gears, or other moving bodies**, to displace the fluid from one area into another
- The positive-displacement family of pumps is so named because there is a **direct connection between pump action and liquid motion**, with NO reliance on an uncertain conversion between kinetic energy and pressure.
- **Reciprocating pumps:** the chamber is stationary cylinder that contains a piston or plunger.
- **Rotary pumps:** Gear pump, Lobe pump, Screw pump *etc.*

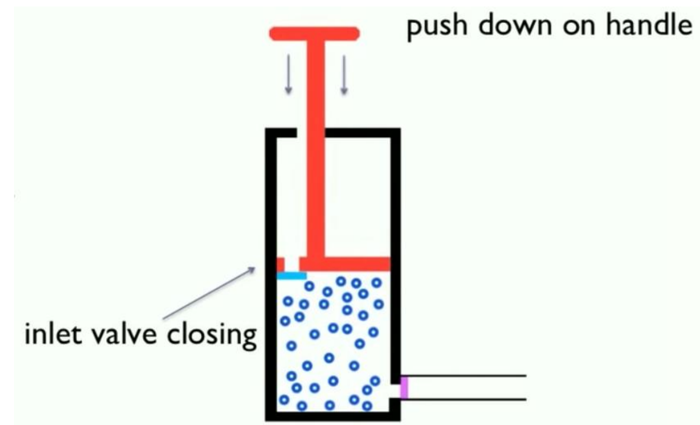




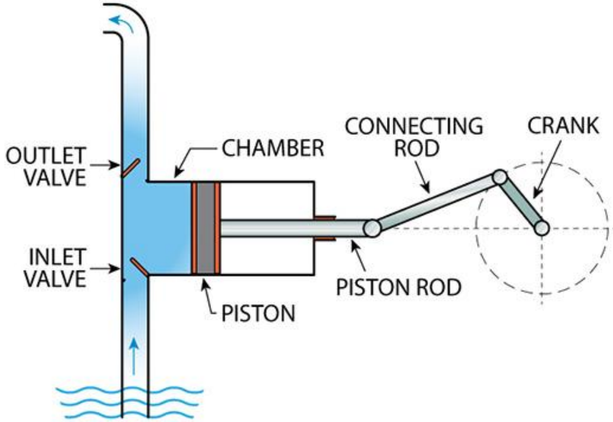
Piston Pump:

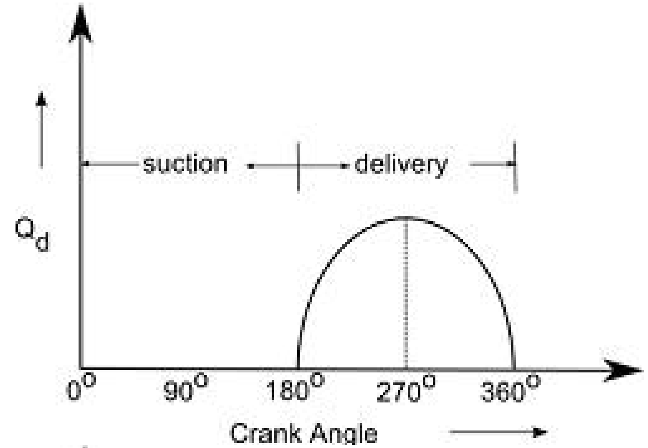


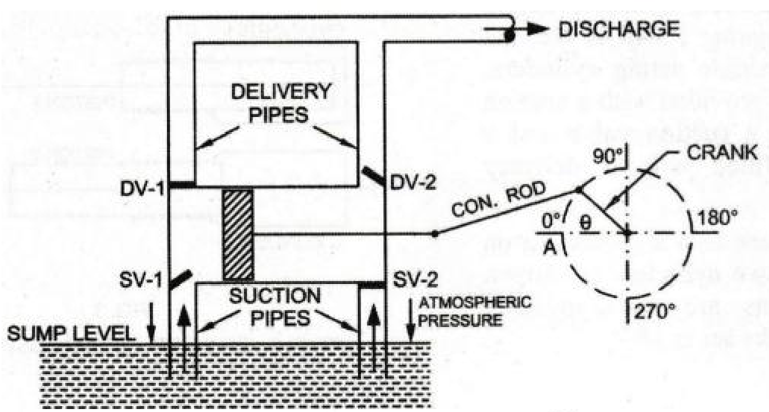


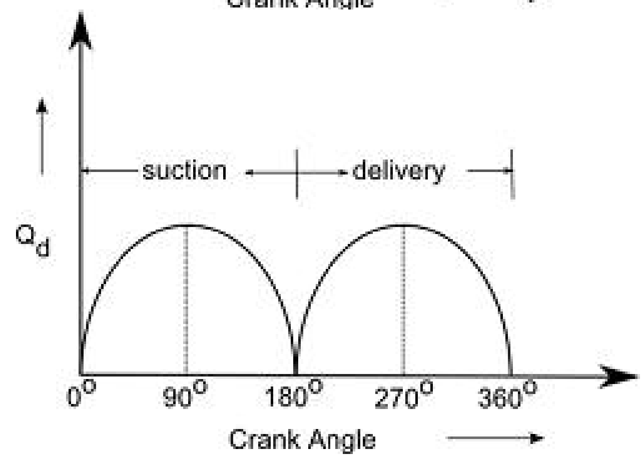


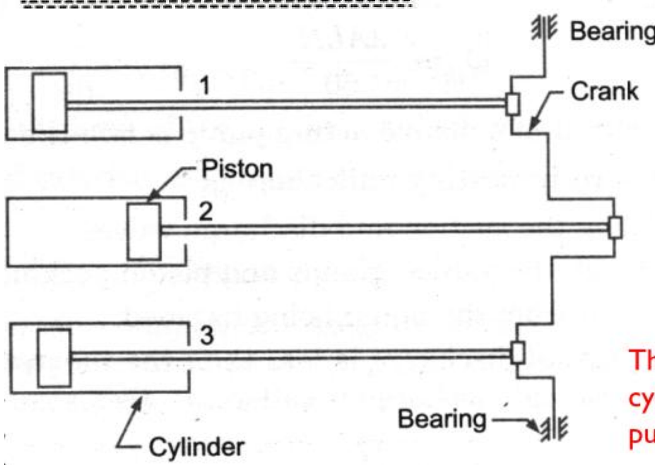
- **When the handle is pushed down**, air is compressed down the tube and then into the tire through the outlet valve
- **When the handle is pulled up again**, the outlet valve closes automatically so that the air cannot escape from the tire and new air is forced sucked into the cylinder through inlet valve.



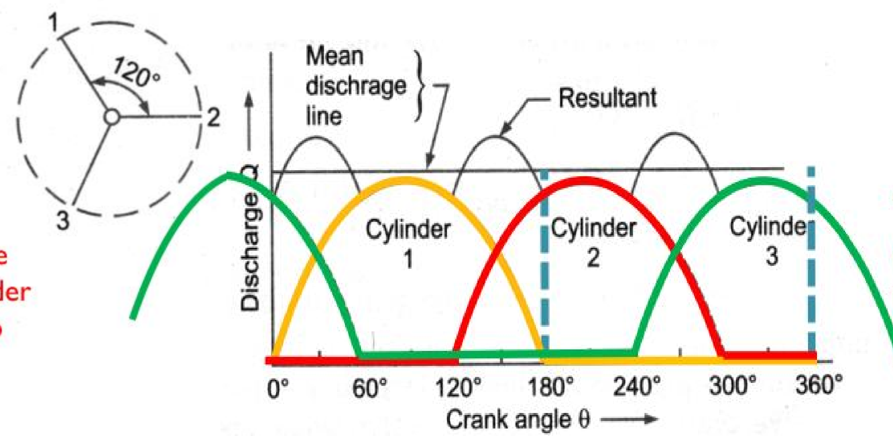








Three cylinder pump

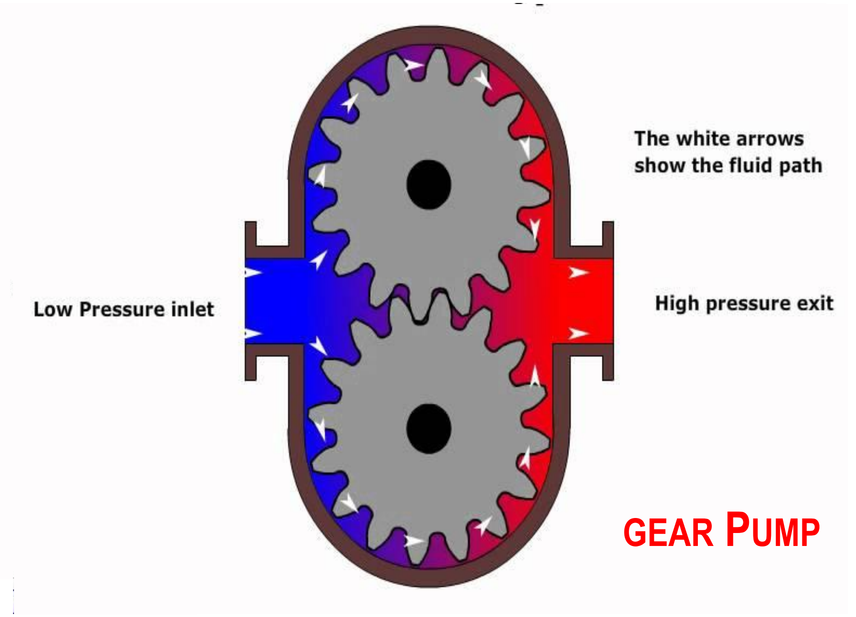


Three cylinder pump

POSITIVE DISPLACEMENT PUMPS: GEAR PUMP, VANE PUMP, SCREW PUMP

Gear Pump

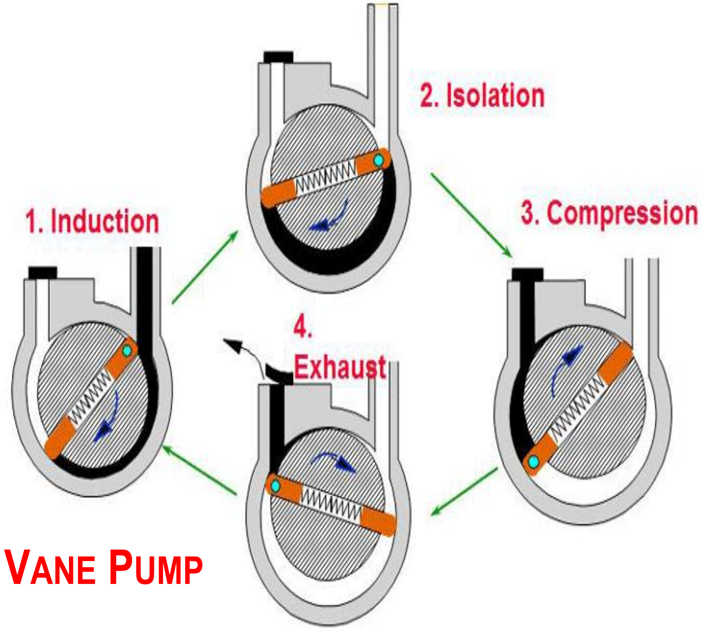
- Gear pumps are primarily used for **high-viscosity liquids**.
- Two or more meshing gears **trap liquid in the space between the gear teeth and the casing wall** and convey it from inlet to outlet.
- Intermeshing gears **rotate with close clearance** inside the casing. Liquid entering the suction line is caught in the **spaces between the teeth and the casing** and is carried around to the other end of the casing and forced out the discharge.
- Gear Pump is self-priming.



Gear Pump

Vane Pump

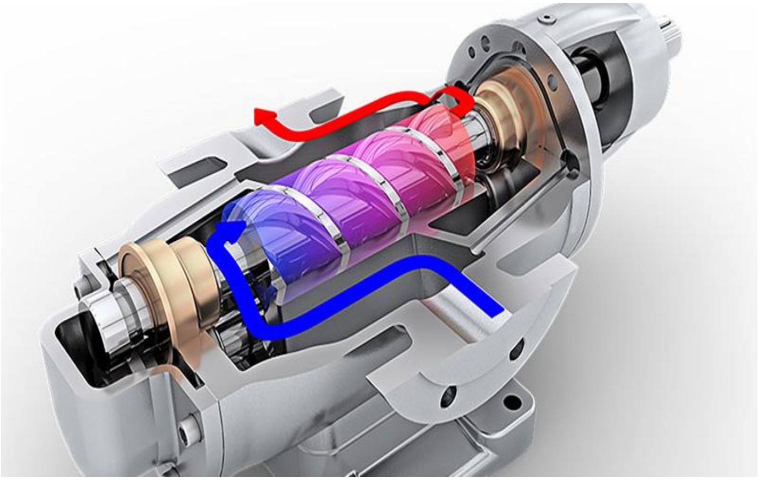
- A disc having sliding vanes in slots, is eccentrically placed in a chamber.
- Liquid is introduced in the chamber that depending on the vane position relative with the inlet port.
- Rotor movement with sliding vane results in contraction of liquid volume therefore pressure rises.
- Liquid at high pressure is discharged through the outlet port depending on the relative position with the outlet port .



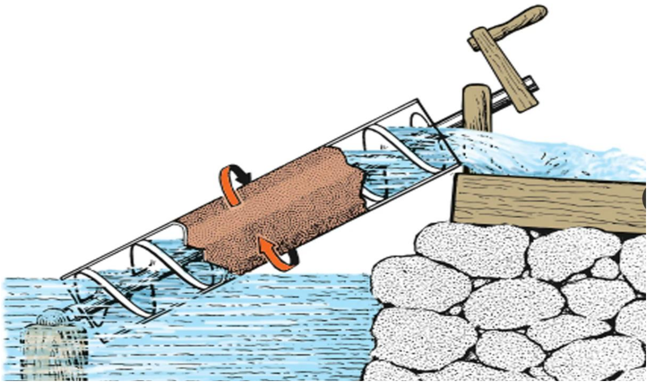
Vane Pump

Screw Pump

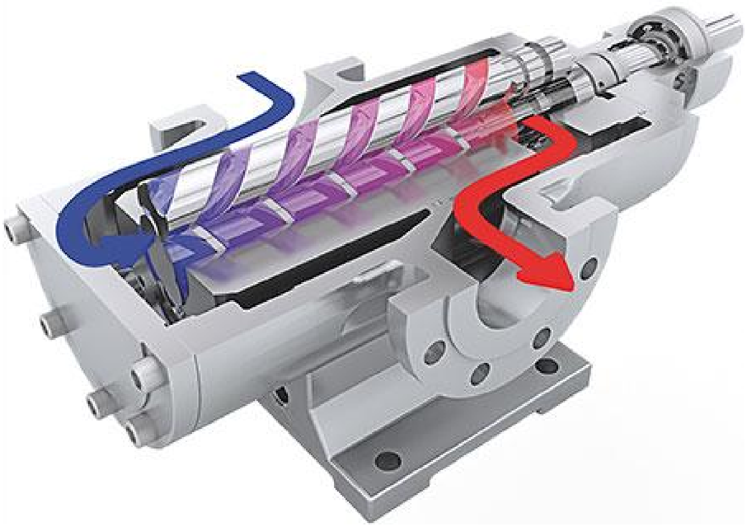
- A screw pump is a positive-displacement rotary pump that uses one or more intermeshing helical screws to move fluids along the screw's axis.
- Fluid enters at the suction side and gets **trapped in pockets between the screw and housing** (Single screw pump) and among screws and housing (Multiple screw pump).
- As the screws rotate, **these pockets advance toward the discharge side**, delivering fluid at a steady flow rate regardless of pressure variations
- Screw pumps excel at smoothly transferring viscous or sensitive fluids with **minimal pulsation and excellent self-priming**



Single-Screw Pump



Archimedes' Screw Pump



Triple-Screw Pump

FAN, BLOWER, COMPRESSOR

- **Compressors, Blowers, and Fans are machines that move and compress gases (Not liquid).**
  - **Fans:**
    - discharge **large volumes of gas** (usually air) into spaces or large ducts
    - are **low-speed machines** that generate very low pressures, on the order of **0.07 atm. (bar)**.
  - **Blowers:**
    - are **high-speed rotary devices** (using either positive displacement or centrifugal force) that develop a max. pressure of about **2-3 atm.** (bar).
  - **Compressors:**
    - are also positive-displacement or centrifugal machines, discharge at pressure from **2 atm. (bar) to several thousands atm. (bar)**

Equipment	Specific Pressure Ratio
Fans	Up to 1.11
Blowers	1.11-1.20
Compressors	More than 1.20

- **Specific Pressure Ratio = Discharge pressure/ Suction pressure**
- **Fans are the low-pressure compressors; blowers are the medium pressure compressors.**

- Fans are used for air circulation in buildings, for ventilation, in automobiles in front of engine for cooling purposes, *etc.*

- Blowers are used in ventilation, power station, workshops etc. Compressors are used in pneumatic control system as well as high pressure applications (5-1000 bars)

Blower

Compressor

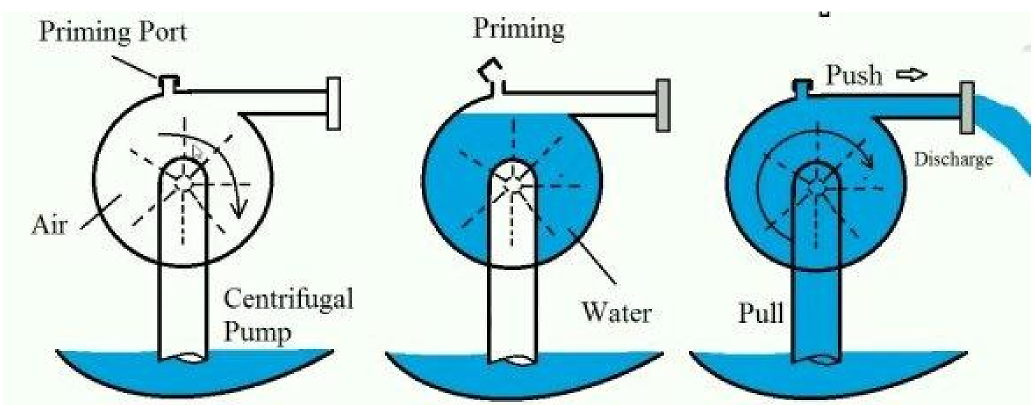
Priming of a Pump

- We often see, pump operator filling the pump with water before starting pump.

- **Priming** is the process of filling the suction pipe, pump casing, and a portion of the delivery pipe with liquid so that all the air, gas, or vapors present in these parts are removed before starting the pump.

- Centrifugal pumps and many other rotodynamic pumps rely on a **pressure difference caused by the centrifugal force** (proportional to the density of the fluid in contact with impeller) developed by the rotating the impeller to draw liquid into the pump and subsequent delivery.

- If air is present in the suction line or casing, the pump cannot create enough pressure difference to lift the water/liquid up to pump impeller, leading to failure to pump liquid (a condition called "**Air Binding**")



Fluid Machinery: Fluid Energy Concept

- **Fluid:** A **fluid** is a substance that can flow and has no fixed shape. May be-
  - **Liquids (fixed volume; unfixed shape)**
  - **Gases (unfixed volume; unfixed shape)**

- Like a solid moving object, flowing fluids possess kinetic energy and poten elevation in the gravity field respectively. In addition to these, it posses ano **energy/ flow work**.

- In dealings fluids and fluid machinery, it is important to know how **to quantify fluid energy content/level.** Usually fluid energy is quantified on the basis of **unit volume**.



Fluid Machinery: Fluid Energy Components

- **Specific Weight of Fluid**:

  In comparing air waves in land on a windy day and that of water waves in sea, you can easily understand the scale of variation in fluid energy level and it is very much related to its density if all other conditions are same. An important fluid property in context to energy content is the **specific weight** (γ) that is **density times gravitational acceleration** (ρg)

- **Fluid flow rate (Q)**:

  Another important parameter related to fluid energy is the **volumetric flow rate** that is the rate of movement of fluid from one place to another expressed in volume unit per unit time.

- **Head (H)**: represents the **energy content per unit weight of fluid**, expressed in meters. It comprises:
  - **Pressure Head**: Energy due to fluid pressure (P)
  - **Velocity Head**: Energy due to Fluid motion (V)
  - **Elevation Head**: Energy due to fluid elevation above a reference point (Z)

- **Bernoulli's Equation:** for incompressible frictionless flow, Total energy is constant:

$$Total\ Head,\ H_T = \frac{P}{\gamma} + \frac{V^2}{2g} + Z = Constant$$

Fluid Energy Concept: The Bernoulli's Equation

$$For\ solid : T.E.(m, v, g, z)$$

$$K.E = \frac{1}{2}mv^2; \quad P.E = mgz$$

$$T.E = K.E + P.E = \frac{1}{2}mv^2 + mgz = Const$$

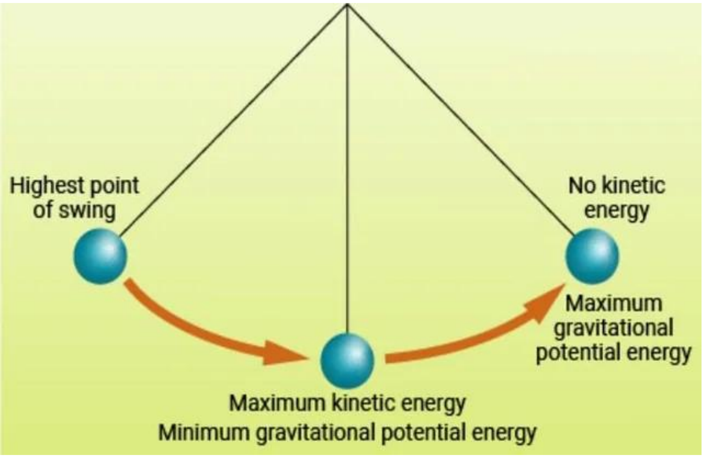
$$T.E.\ Per\ unit\ weight : \left(\frac{1}{2}mv^2 + mgz\right)\Big/mg; \quad \frac{v^2}{2g} + z = Const$$

$$For\ Fluid\ \ T.E.(P, V,\ \rho, v, g, z);$$

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}\rho V v^2$$

$$P.E. = mgz = \rho V g z;$$

$$\Pr esssure\ \ E. = PV = P\frac{m}{\rho}$$



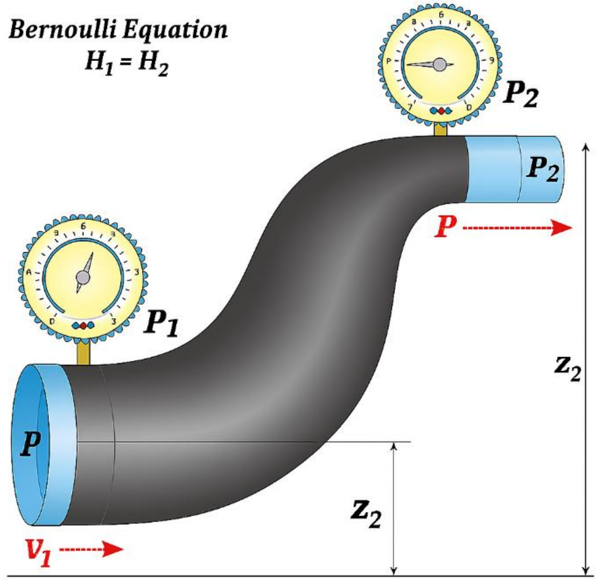
$$Bernoullies\ Equation\ For\ Ideal\ Fluid\ Flow:$$

$$T.E.\ per\ unit\ weight\ of\ \ Fluid, H_T = Const$$

$$(K.E. + P.E. + \Pr.E.)/mg = Const$$

$$\left[P(m/\rho) + (1/2)mv^2 + mgz\right]/mg = Const$$

$$H_T = \frac{P}{\rho g} + \frac{v^2}{2g} + z = Const$$



$$Bernoullies\ Equation:$$

$$H_T = \frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 = Const$$

Fluid Machinery: Power Concept

- **Bernoulli's Equation:** for incompressible frictionless flow, Total energy is constant:

$$Total\ Head, H_T = \frac{P}{\gamma} + \frac{V^2}{2g} + Z = Constant$$

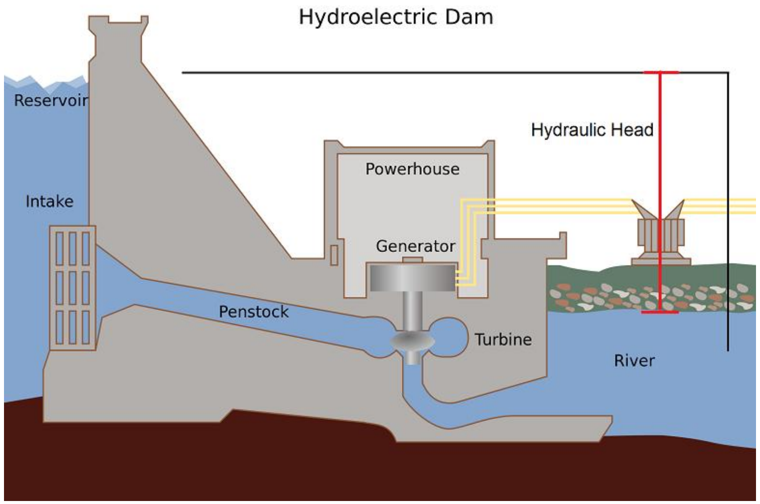
- **Power (P_f)**: Energy transfer from fluid to machine or machine to fluid causes a change in Head or energy content in the fluid (ΔH).

- Time rate of energy transfer to/from fluid called **Fluid Power (P_f)**. It can be estimated as:

$$P_f = \gamma Q \Delta H$$

- **Mechanical Power** associated with the shaft of the fluid machine is called Mechanical Power, P_m and can be estimated as the product of shaft Torque and rotational speed:
  - Shaft Power, P_m = Torque, (T)× Angular Speed (ω)

$$\omega = \frac{2\pi N}{60};\ N : Rotational Speed\ in\ r.p.m$$



Fluid Machinery: Efficiency Concept

- Efficiency of any system is defined by: **System Output or performance/ Input requirement or effort**
- Fluid Machines might be assumed a series of the following blocks
  - **Electric Motor-Impeller Shaft-Fluid** (Power conversion direction: from motor to fluid)
  - **Electric Generator –Turbine Shaft-Fluid** (Power conversion direction: from fluid end to generator)
- Ratio of Fluid Power (P_F) and Mechanical Power (P_M) is called Hydraulic Efficiency, η_h:

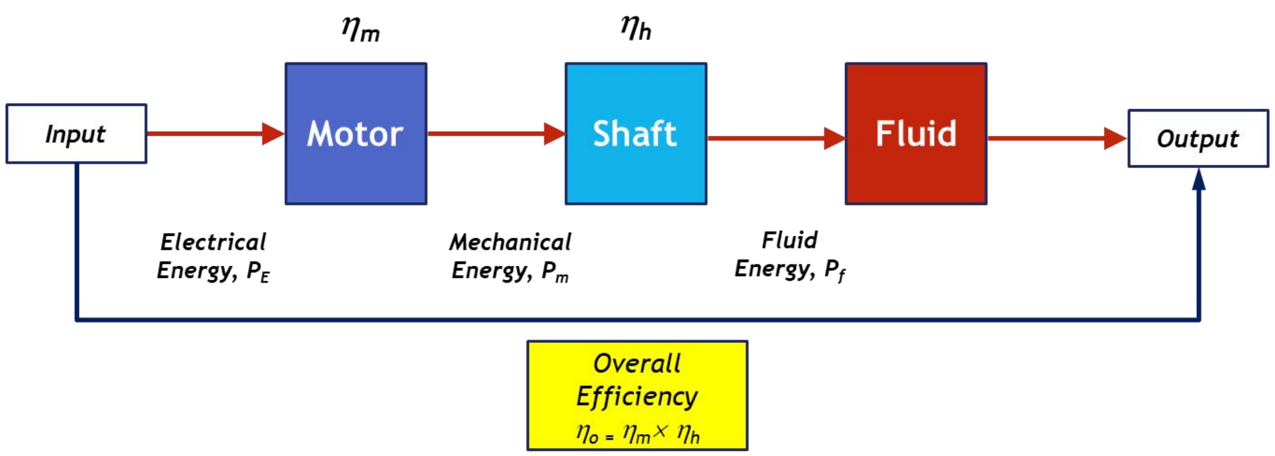
$$\eta_h = P_f / P_m = \gamma Q \Delta H / T\omega$$

- Ratio of Mechanical Shaft Power (P_M) to Motor Electrical Power (P_E) and is called Mechanical Efficiency, η_m:

$$\eta_m = P_m / P_E$$

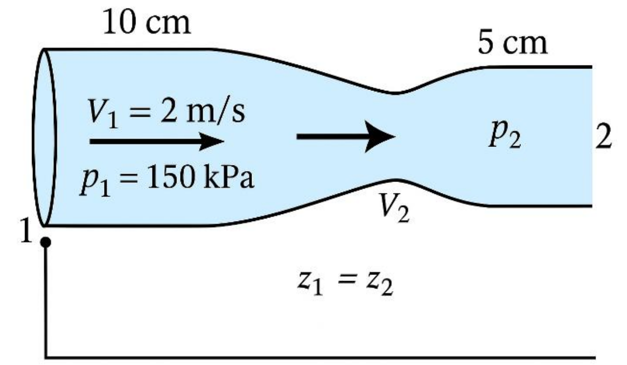
- For consecutive power conversion in different systems connected in series configuration, the overall efficiency, η_O:

$$\eta_O = \eta_m \times \eta_h$$



Problem # 1

Water is flowing steadily through a horizontal pipe that narrows from a diameter of **10 cm** to **5 cm**. At the wider section (Point 1), the velocity of water is **2 m/s**, and the **pressure is 150 kPa**.
Determine the **pressure at the narrow section (Point 2)** using Bernoulli's Equation. Assume the pipe is **horizontal**, the flow is **incompressible and frictionless**, and the **density of water is 1000 kg/m³**. Assume steady, incompressible, inviscid flow.



- $D_1 = 0.10\,\mathrm{m}$
- $D_2 = 0.05\,\mathrm{m}$
- $V_1 = 2\,\mathrm{m/s}$
- $P_1 = 150\,\mathrm{kPa} = 150{,}000\,\mathrm{Pa}$
- $\rho = 1000\,\mathrm{kg/m^3}$

$$A_1V_1 = A_2V_2 \quad \Rightarrow \quad V_2 = \frac{A_1}{A_2}V_1$$

$$A_1 = \frac{\pi D_1^2}{4} = \frac{\pi(0.10)^2}{4} = 7.85\times10^{-3}\,\mathrm{m}^2$$

$$A_2 = \frac{\pi D_2^2}{4} = \frac{\pi(0.05)^2}{4} = 1.96\times10^{-3}\,\mathrm{m}^2$$

$$V_2 = \frac{7.85\times10^{-3}}{1.96\times10^{-3}}\times 2 = 4\times 2 = 8\,\mathrm{m/s}$$

As per the Bernouli's Eqn.:

$$H_T = \frac{P}{\gamma} + \frac{V^2}{2g} + Z = Constant$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2$$

$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} \quad (Z_1 = Z_2)$$

$$\frac{P_2}{\gamma} = \frac{P_1}{\gamma} + \frac{V_1^2}{2g} - \frac{V_2^2}{2g} = \frac{P_1}{\gamma} + \frac{1}{2g}\left(V_1^2 - V_2^2\right)$$

$$P_2 = P_1 + \frac{\gamma}{2g}\left(V_1^2 - V_2^2\right) = P_1 + \frac{\rho g}{2g}\left(V_1^2 - V_2^2\right)$$

$$P_2 = P_1 + \frac{\rho}{2}\left(V_1^2 - V_2^2\right)$$

$$= 150*10^3 + \frac{1000}{2}\left(2^2 - 8^2\right)Pa = 120*10^3\ Pa = 120\,kPa$$

Problem # 2

- A farmer runs a centrifugal water pump for 8 hours per day, 30 days in a month to irrigate his field.

  Given:

  - Pump flow rate $Q = 0.02\ m^3/s$
  - Suction lift $h_s = 3$ m
  - Delivery head $h_d = 20$ m
  - Frictional head loss $h_f = 2$ m
  - Overall hydraulic efficiency $\eta_h = 70\%$
  - Mechanical efficiency $\eta_m = 90\%$
  - Electricity rate: 12 BDT per kWh

- Calculate the monthly electricity bill.

$$P_H = \gamma Q H_T = \rho g Q H_T$$

$$\rho = 1000\, kg/m^3;\ g = 9.81\, m/s^2$$

$$Q = 0.02\, m^3/s;\ H_T = (3+20+2) = 25\, m$$

$$P_H = 1000 \times 9.81 \times 25 \times 0.02 = 4.905\ kW$$

$$\eta_h = 0.7;\ \eta_m = 0.9;$$

$$\eta_o = \eta_h \eta_m = 0.7 \times 0.9 = 0.63$$

$$\eta_o = \frac{Hydraulic\ Power}{Input\ power} = \frac{P_H}{P_{in}} = 0.63$$

$$P_{in} = \frac{4.905\ kW}{0.63} = 7.79\, kW$$

$$Energy\ Consumtion\ @\ 8 Hrs, 30\ Day\ month:$$

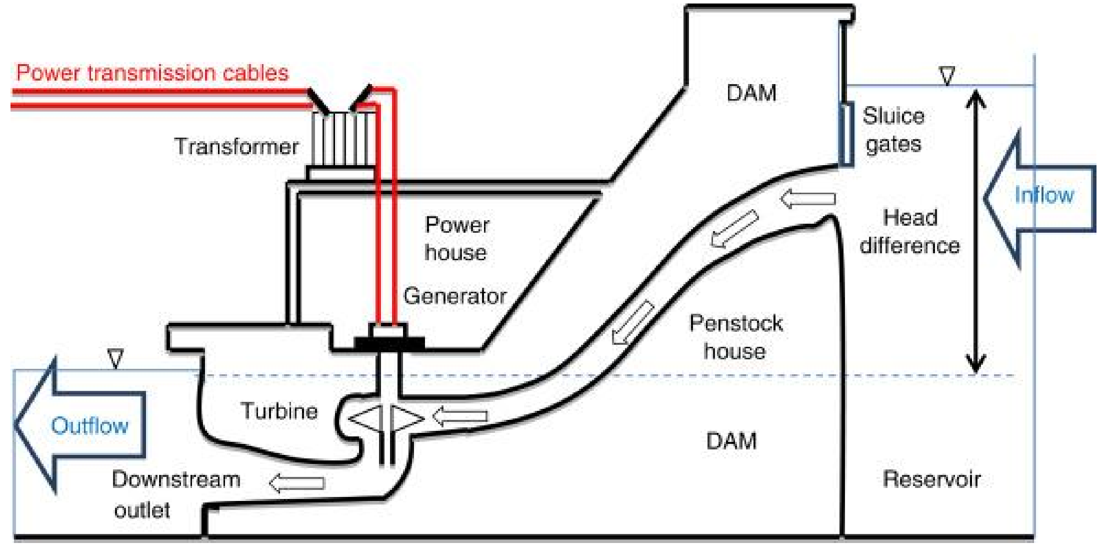
$$E = 7.79 \times (8 \times 30)\, kW.h = 1869.6\, kWh$$

$$Energy\ Bill\ @\ 12\ BDT\ per\ kWh:$$

$$Bill: 1869.6\, kWh \times \frac{12\ BDT}{kWh} = 22435.2\ BDT$$

Problem # 3

- Consider the Power Generation of a Hydraulic Turbine running at 145 m Gross Head rate and 75 m³/s water flow rate. If the Turbine Shaft rotates at 3000 rpm and the Shaft Torque is measured to be 3×10^5 N.m,
  - Calculate Hydraulic Power and Shaft Mechanical Power
  - What is the Hydraulic Efficiency, η_H?
  - If the Shaft is connected to a Generator with a Generator efficiency, η_G = 95%, what will be the generator output power?



$$P_H = \gamma Q \Delta H = \rho g Q \Delta H$$

$$\rho = 1000\,kg/m^3;\ g = 9.81\,m/s^2$$

$$Q = 75\,m^3/s;$$

$$\Delta H = 145\,m$$

$$P_H = 1000\times9.81\times75\times145 = 106.68\,MW$$

$$P_M = T\omega = T\times\frac{2\pi N}{60} = \frac{3.0\times10^5\times2\pi\times3000}{60}$$
$$= 94.24\,MW$$

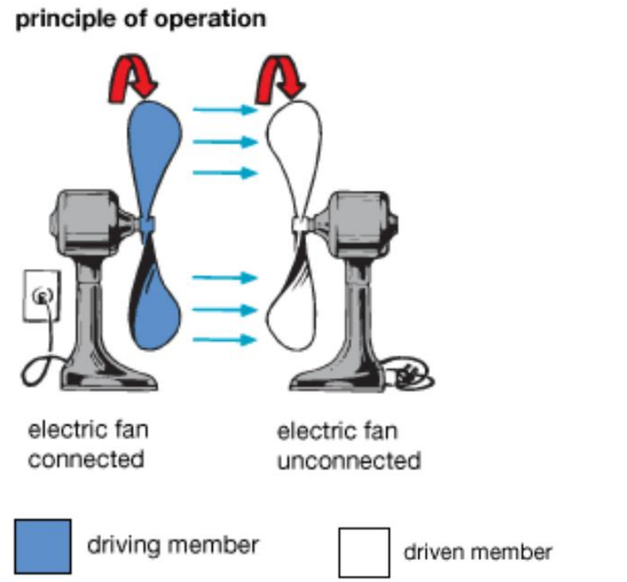
$$\eta_H = \frac{Shaft\ Mechanical\ Power, P_M}{Hydraulic\ Power, P_H} = \frac{94.24\,MW}{106.68\,MW} = 88.33\%$$

$$\eta_G = \frac{Generator\ Output\ Power, P_G}{Shaft\ Mechanical\ Power, P_M}$$

$$0.95 = \frac{P_G}{94.24\,MW};\quad P_G = 89.5\,MW$$

Fluid Machinery: Fluid/Hydraulic Coupling

- Fluid coupling is also known as hydraulic coupling.
- It is a hydrodynamic device that is used to transfer rotational power from one shaft to another by the use of transmission fluid.
- It is used in the automotive transmission system, marine propulsion system, and in industries for power transmission.



- Main Components:
  - Housing / Casing
    Fully encloses the working fluid and internal rotors.
  - Impeller/Pump Wheel (Driving Member)
    Connected to the input shaft (e.g., engine or prime mover).
    Blades propel fluid outward by centrifugal force
  - Turbine (Driven Member)
    Mounted on the output shaft.
    Fluid from the impeller strikes its blades, creating torque and rotation
  - Fluid (usually Mineral Oil)
    Fills the casing, transmitting energy through inertia and momentum.
  - Bearings & Seals
    Support the shafts (Pump/Turbine) and prevent fluid leakage