Systems In Mechanical Engineering

Unit 1

Energy Sources & its conversion

Mr. Girish G Khope

- Which are the available Energy Sources?

Conventional Energy

Non-Renewable Energy

e.g. Coal
Nuclear energy
Petroleum products
Natural Gas

Non-Conventional Energy

Renewable Energy

e.g. Solar energy
Wind energy
Ocean energy
Thermal energy
Tidal energy
Geothermal energy

Power Plants

- Power Plants plays important role in various areas like in Process Industries, Agriculture, Transportation, Human Comfort.

- This power is produced from various available energy sources.

Various Power Plants

- Thermal Power Plant *(Steam Power Plant)*
- Nuclear Power Plant
- Hydroelectric Power Plant
- Solar Power Plant
- Wind Power Plant
- Solar-Wind Hybrid Power Plant

Thermal Power Plant

- *Introduction*
- *Representation*
- *Working*
- *Energy Conversions*
- *Advantages*
- *Disadvantages*
- *Location of Thermal Power Plants*

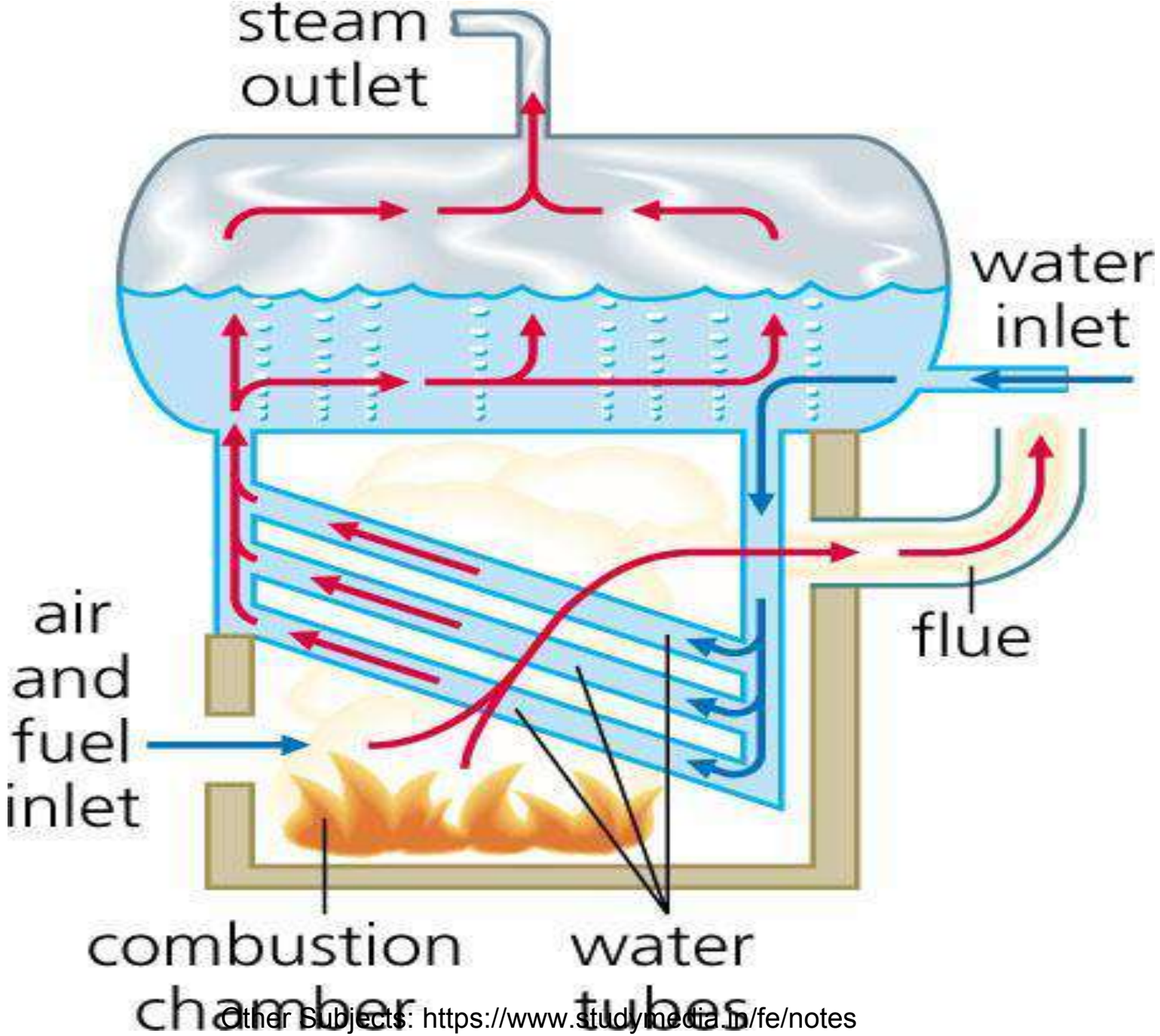
• *Introduction*

- *Steam* is used as *Working Fluid*.

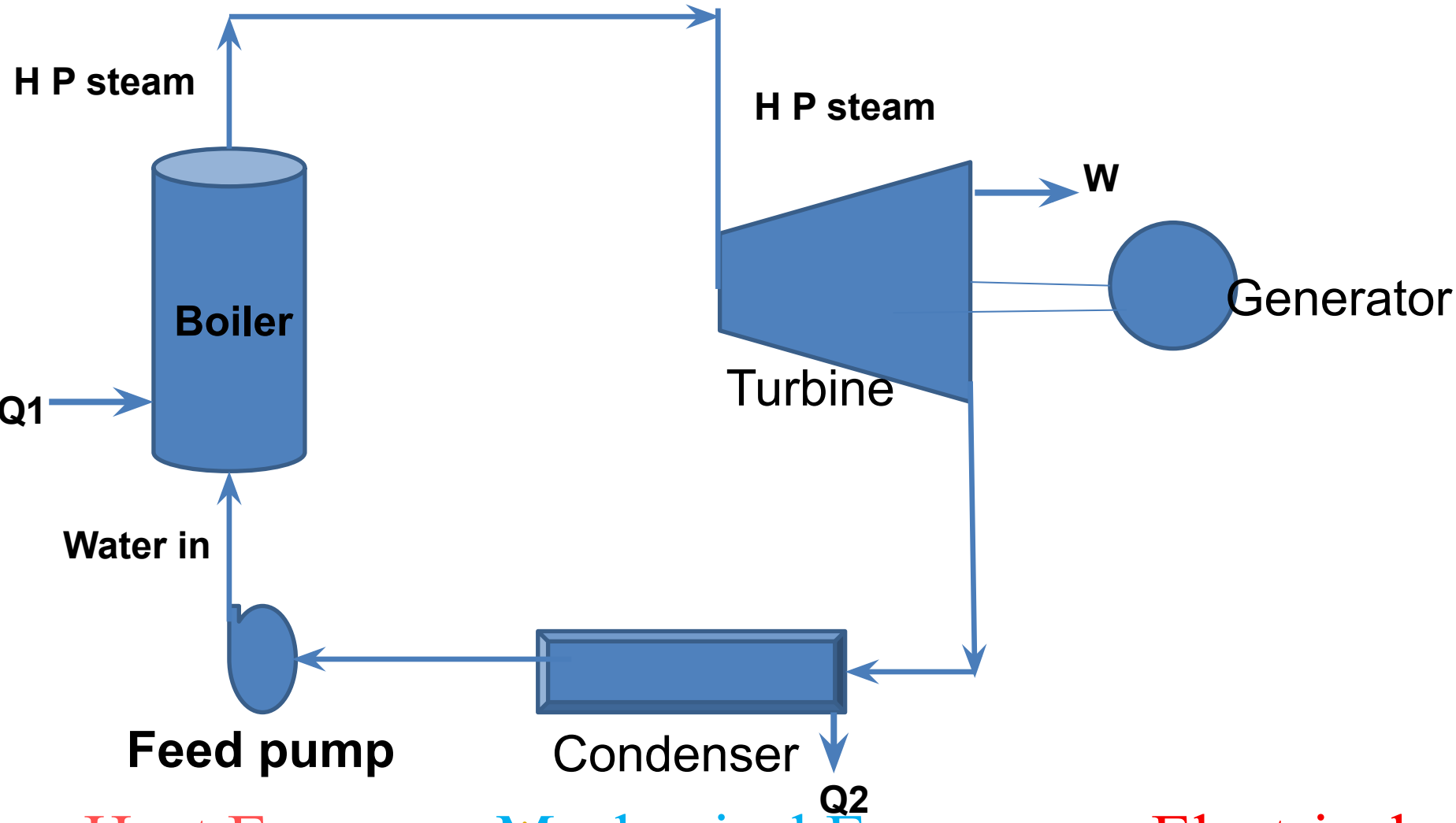
- *Heat* is converted into *Mechanical Energy* which further converted into *Electrical Energy*.

Heat Energy → Mechanical Energy → Electrical Energy

- *Steam* is produced in the *Boiler* & is used to drive the *Steam Turbine* which is coupled with a *Generator*.



Block Diagram of Thermal Power Plant



Heat Energy → Mechanical Energy → Electrical Energy

1. Boiler:-

- Used to generate high pressure and high temperature steam.
- For better efficiency boiler consist of superheater , economiser & Preheater.

2.Steam Turbine:-

- It converts high pressure and high temperature steam supplied by boiler into shaft work and low temperature steam is exhausted to a condenser.

3. Generator:-

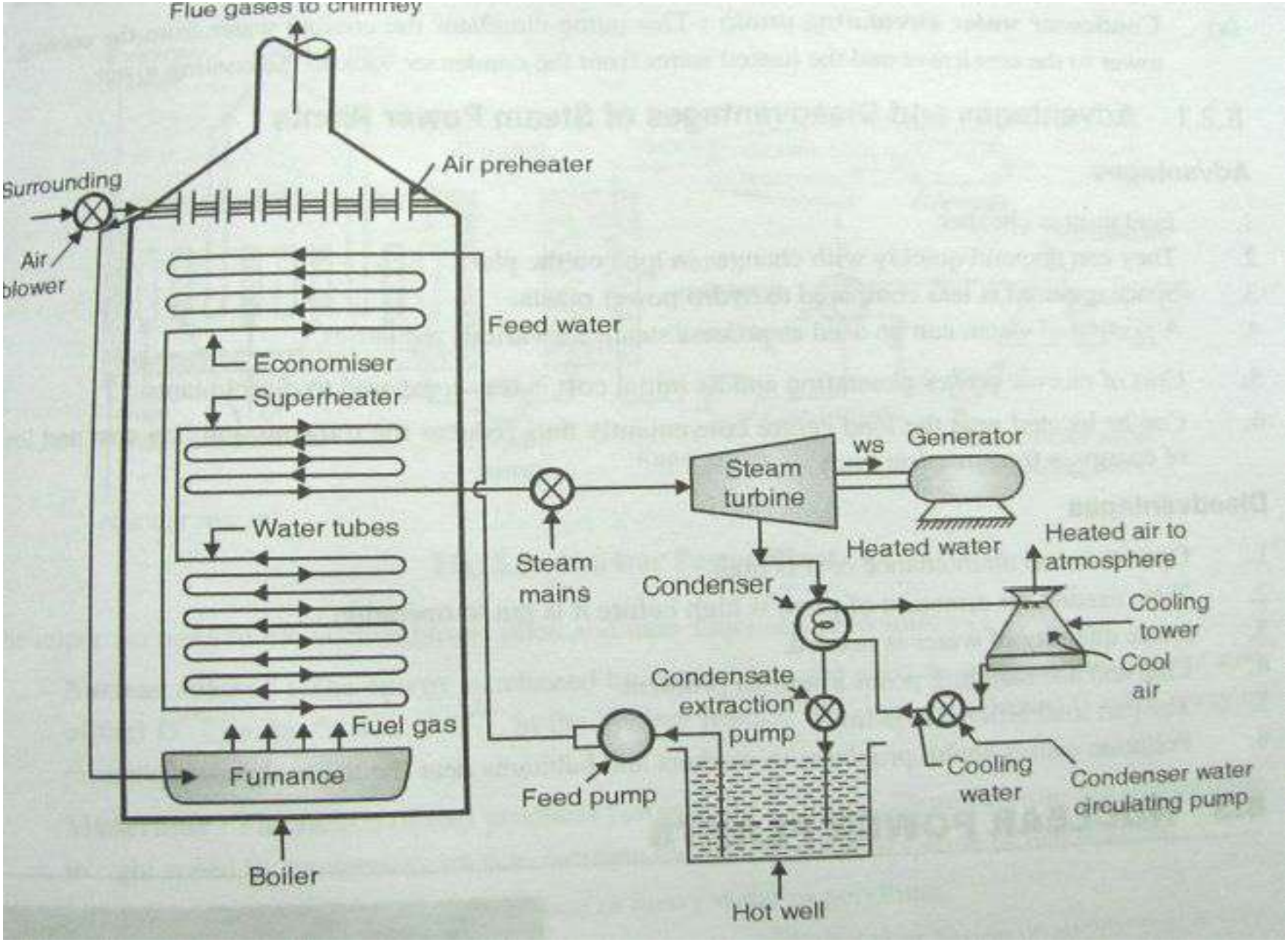
- Shaft of steam turbine is coupled to a shaft of generator & mechanical energy of steam turbine is converted into electrical energy.

4. Condenser:-

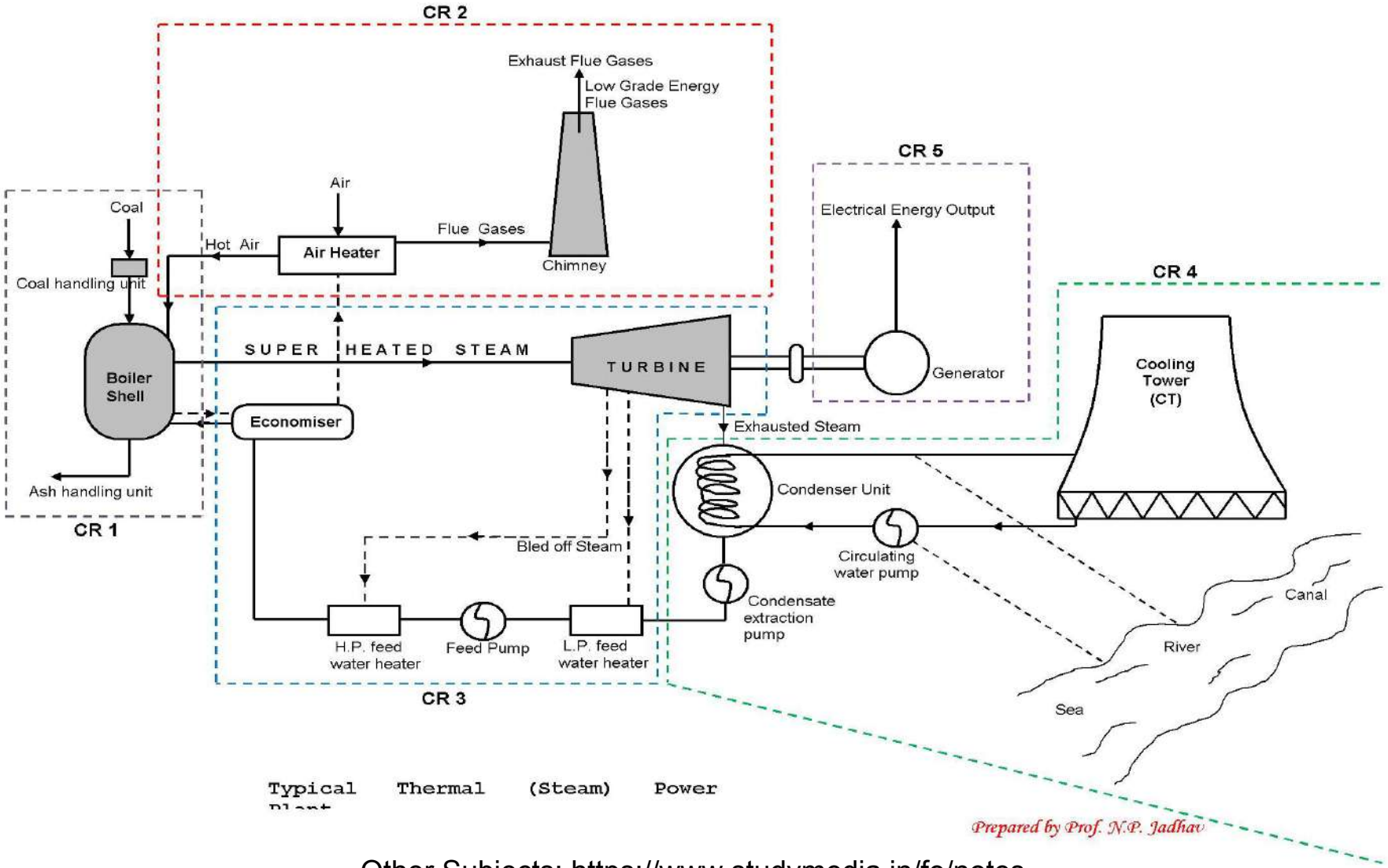
- Steam exhausted from steam turbine is collected in condenser & condensed by using recirculating cooling water.
- The condensed amount of water is known as condensate.

5. Feed Pump:-

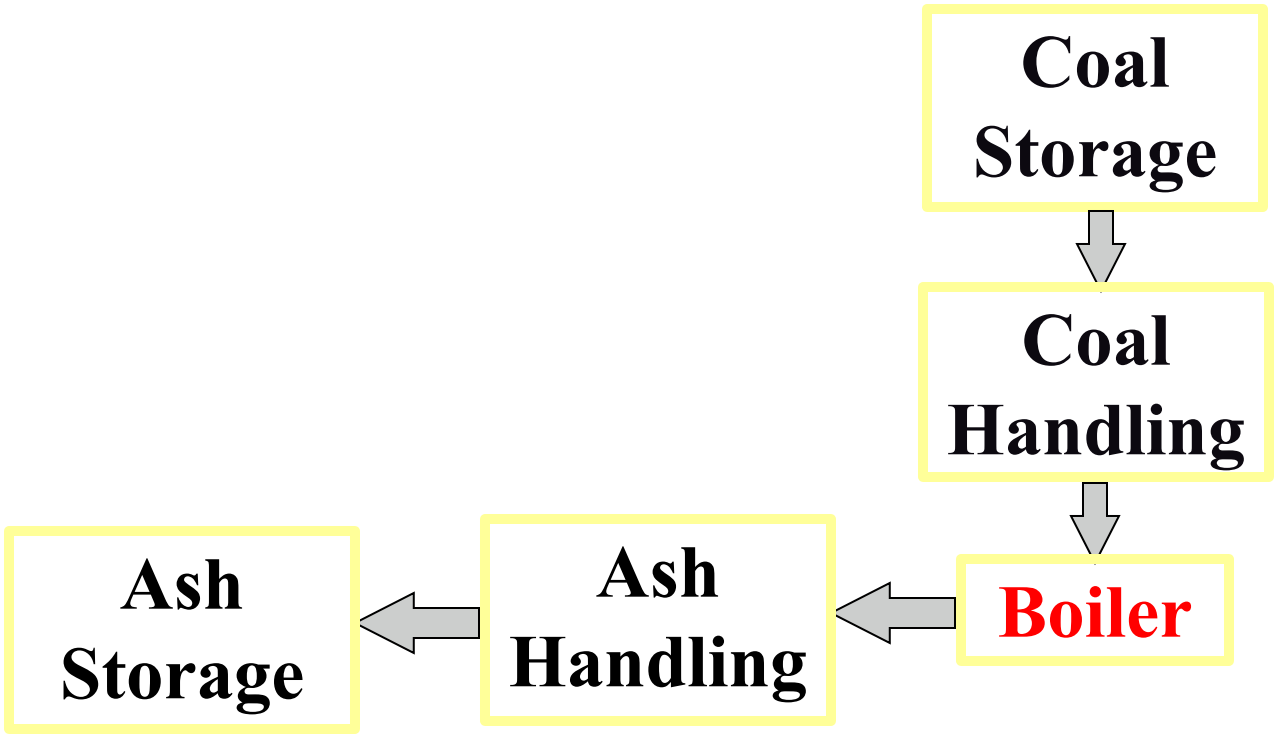
- The collected amount of condensate is again fed back to the boiler with the help of feed pump.



• Representation

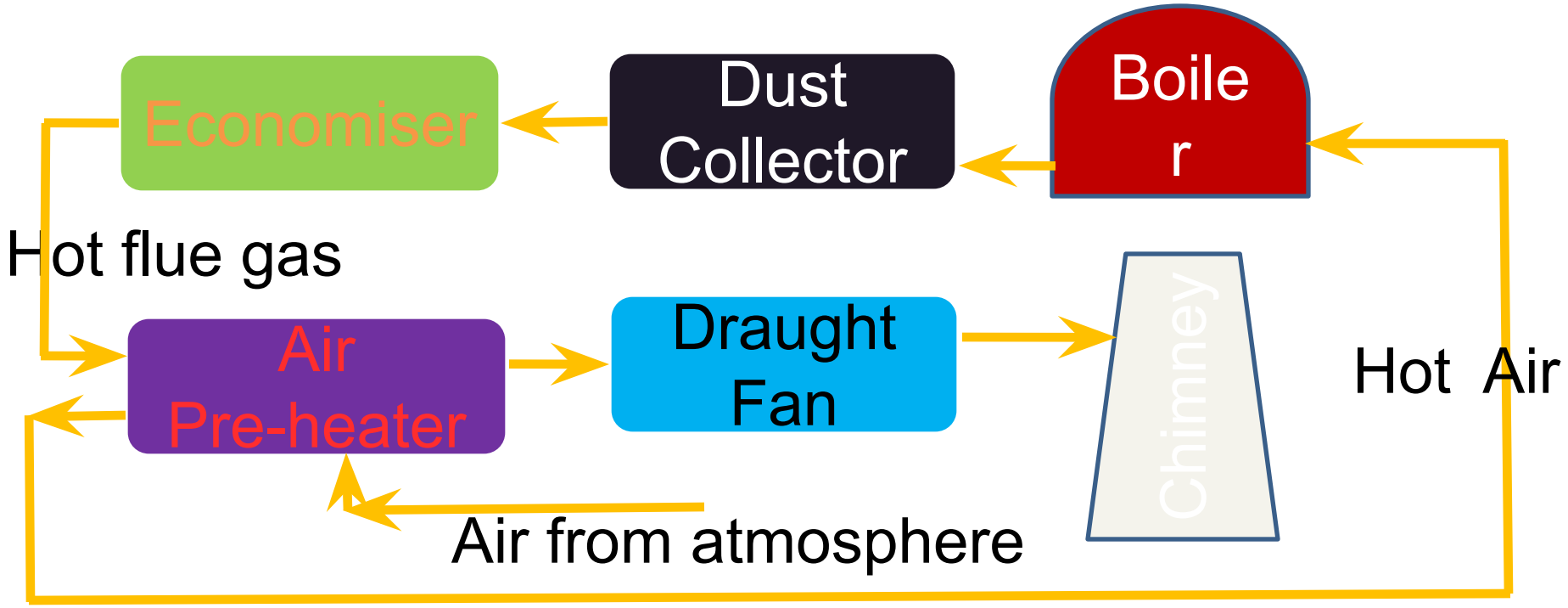


CR 1 : Coal and Ash Handling Circuit



- *Coal* is used as the *fuel* & burnt in the *Boiler* for generation of *Steam*.
- Ash produced due to combustion of coal is removed to the Ash Storage.

CR 2 : Air and Flue Gas Circuit



- Air is taken from atmosphere through fan.
- Air is heated by hot flue gases which is passing to chimney.
- Hot Air is supplied to the boiler.

Energy Conversions

- ***Advantages***

  - *Fuel* used is *cheaper*.

- *Space* required is *less* compared to Hydro Power Plant.
- Portion of *generated steam* can be used as *process steam* for various industries.
- *Initial cost* is *less* compared to Diesel Power Plants.
- *Plants* can be *located near the load centre* which *reduces transmission line cost & loss of energy in transmission lines*.

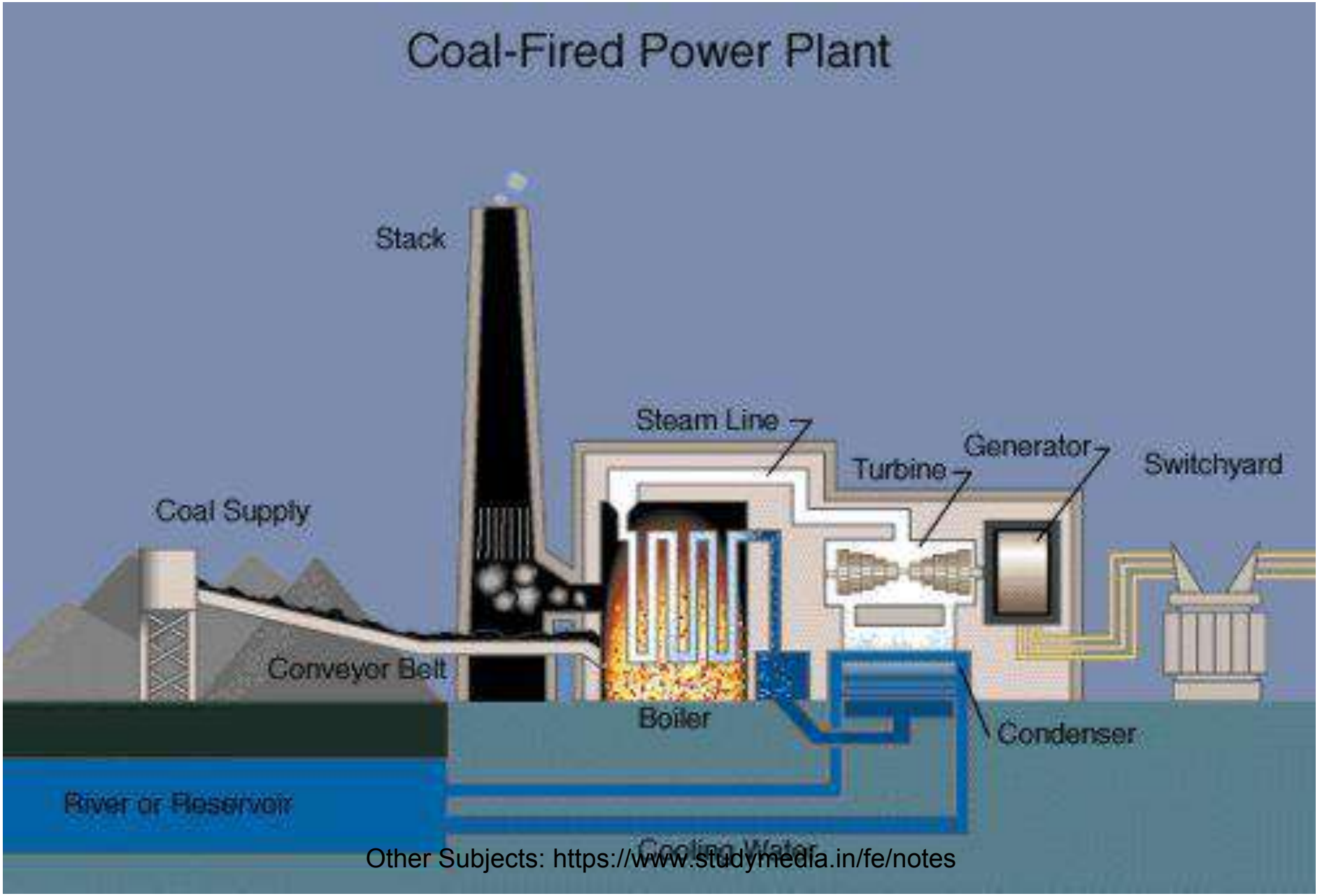
• *Disadvantages*

- *Operation & Maintenance Cost High*.
- *Time* needed for *erection* of plant is *high* before it is put to operation.
- *Large quantity of Water* is required.
- *Coal & Ash Handling* causes *serious problems*.
- *Pollution* causes *health problems* to workers & habitants near the power plant.

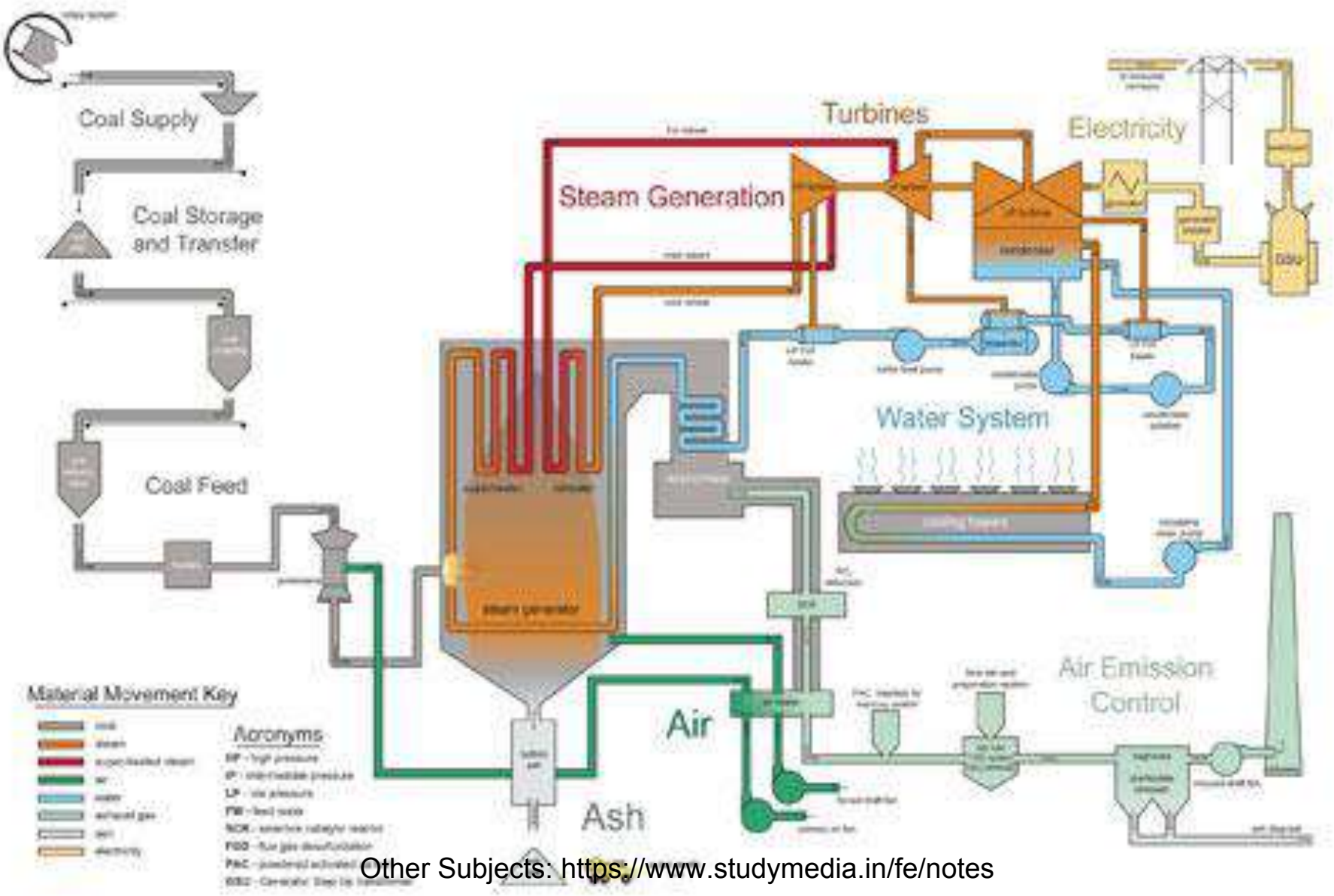
Thermal Power Stations in India

- Ramagundam in Andhra Pradesh.
- Raichur in Karnataka.
- Korba in Madhya Pradesh.
- Farraka in West Bengal.
- Chandrapur in Maharashtra.
- Khaparkheda in Maharashtra.
- Sindri in Zharkhand.
- Amarkantak in Madhyapradesh.
- Durgapur in West Bengal.
- Baroni in Bihar.

• *Layout of Thermal Power Stations*



Layout of Thermal Power Stations



Nuclear Power Plant

- *Introduction*
- *Representation*
- *Components*
- *Energy Conversions*
- *Advantages*
- *Disadvantages*
- *Location of Thermal Power Plants*

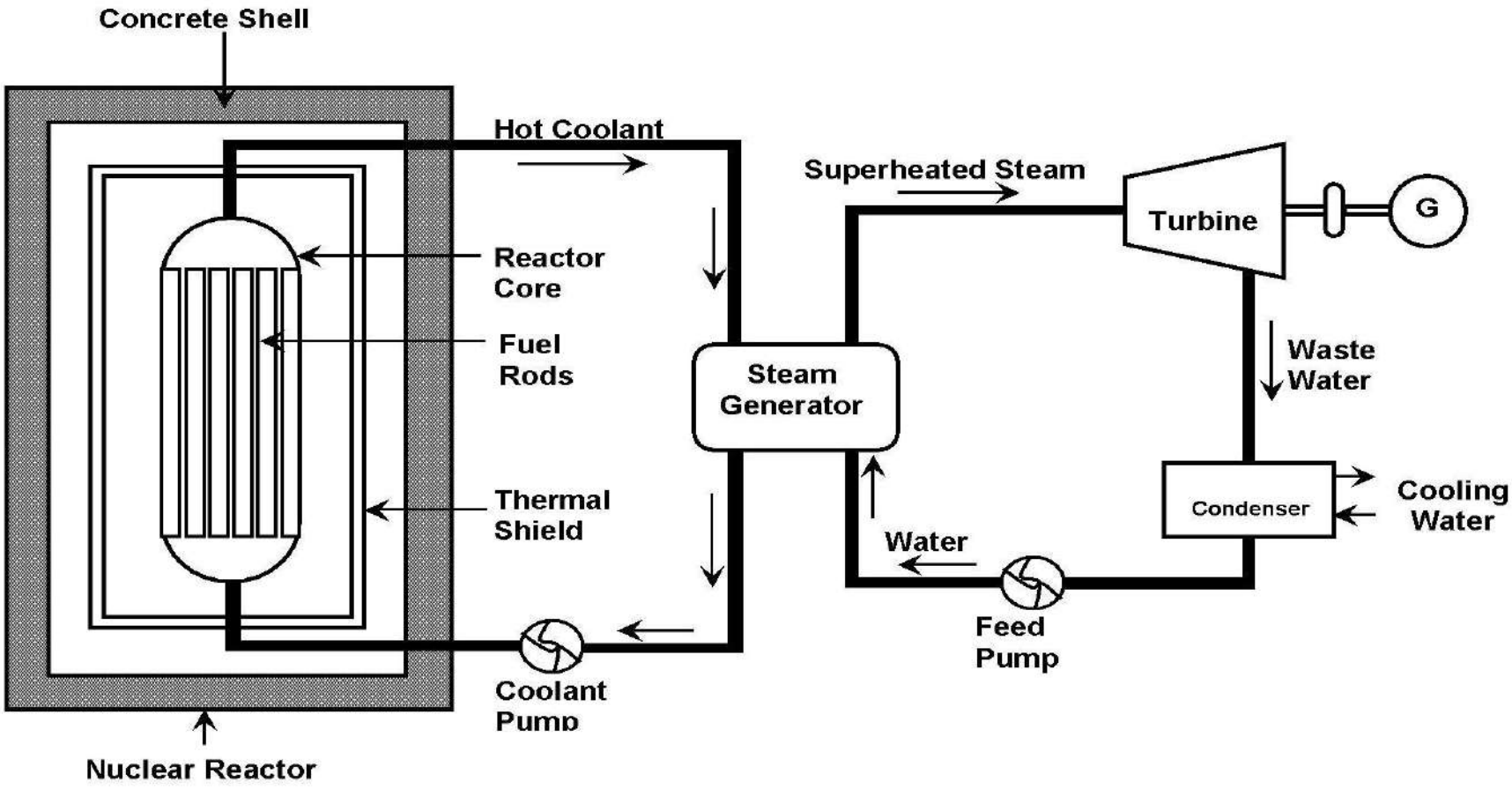
- ***Introduction***

- Utilises *Energy* which is produced by *Nuclear Reactions* by Fission.

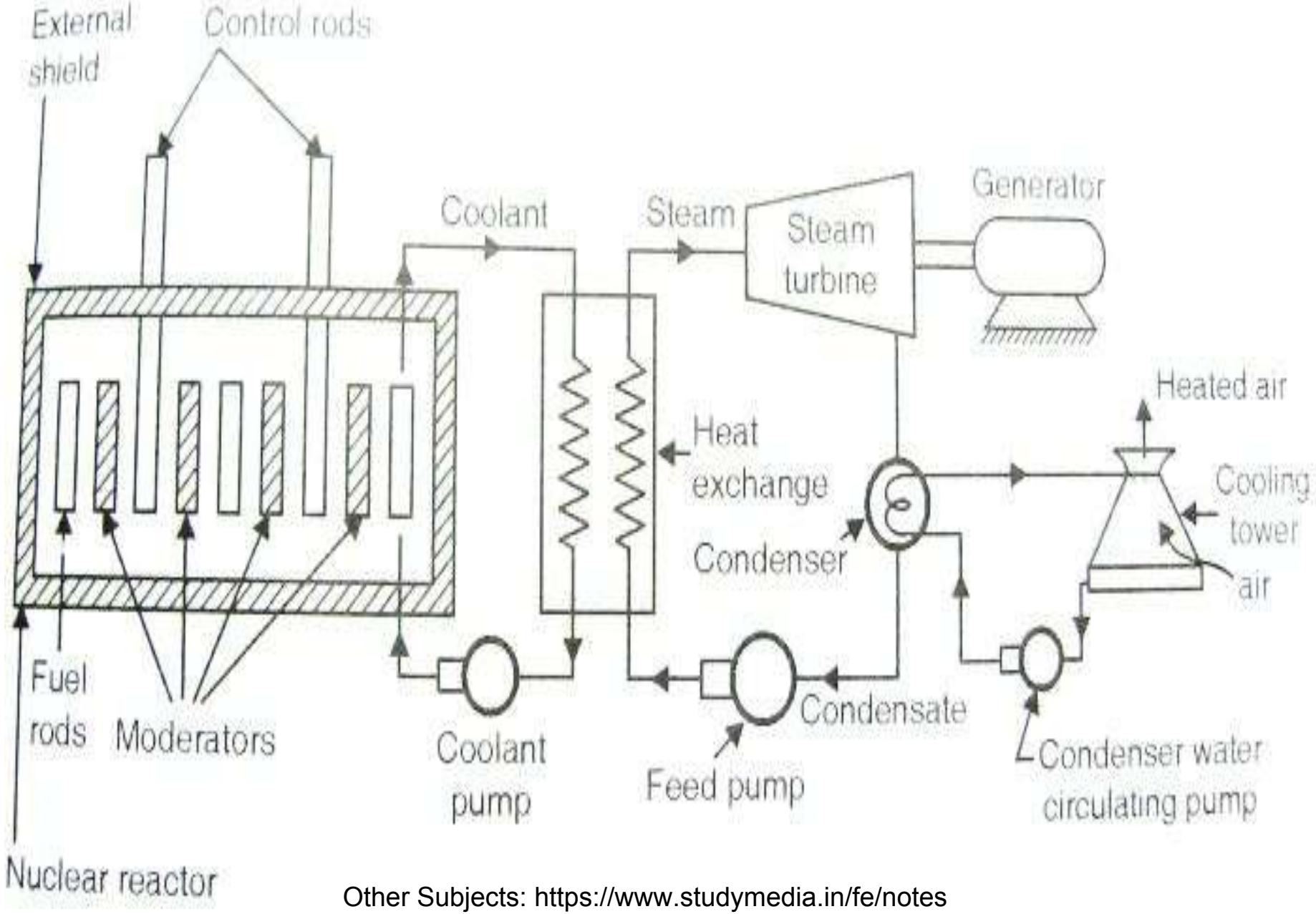
- *Nuclear Reactor* substitute Boiler of Thermal PP.

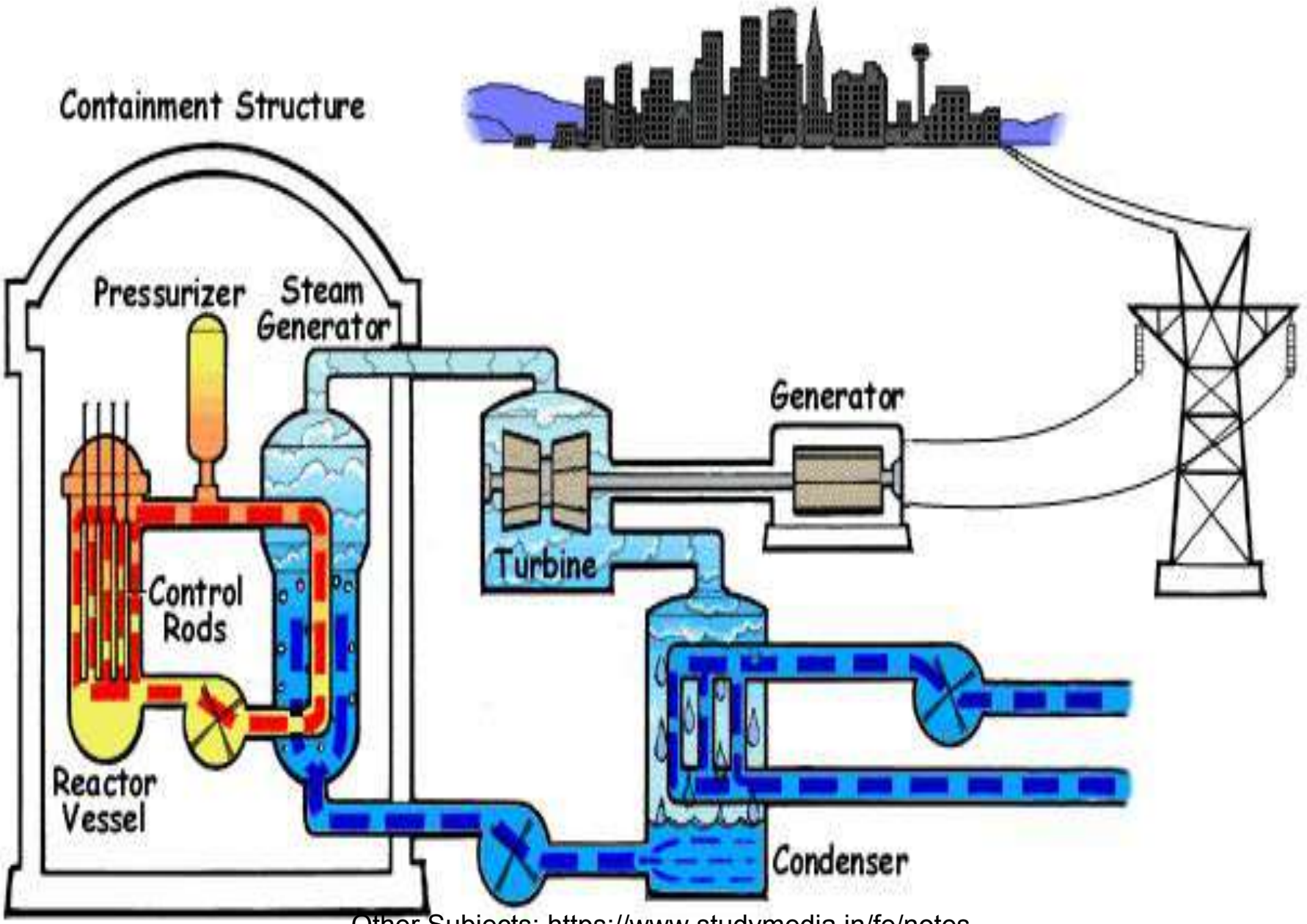
- *Heat* produced in *Nuclear Reactor* by process of *Fission* carried on *Radioactive materials*.

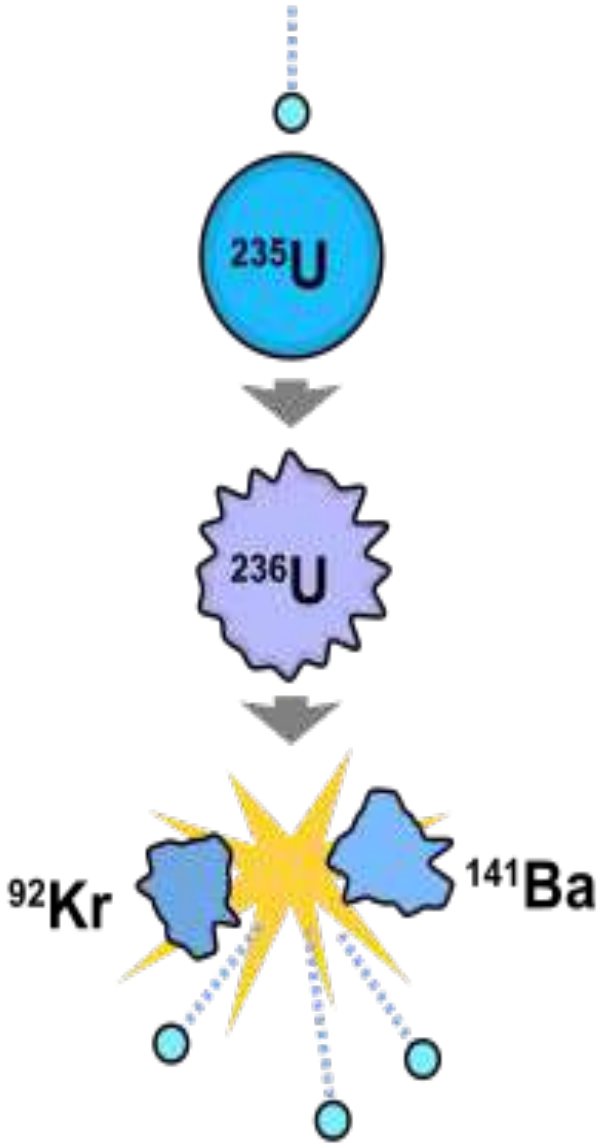
- Radioactive materials –
  Uranium (U^{235}) *Thorium* (Th^{232})
  Plutonium (Pu^{239})



Nuclear Power Plant







A neutron is absorbed by a uranium-235 nucleus, turning it briefly into an excited uranium-236 nucleus, with the excitation energy provided by the kinetic energy of the neutron plus the forces that bind the neutron. The uranium-236, in turn, splits into fast-moving lighter elements (fission products) and releases a small amount of free neutrons.

• *Components*

- *Nuclear Reactor* :

• Nuclear Energy is produced by nuclear fission of unstable atoms like uranium.

•Uranium is in the form of thin rods & plates.

- *Moderator*

Reduces speed of neutrons without absorbing

- *Control Rods*

Regulates energy release by absorbing neutrons

Components

- *Concrete Shell*

  Provide for physical safety of persons.

- *Coolant*

  Absorbs heat from reactor core & supplied it to Heat exchanger(boiler) for steam generation

  Gas Coolants : Carbon dioxide ; Helium

  Liquid Coolants : Sodium, Potassium & their alloys.

Components

- *Steam Generator* :

  One Type of heat exchanger.

  Absorbs heat from coolant & produces steam.

- *Steam Turbine*

- *Condenser*

- *Cooling Tower (CT)*

Energy Conversions

• *Advantages*

- *Large quantity of energy* is released by very *small amount of fuel*.
- *Avoids transportation* & *storage* of large amount of fuel.
- Does not cause *air pollution*.
- Plan requires *less space*.
- *Performance* of Nuclear Plant is *high*.
- *Reduces demand* of *consumable resources*.

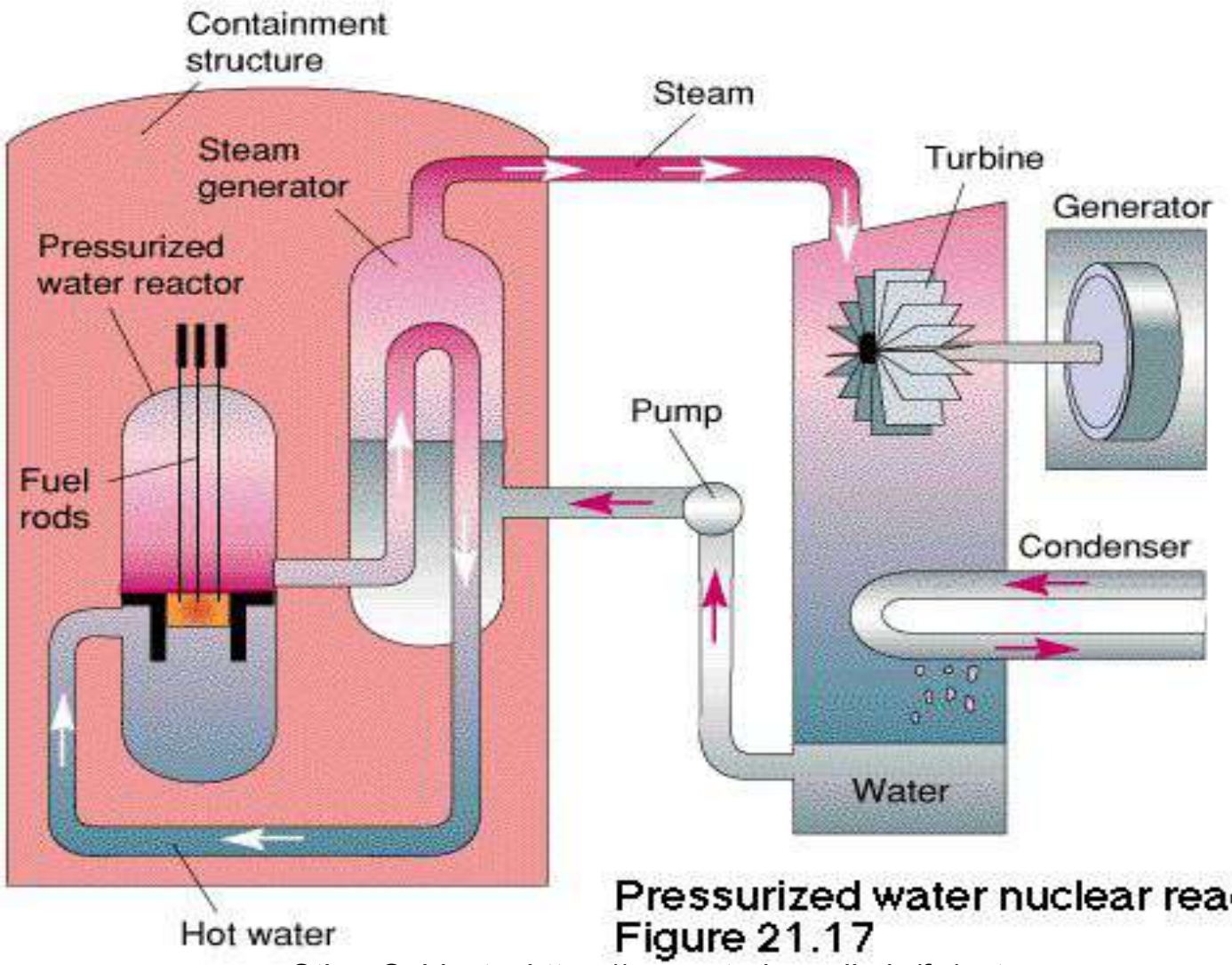
- ***Disadvantages***

- *Capital Cost High*.
- Needs *trained man power*.
- Problem of *radioactive waste disposal*.
- *High degree of safety* is needed for persons.
- *Performance* of power plant is *high*.
- *Cost of power generation is very high*.

Nuclear Power Stations in India

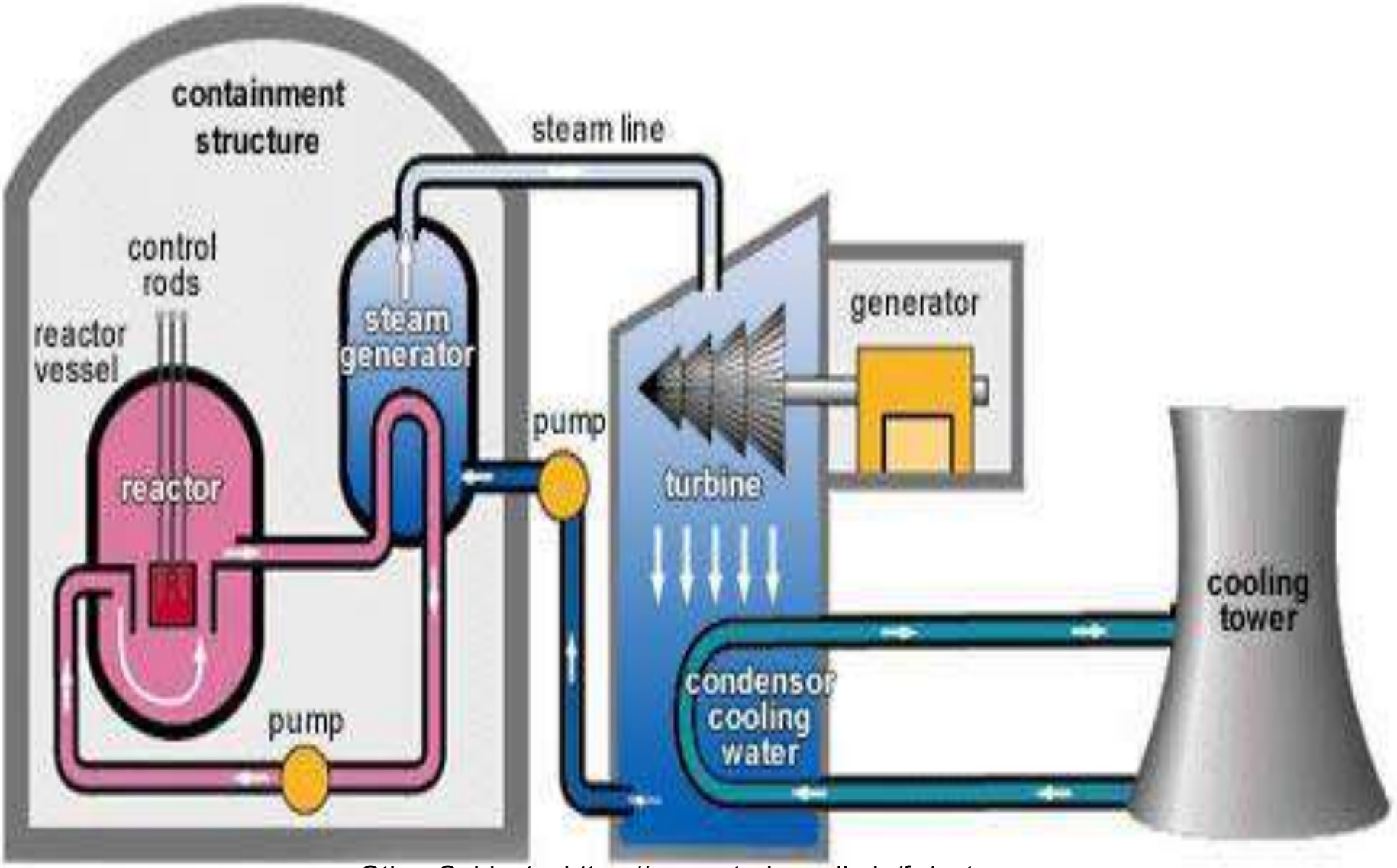
- Tarapur in Maharashtra.
- Kalpakkam in Tamilnadu.
- Narora in Uttarpradesh.
- Kaiga in Karnataka.
- Kakrapara in Gujarat.
- Rawatbhata (Ranapratap Sagar) in Rajasthan.

Pressurised Water Nuclear Reactor



Pressurized water nuclear reactor.
Figure 21.17

Nuclear Power Plant



Kakrapar Nuclear Power Station

Hydroelectric Power Plant

- Introduction
- Representation
- Components
- Energy Conversions
- Advantages
- Disadvantages
- Location of Thermal Power Plants

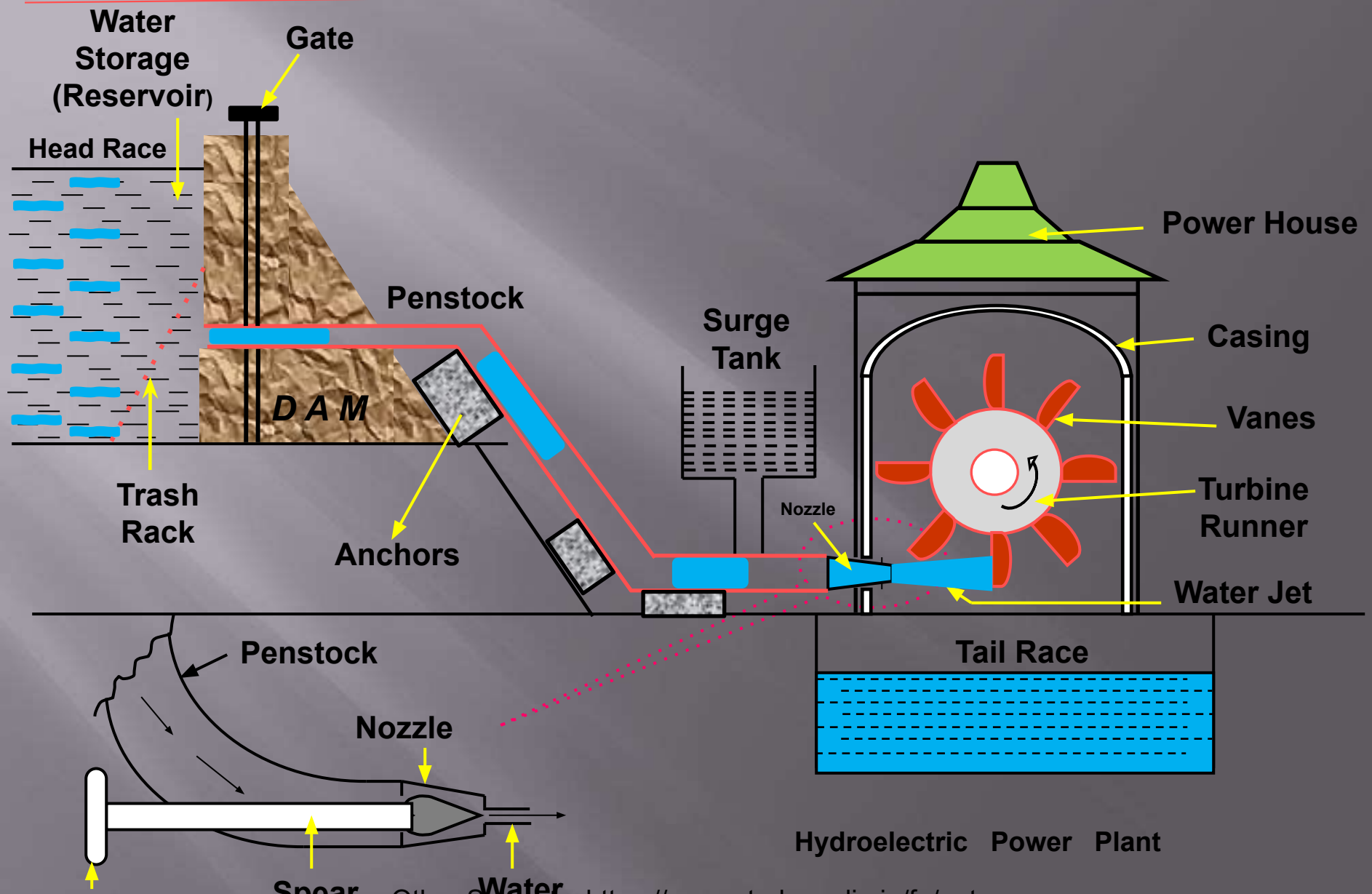
Introduction

- Basic requirement of plant is a ***reservoir*** where large quantity of water is stored during flood season and used during dry season.
- Reservoir is generally built by constructing a dam across a river.
- The water from reservoir is drawn through the penstock.

Introduction

- Due to head difference potential energy converted into kinetic energy.
- High velocity jet of water is supplied to the prime mover, where K.E. is converted into mechanical energy.
- This results rotation of turbine shaft and ultimately the generator shaft to produce the electric power.

REPRESENTATION



Hydroelectric Power Plant

Components

- *Reservoir* : Water storage
- *Dam*

  Provide working head of water ; increase storage capacity of reservoir
- *Trash Rack*

  Prevent entry of debris (waste material, dust) into penstock from dam
- *Gate*

  Controlling flow of water from reservoir

  Closed when maintenance of system is required.

Components

- *Surge Tank*

  Protect penstock due to sudden variation of flow or the velocity of water

- *Penstock*

  Water carrying pipe from Reservoir to Turbine

- *Anchors*

  Concrete blocks to support penstock

- *Hydraulic Turbine*

  Converts K.E. of water into mechanical energy

Components

- *Draft Tube*

  Exit to tail race water level

- *Head Race*

  Distance between reservoir and tail race level

- *Tail Race*

  Water way discharged from turbine to the river

Energy Conversions

Potential Energy

Kinetic Energy

Mechanical Energy

Electrical Energy

• *Advantages*

Capital cost high.

- Operation cost less.
- Cost of power generation per unit is low.

- Starting & stopping of plant takes very short time compared to steam & nuclear pp.

- No ash & nuclear waste disposal problem.

- Life expectancy higher.

• *Advantages*

- High efficiency over wide range of loads.
- require less supervising staff.
- Apart from power generation plant also used for irrigation & flood control purposes.

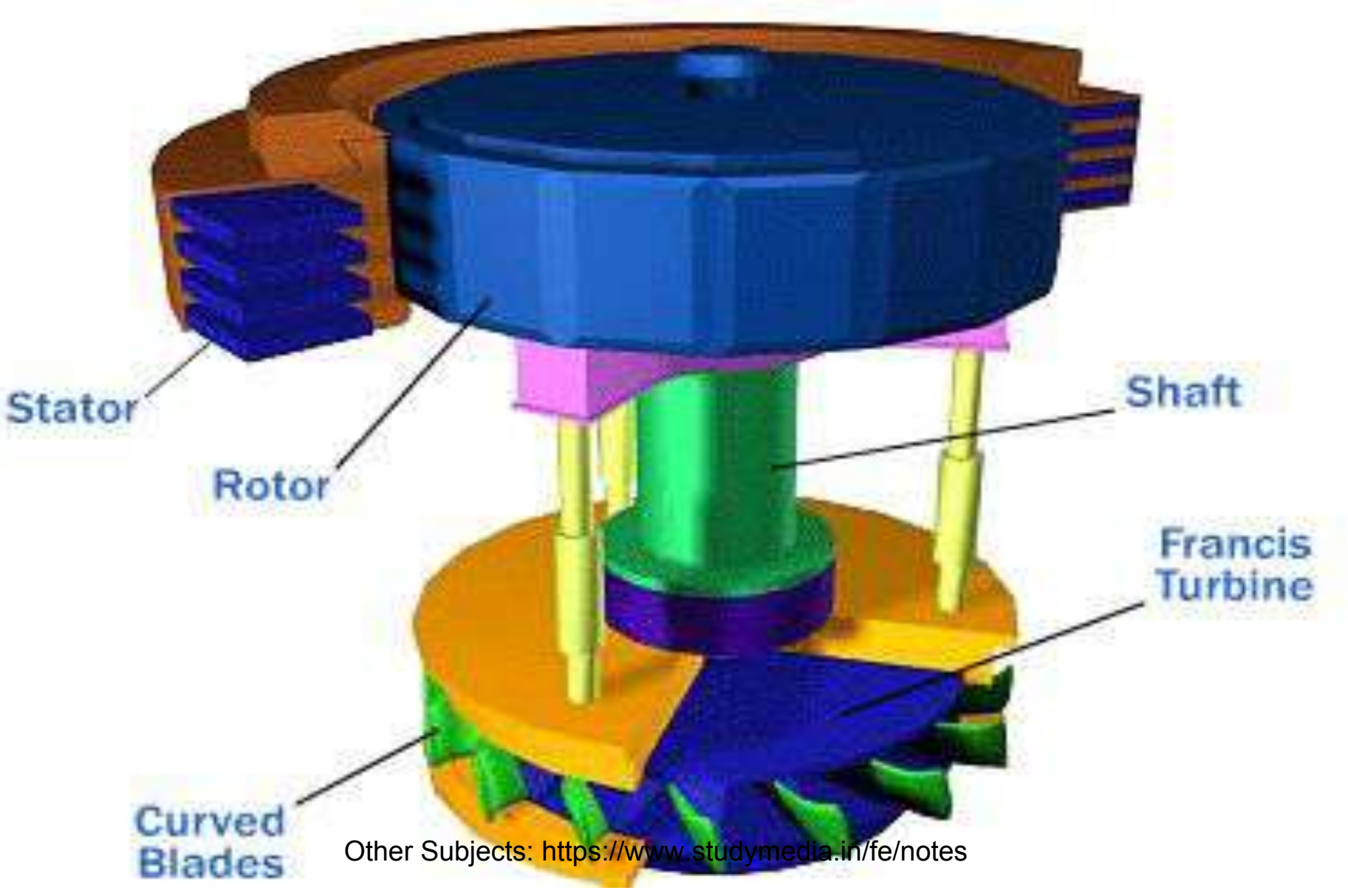
Disadvantages

- Depends upon availability of quantity of water, rainfall.
- Far away from needful electrical power, which requires long transmission lines.
- This increases cost of transmission lines & power loss.
- Time required for development of plant is high.

Hydroelectric Power Stations in India

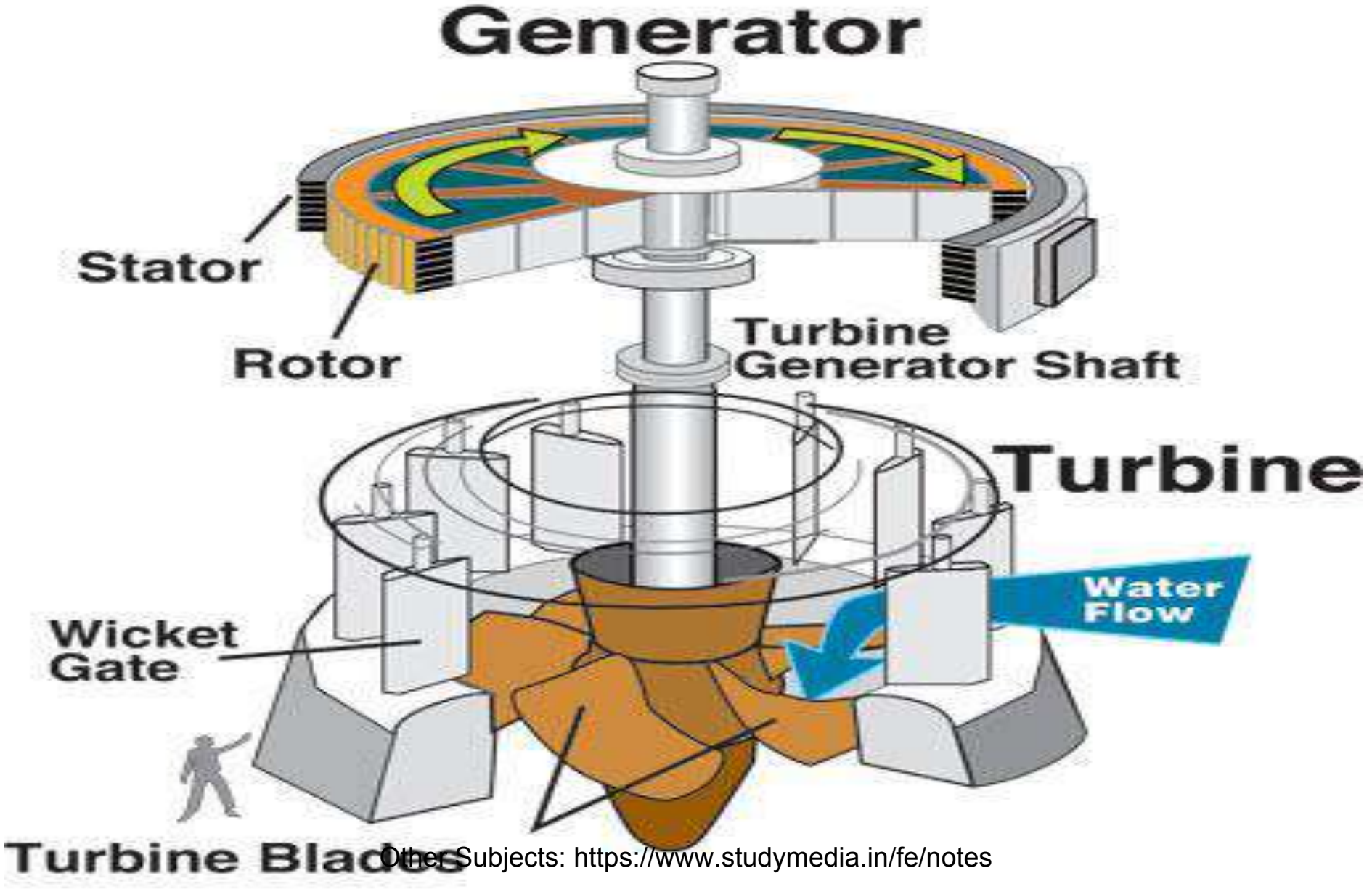
- Bhakra-Nangal in Himachal Pradesh & Punjab.
- Hirakud in Orissa.
- Tihari in Uttaranchal Pradesh.
- Koyana in Maharashtra.
- Narmada in Gujarat & Madhyapradesh.
- Jaikwadi in Maharashtra.
- Shrishailam in Andhrapradesh.

• *Hydroelectric PP : Francis Turbine*

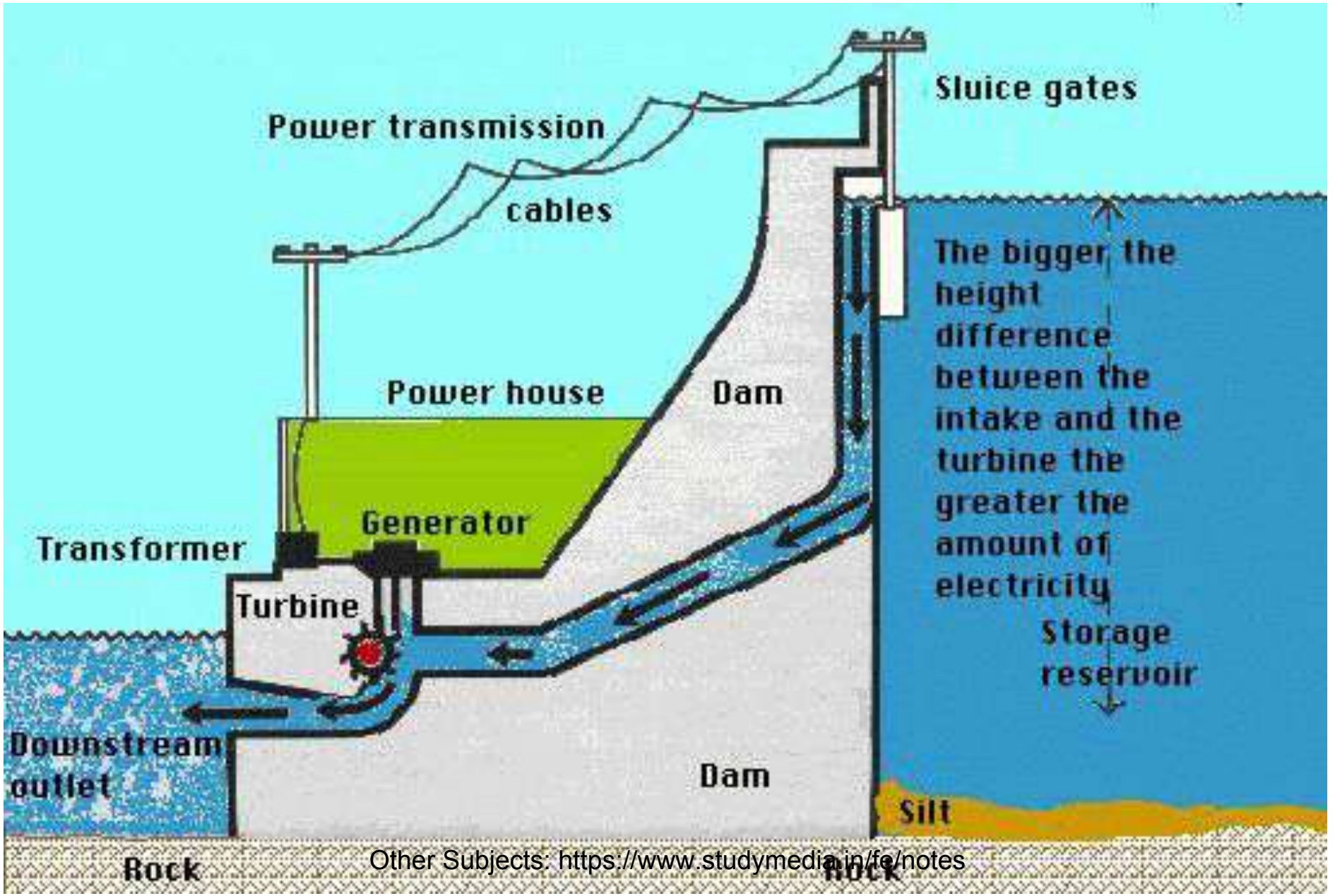


Hydroelectric PP : Francis Turbine Blades

Hydroelectric PP : Propeller Turbine



• *Hydroelectric PP :*




Other Subjects: https://www.studymedia.in/fe/notes

Solar Power Plant

- ***Introduction***
- ***Representation***
- ***Components***
- ***Energy Conversions***
- ***Advantages***
- ***Disadvantages***
- ***Location of Thermal Power Plants***

Introduction

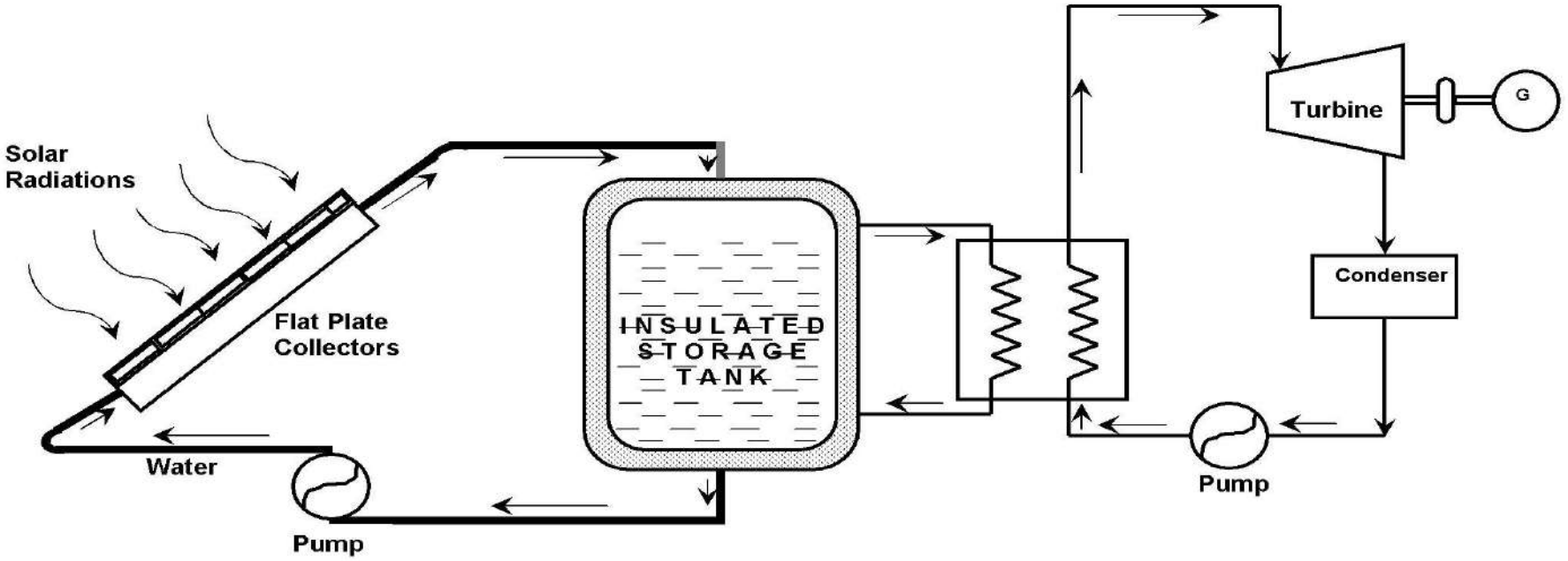
- Two obstacles in harnessing Solar Energy.

  (i) Solar Energy not available constantly on Earth.

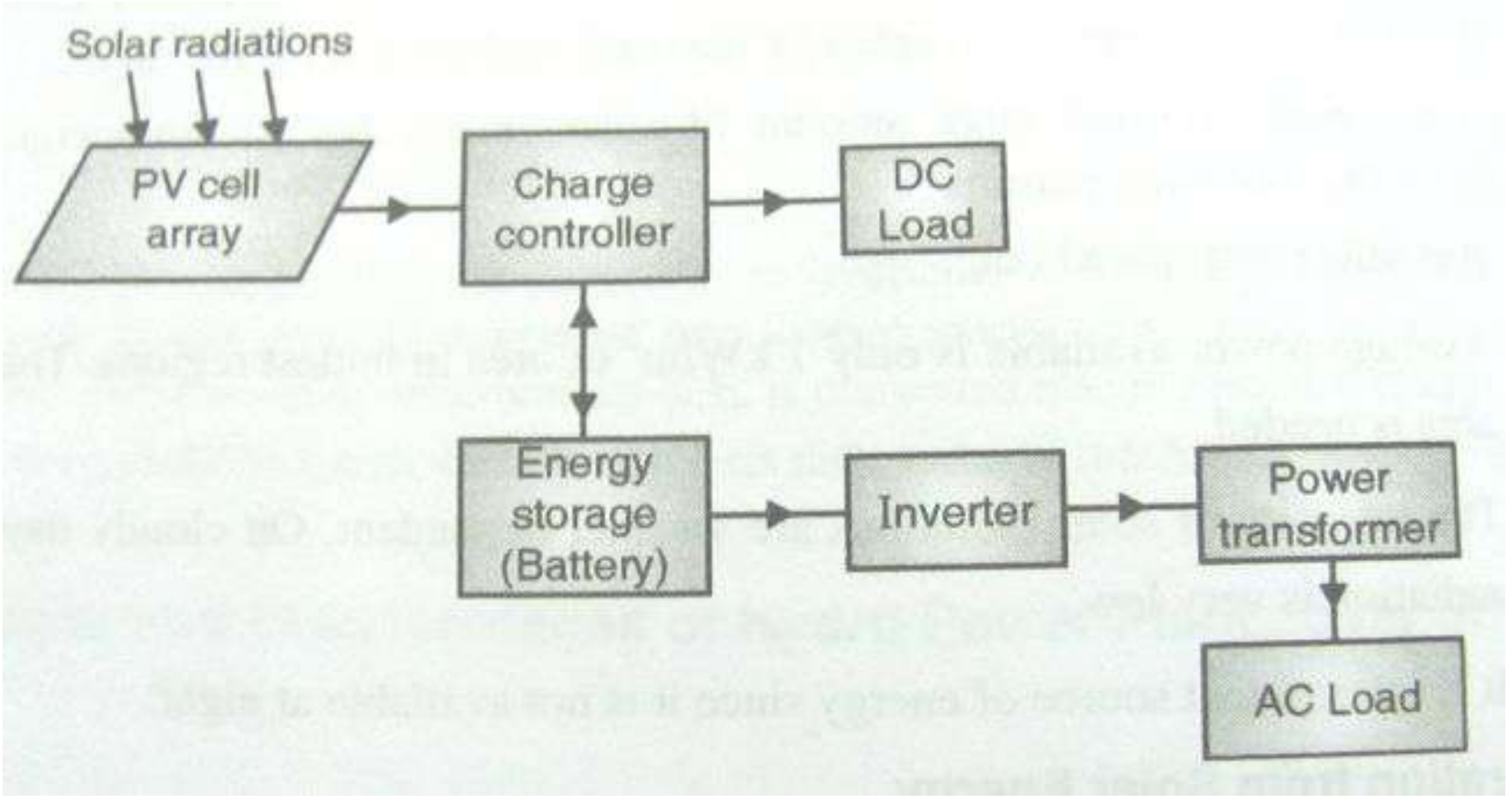
  (ii) Solar Energy available is diffused energy.

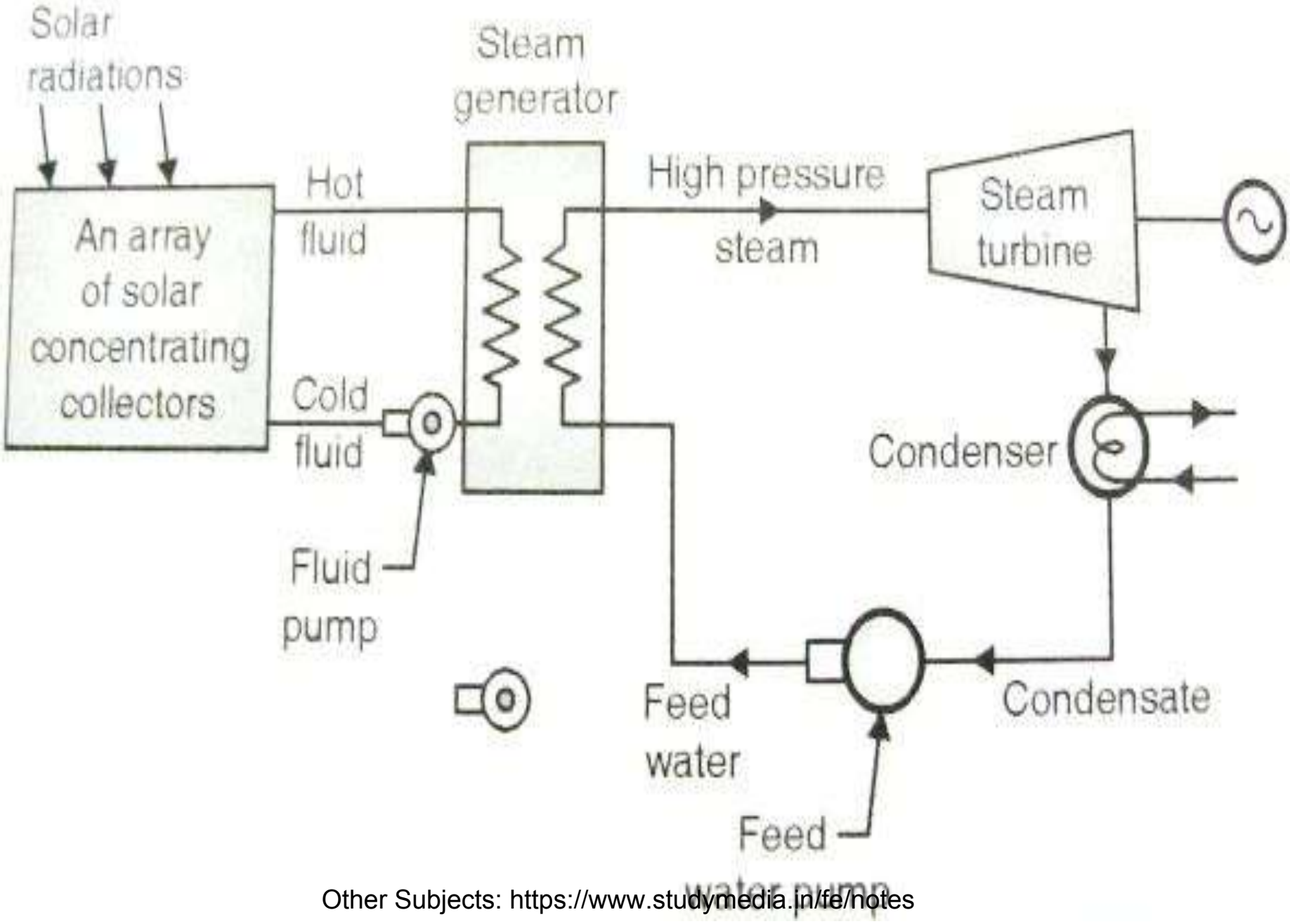
- Controller Plates are used to collects diffused energy.
- But the manufacturing cost of controller plates requires large capital investment.

• Representation



Solar Power Plant (Low Temperature





• *Components*

- ***Absorber Plate:*** absorbs maximum possible amount of solar radiations & allow very less amount of heat loss to the atmosphere.

- ***Transparent Covers:***

  Made of glass

  They are one or two in numbers.

  It covers the absorber plate in order to reduce convective heat loss.

  Allow solar energy to reach absorber plate.

  Reduces conduction, convection & re-radiation heat losses.

- ***Components***

- ***Insulation***

  Protects absorbing surface from heat losses

- ***Metallic Tubes***

  Carries working fluid (water).

  Water circulates by natural circulation currents.

  Produces steam by absorbing solar energy

- ***Condenser***

  Condensate exhaust steam.

- ***Feed Pump***

  Feeds condensate water back to metallic tubes

Turbine

Energy Conversions

Heat Energy

Mechanical Energy

Electrical Energy

Advantages

- Simple to construct & install.
- Almost no maintenance & running cost.
- Ecofriendly.
- Available at free of cost.
- No cost spent on fuel.
- Save time & energy.

Disadvantages

- Collection & conservation of solar energy into useful forms must be carried out over large area which requires a large capital investment for conservation.
- Collectors requires direct sunlight & plant is not operative when the sun is partly covered with clouds.
- Uneconomical.

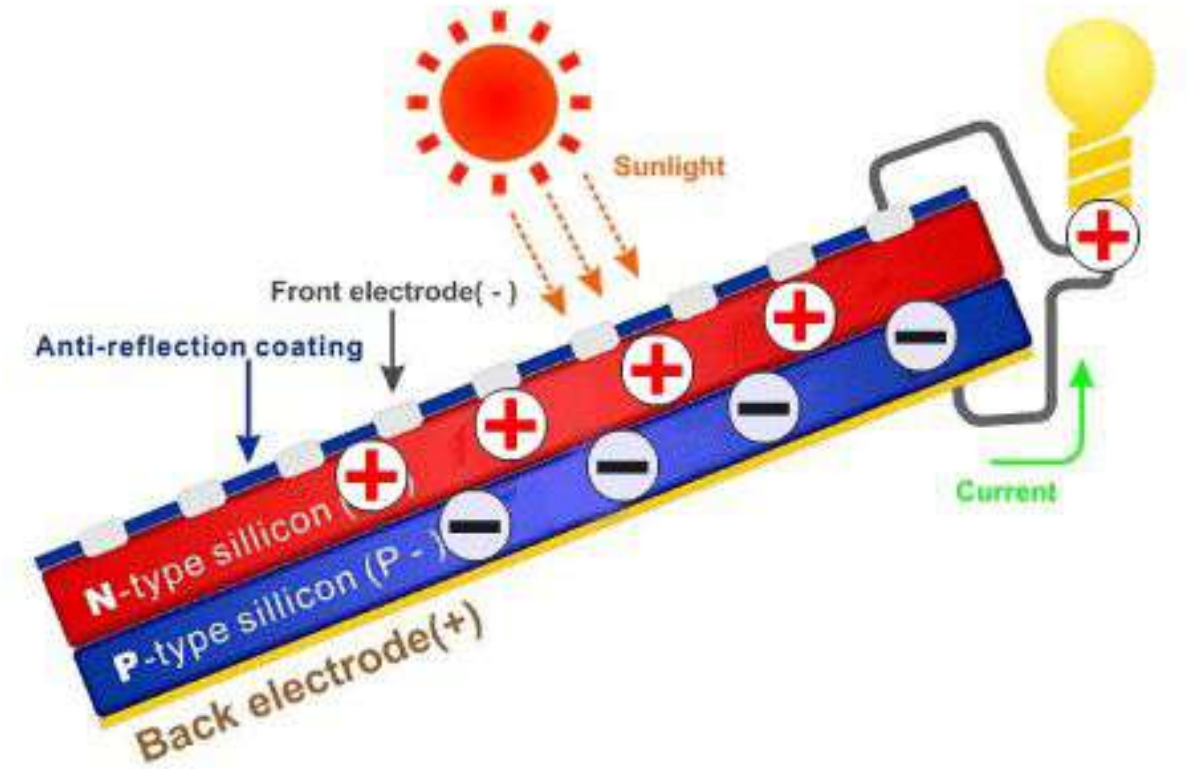
Solar Photovoltaic cells

- ***Introduction***
- ***Representation***
- ***Components***
- ***Applications***
- ***Energy Conversions***
- ***Advantages***
- ***Disadvantages***

Introduction

- A *solar cell*, or *photovoltaic cell*, is an electrical device that converts the energy of light directly into electricity by the *photovoltaic* effect, which is a physical and chemical phenomenon
- Photons in sunlight hit the solar panel and are absorbed by semiconducting materials, such as silicon. Electrons are excited from their current atomic orbit

Representation



Solar → Chemical → Electrical

Components

- N-Type Silicon: Rich of Electron
- P-Type Silicon: Deficiency of Electrons
- Front Electrode: Connected to N-type
- Back Electrode: Connected to P-type

Advantages

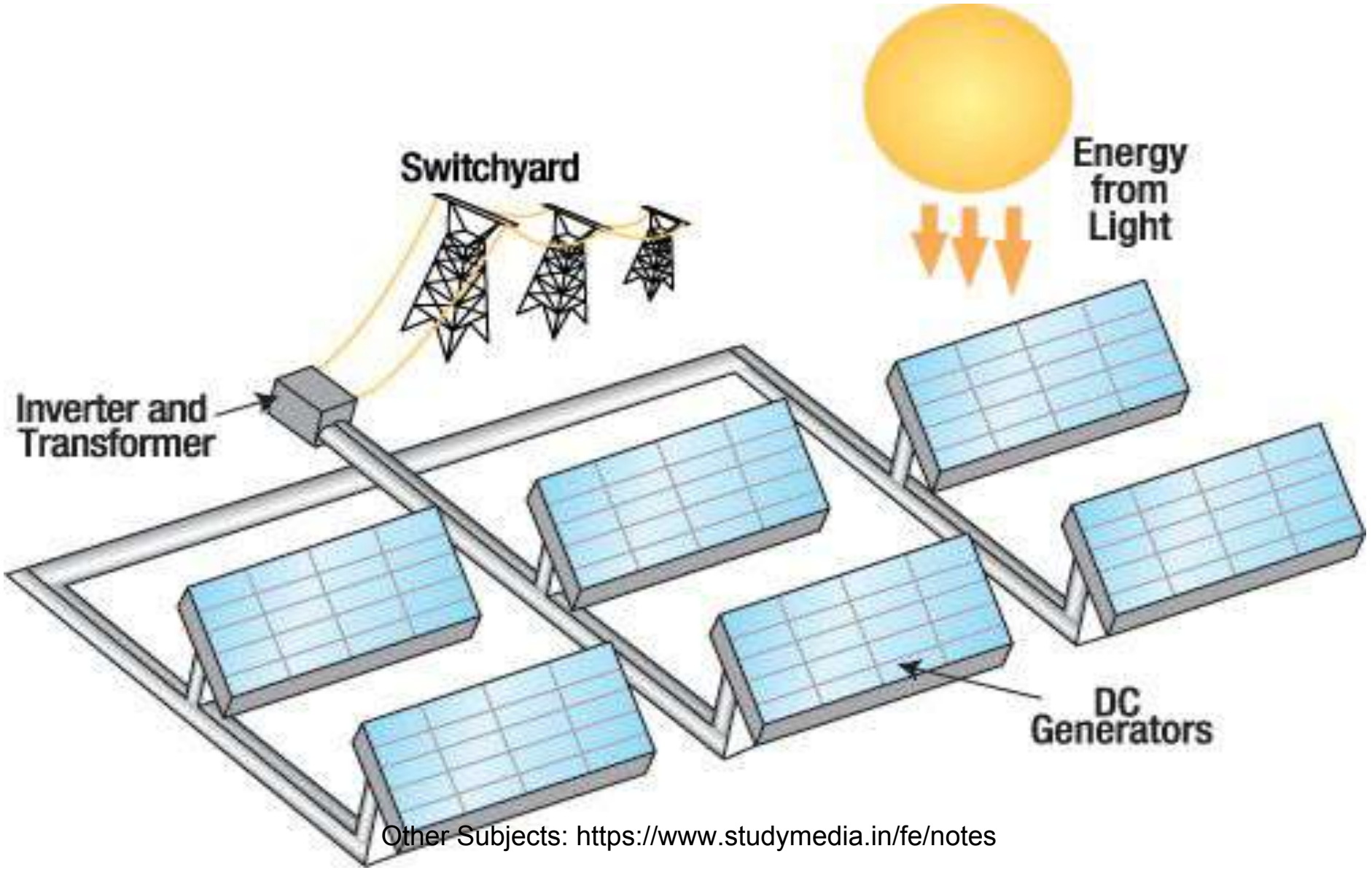
- **Solar** power is pollution free and causes no greenhouse gases to be emitted after installation.
- Reduced dependence on foreign oil and fossil fuels.
- Available every day of the year
- Even cloudy days produce some powe

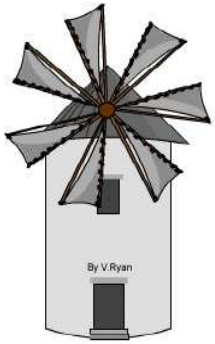
Disadvantages

- Location & Sunlight Availability
- Installation Area.
- Reliability.
- Less efficiency (18%)
- Expensive Energy Storage.
- High Initial Cost.

Solar Photovoltaic Panel

• *Solar P P*



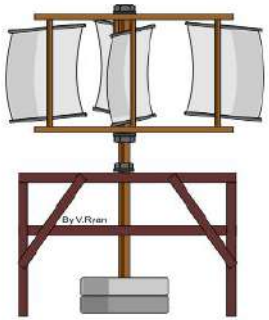


1300-1850 AD
(Europe)

Wind Power Plant

1000 AD
(Greek Islands)

- ***Introduction***
- ***Representation***
- ***Components***
- ***Applications***
- ***Energy Conversions***
- ***Advantages***
- ***Disadvantages***
- ***Location of Thermal Power Plants***



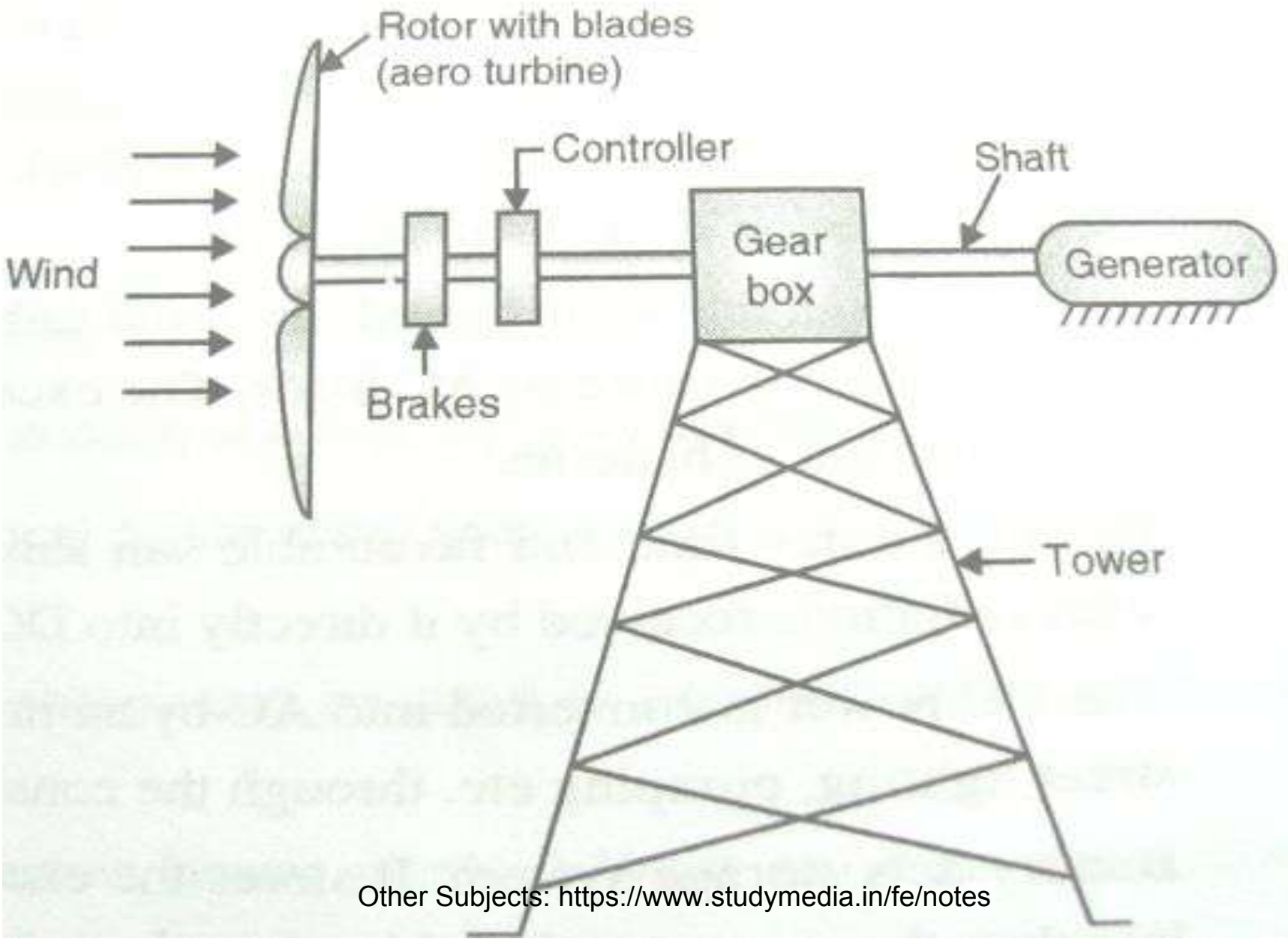
Persia 500 BC

Representation

Introduction

- High Velocity wind is required.
- High Velocity wind is available in costal areas.
- High Velocity wind strikes the rotor which is mounted over the Hub.
- K.E. of wind is converted by wind mills to produce mechanical energy which in turn converted into electrical power.

Wind Power Plant



Components

- *Rotor*

  Generally rotating blades mounted on Hub.

- *Hub*

  Central part of rotor, coupled with gear box shaft.

- *Gear Box*

  R.P.M. of shaft is increased by ratio of 1: 100

- *Supporting Structure (Tower)*

  Designed for support & to withstand the wind load.

- *Generator*

Applications

- Irrigation Pumps.
- Navigational Signals (Light Houses).
- Remote Communication.
- Power Relays.
- Weather Stations.
- Offshore Oil Drilling Platforms.
- Aero generators.
- Co-operative Farms.
- Small Industries.

Energy Conversions

Kinetic Energy

Mechanical Energy

Electrical Energy

Advantages

- Available at free of cost.

  Ability to supply power to remote areas.

- Cost effective & reliable.

- Pollution free.

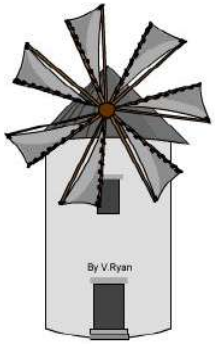
Disadvantages

- Continuous supply of electrical power can not be obtained.
- Favorable to geographical locations & conditions.
- Wind turbine design, manufacturing & installation is different for different atmospheric conditions.
- High Capital Cost.
- Requires large storage batteries.
- Wind mills are located in open area only which are far away from load centers.

Wind Power Stations in India

- Deogarh, Vijaydurga in Maharashtra.
- Puri in Orissa.
- Kanjikode in Kerala.
- Lamba, Dwarka in Gujarat.

Hybrid Solar Wind Power Plant



- *Introduction*
- *Representation*
- *Components*
- *Applications*
- *Energy Conversions*
- *Advantages*
- *Disadvantages*
- *Location of Thermal Power Plants*

Introduction

- Combination of Solar Collector & Wind Mill.
- Solar Collector is nothing but Photovoltaic Cell.
- PV cells directly convert Solar Energy into Electrical Energy.
- Electrical Energy generated by PV cell used in two ways –

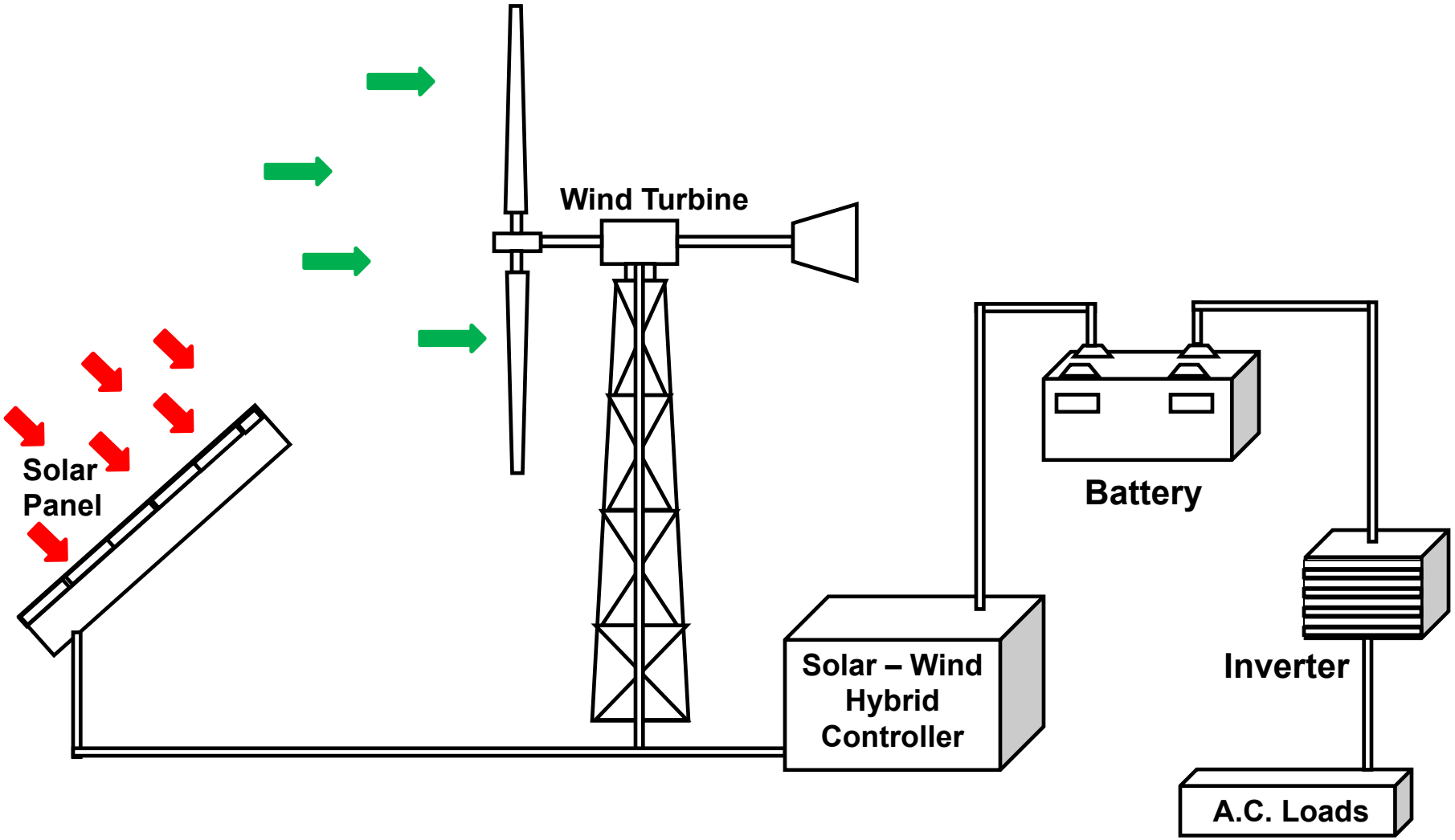
  (i) For DC Load

  (ii) Part of Electrical Energy stored into battery used for AC Load after inverting it from DC to AC.

Introduction

- Wind Mill generates AC power, which will be used directly.
- Part of AC power is converted into DC by Rectifier & stored in batteries.
- PP works for day & night season, which provides continuous power supply.

Representation



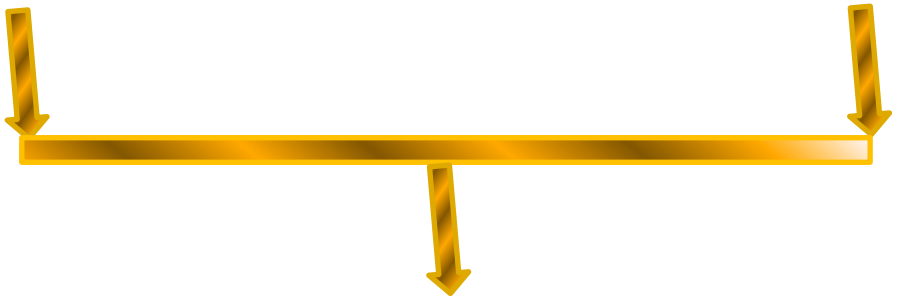
Applications

- Street Lighting.
- Pumping.
- Power Generation.

Energy Conversions

Kinetic Energy

Heat Energy



Mechanical Energy

Electrical Energy

Advantages

- Provides continuous power supply.

  Suitable for remote areas where transmission lines are not possible.

- Reduces size of large energy storage by using batteries.

Disadvantages

- Initial Cost is High.
- Disposal of batteries is difficult.

Geothermal Power Plant

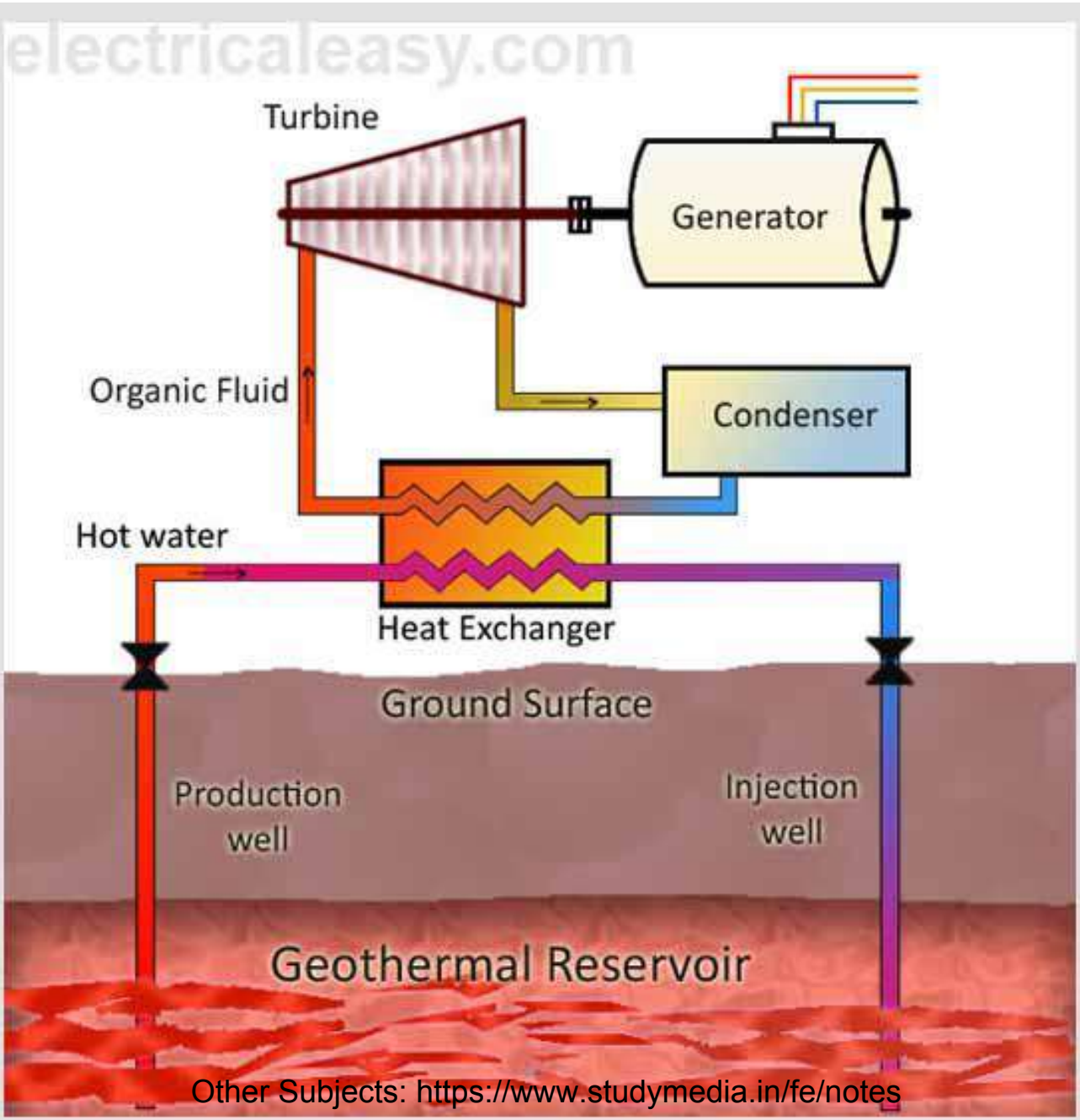
- Energy which lies embedded within the earth.
- Steam & hot water comes naturally to the surface of earth in some locations of earth.
- At the places of fresh volcanic activities ,where the molten interior mass of earth vents to the surface through fissures(cracks) & high temperatures(450 to 550 degree celsius).
- By using coil of pipes & sending water through them can be raised.

- From the well head the steam is transmitted by pipe line upto 3 km to power station.

- Nowadays only geothermal steam is used & hot water is discarded.(30 % dissolved salts & minerals may corrode turbine blades)

- Exist in USA, Japan, New Zealand,Italy & Mexico.

- In india: Himachal Pradesh



Advantages

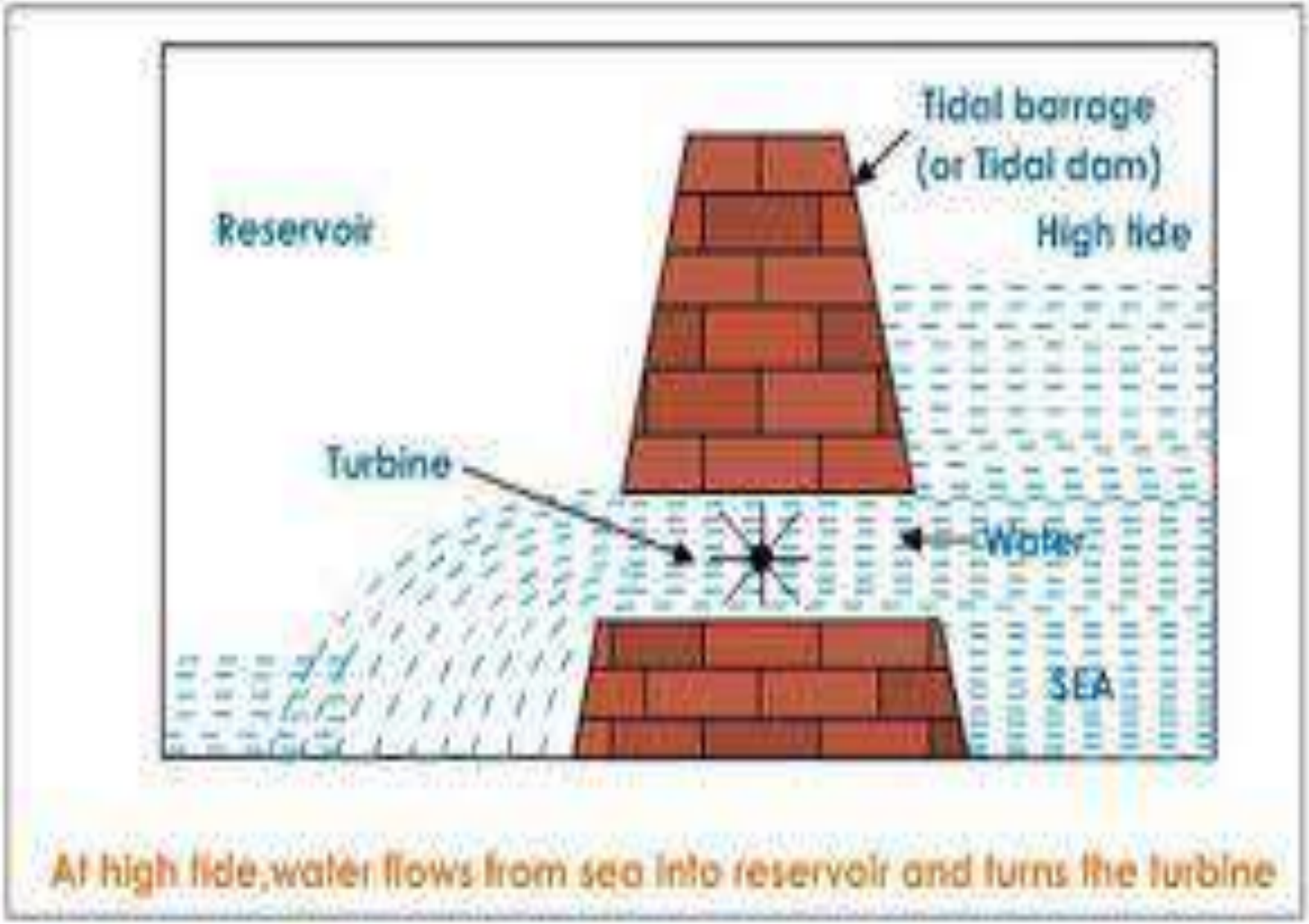
- Reliable source of renewable energy.
- No emmissions.
- High Efficiency.
- Low maintenance.
- Compact in size.

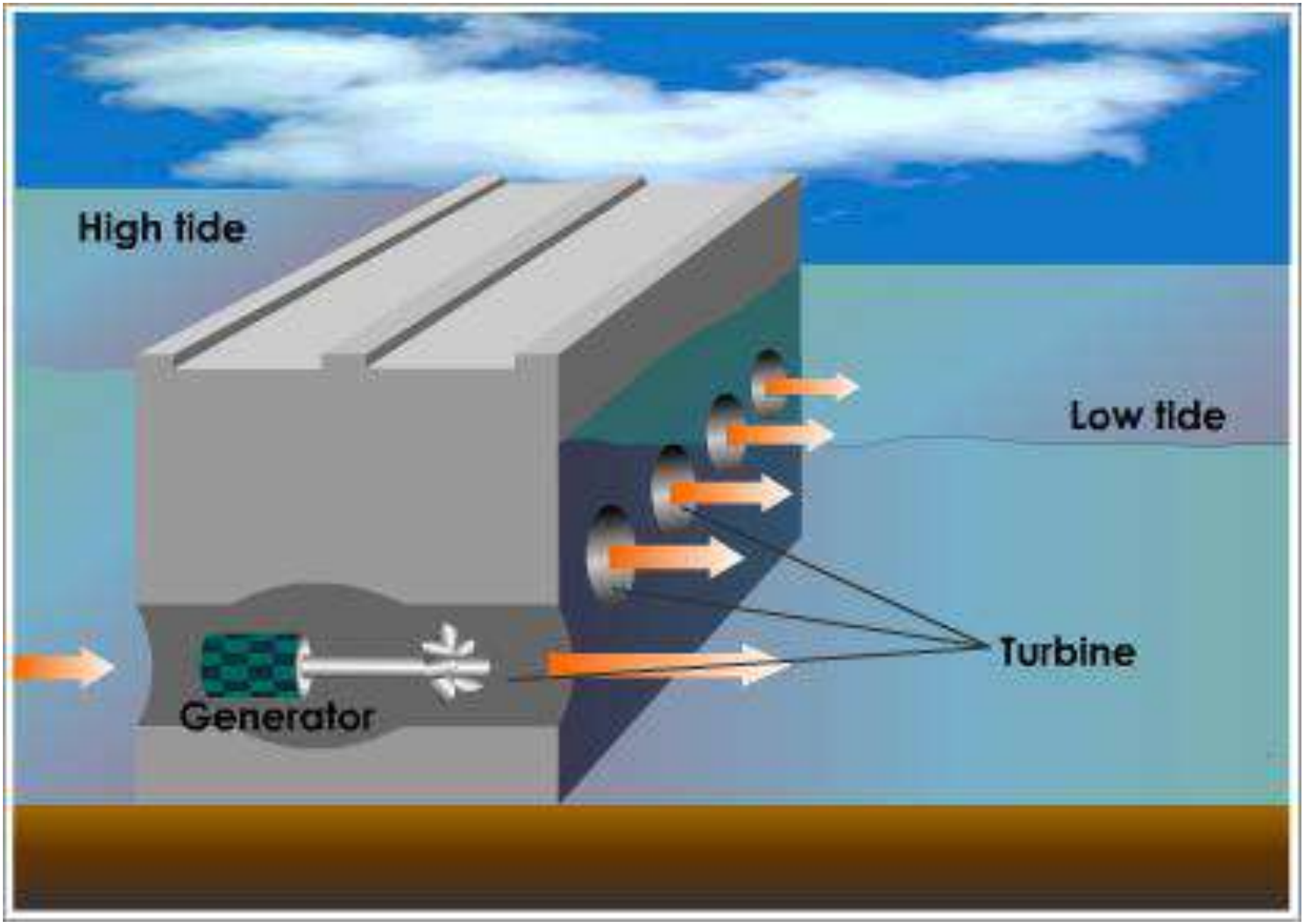
Disadvantages

- Possibility of depletion of geothermal sources.
- High investment.
- Energy is difficult to transport.
- Can suddenly stop working(depends on source)

Tidal Energy

- Tides in sea are result of gravitational effect of heavenly bodies like sun & moon.
- Periodic rise & fall of water level of sea is known as Tide.
- These tides are used in producing electric power known as tidal power.
- If water is above sea level it is known as flood tide.
- If water is below sea level it is known as ebb tide.
- To harness the tides, a dam is built .


Tidal barrage
(or Tidal dam)
Reservoir
High tide
Turbine
Water
SEA
At high tide,water flows from sea into reservoir and turns the turbine


High tide
Low tide
Turbine
Generator

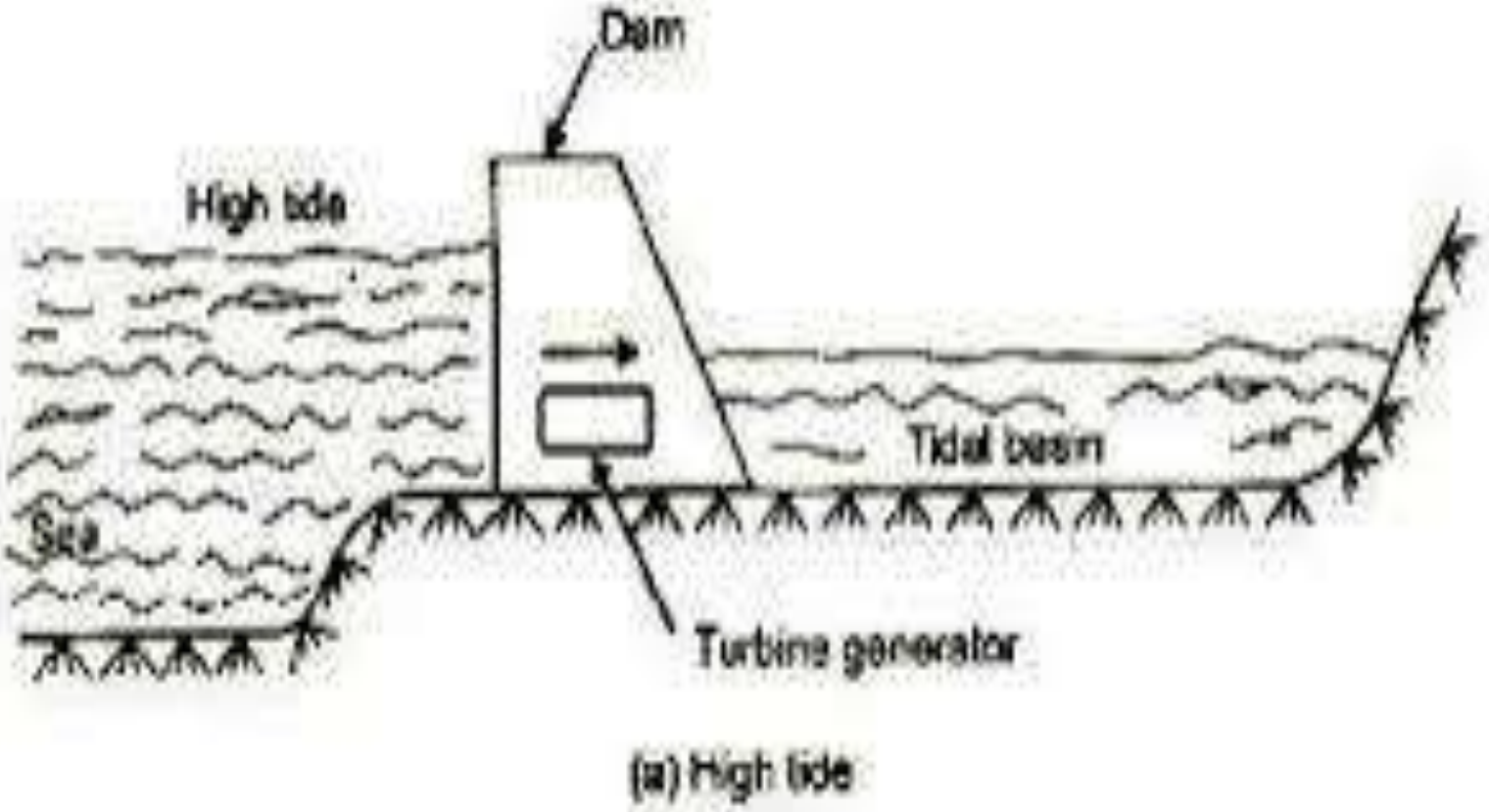
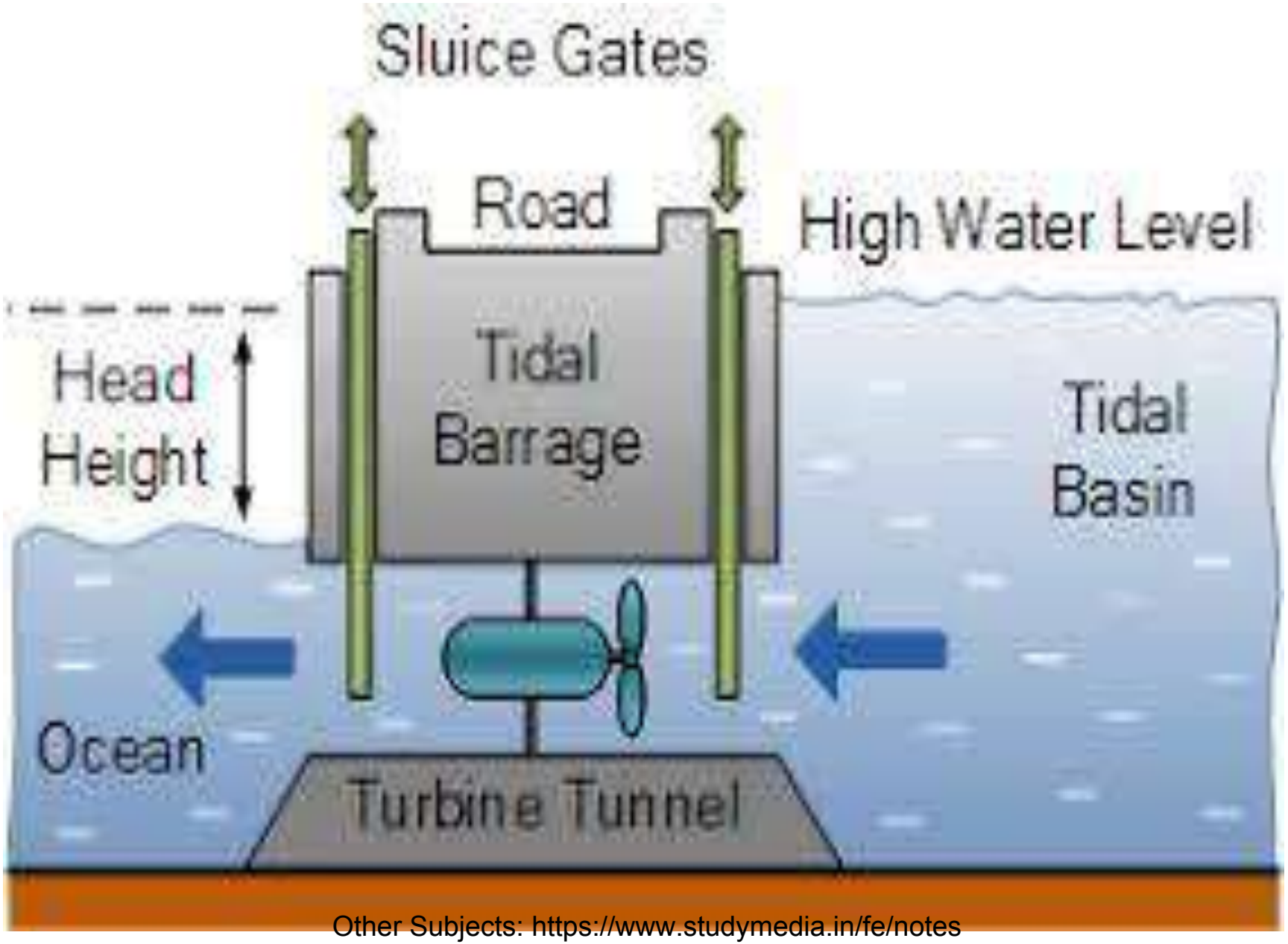


Figure: High tide



- A tidal basin is formed which gets separated from sea by dam.
- Difference in water level is obtained between basin & Sea.
- Basin is filled with high tide & emptied with low tide.
- P.E of water stored in basin as well as energy during high tide is used to drive the turbine.
- The plant continues to generate power till the tide reaches its lowest level.

Advantages

- Pollution Free.
- Renewable source.
- More efficient than wind & solar energy.
- Construction cost high but low maintenance cost.

Disadvantages

- Expensive.
- Sea water is corrosive which can damage turbine.
- Power will be developed only when high tide.
- Transmission of power is expensive & difficult.

Hydrogen Energy

- Attractive feature:- it can be produced from water which is easily available in nature.
- Hydrogen has the higher energy content per unit mass of any chemical fuel.
- Its burning process is also non polluting.
- Combination of hydrogen with oxygen results in liberation of energy with water.
- Hydrogen is chemically very reactive & hence not found in its free state on earth.
- Applications in nitrogeneous fertilizers & coal liquefaction, Electric power producing fuel cells, can be used as a fuel for Gas turbine & petrol engine .
- As the heating value of hydrogen is high it is used in air crafts to reduce take off loads.

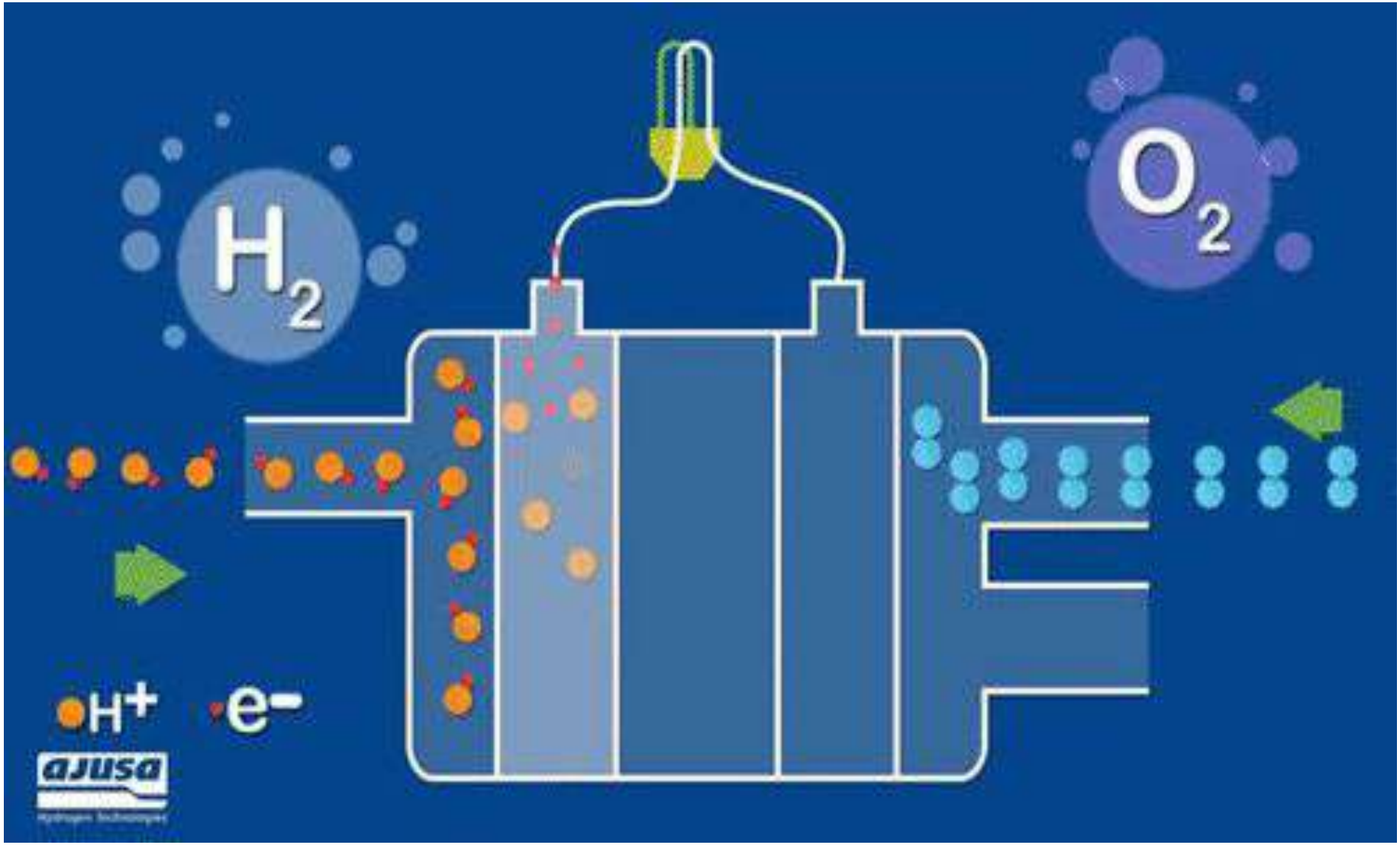
Hydrogen Fuel

- Zero emission fuel when burned with oxygen.
- It can be used in fuel cells or internal combustion engines
- It has begun to be used in commercial fuel cell vehicles such as passenger cars, and has been used in fuel cell buses for many years.
- It is also used as a fuel for spacecraft propulsion.

Combustion

- Hydrogen is the first element on the periodic table, making it the lightest element. Since hydrogen gas is so light, it rises in the atmosphere and is therefore rarely found in its pure form, H_2.
- In a flame of pure hydrogen gas, burning in air, the hydrogen (H_2) reacts with oxygen (O_2) to form water (H_2O) and releases energy.
- $2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (g) + \text{energy}$

Hydrogen Fuel Cell



Working Principle

- A fuel cell is composed of an anode, a cathode, and an electrolyte membrane. A fuel cell works by passing hydrogen through the anode of a fuel cell and oxygen through the cathode. At the anode site, the hydrogen molecules are split into electrons and protons. The protons pass through the electrolyte membrane, while the electrons are forced through a circuit, generating an electric current and excess heat. At the cathode, the protons, electrons, and oxygen combine to produce water molecules.

Advantages

- Renewable energy source.
- Bountiful in supply.
- Clean energy source.
- Nontoxic.
- Used for powering spaceships.

Disadvantages

- Expensive.
- Low density of hydrogen so more storage complications.
- Highly flammable.
- Transportation is difficult.

Biomass Energy

- Biomass is plant or animal waste used for production of energy.
- Produced by growth of microorganisms, plants or animals.
- It includes energy from all plant matter & animal dung.

Biomass Resources

- Agricultural Residues.
- Animal Waste.
- Forestry Residues.
- Wood wastes.
- Industrial Wastes.

Biomass Conversion

1.Thermochemical Conversion:-

- Gasification takes place by heating biomass with limited oxygen to produce low heating value gas.

- It can also take place by reacting biomass with steam & oxygen at high pressure & temperature to produce medium heating value gas.

- Fuel gas produced can be used in liquefaction by converting it into methanol or ethanol.

2. Biochemical conversion:

a. Anaerobic Digestion:-

- Involves microbial digestion of biomass under anaerobic conditions.

- Process takes place at low temperature 65 °c & requires 80 % moisture.

- This generates Carbon dioxide & methane: used as synthetic natural gas.

b. Fermentation:-

- Breakdown of complex molecules in organic compound with the help of ferment such as yeast ,bacteria ,enzymes.

- After anaerobic digestion and fermentation , the residue & other feed stuffs contains high protein content which can be useful cattle feed supplement.

Biomass Conversion Technologies

- Biomass fuel is burned in a boiler to produce high pressure steam.
- Steam is introduced in a steam turbine where it flows over series of turbine blades causing the turbine to rotate.
- Turbine is connected to an electric generator.
- Steam flows over & turns the turbine.
- The electric generator rotates & produces electricity.

Biomass Gasification

- It is the production of gas from biomass under restricted air supply for the generation of producer gas.

- Producer gas contains 18 -22 % CO ,8-12% Hydrogen,carbon dioxide,2-4 % Methane & 45-50 % Nitrogen.

- Following processes takes place in biomass gasifier:-

1. **Drying:-**

- Biomass fuels usually contains 10-35 % moisture.

- When biomass is heated to 100 ° C ,moisture is converted into steam.

2. Pyrolysis :-

- It involves burning biomass completely without supplying any oxygen.
- Charcoal is the solid part, tar is the liquid part & flue gases make up gaseous part .

3. Oxidation:-

- Takes place at 700 – 1400 ° C.
- Charcoal reacts with oxygen in the air to produce carbon dioxide & heat.

$$C + O_2 = CO_2 + \text{Heat}$$

4. Reduction:-

- At higher temperature & reducing conditions , when not enough oxygen is available the following reactions takes place.

- $C + CO_2 = 2\,co$
- $C + H_2O = CO + H_2$
- $CO + H_2O = CO_2 + H_2$
- $C + 2H_2 = CH_4$

Grades of energy

- Low Grade Energy

  -Energy which can be partly converted in to work is called low grade energy.

  - Converting in to usefull work is difficult

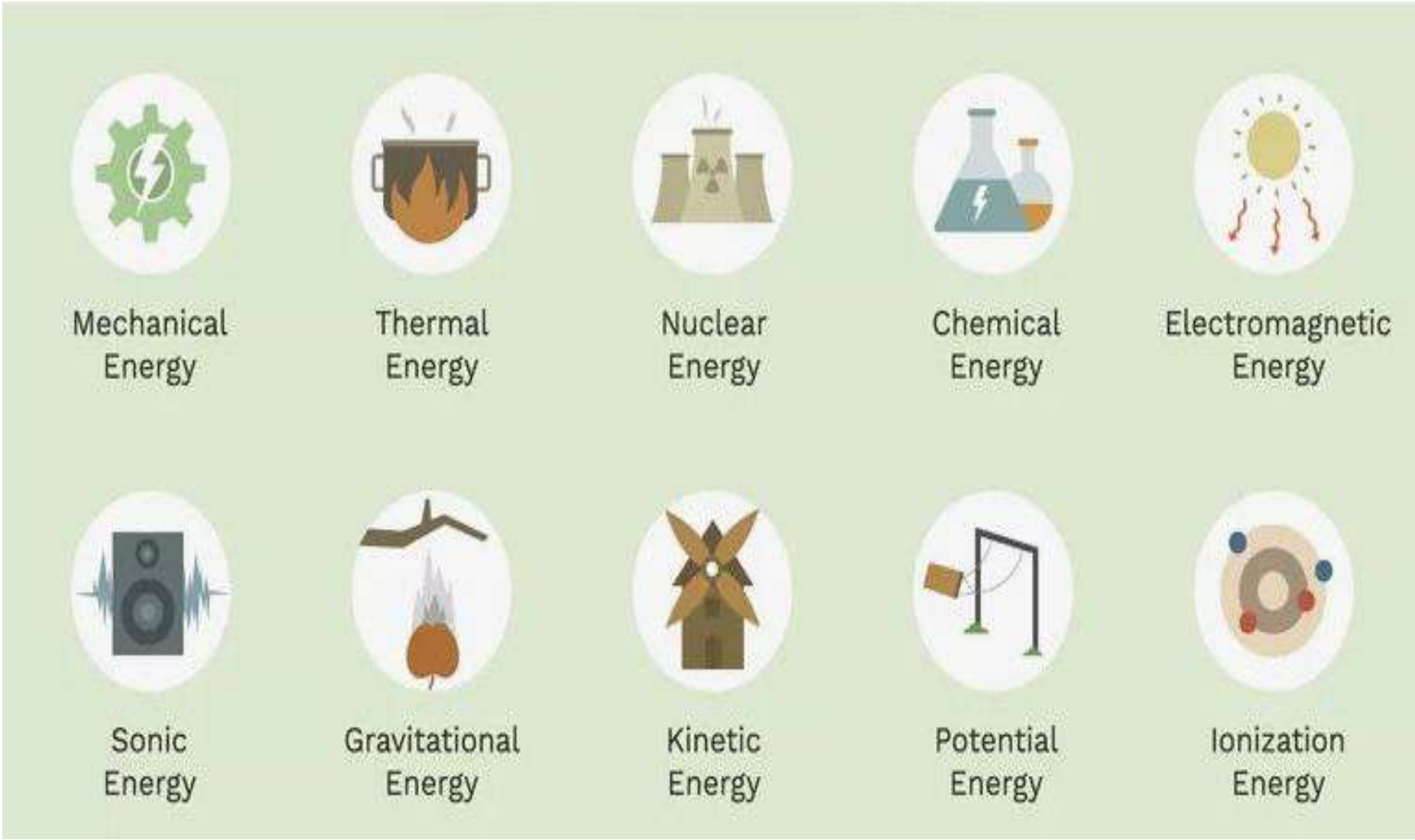
  - available in cheap rate

Example: Heat energy, Solar energy, Fossil fuel combustion

High Grade Energy

- Energy that can be easily converted in to usefull work is called high grade energy
- 100% utilisation of energy
- Expensive energy
- Example: Electrical energy, Mechanical Energy, Hydraulic energy, Wind energy, Tidal energy

Grades Of Energy



Numericals Based on Steam Power Plant

1. A Steam Power Plant has Coal Consumption of 165 Tons Per Hour. Calorific Value of Coal is 3500 kcal/kg. If the power generation is 250 MW, find overall efficiency of the plant. Use relation 1 kcal = 4.18 kJ.
2. A small generating plant of 100 KW capacity uses gas of a calorific value of 4000 KJ/m3.The volume of gas required per hour when the plant is running at full load condition is 450 m3 / hr. Find: (a) Input Power and (b) Overall Efficiency of the plant.
3. A Steam Power Plant has Coal Consumption of 16200 Kg/hr with Calorific Value of Coal as 17793.9 kJ/kg. If the speed of steam turbine is 1000 rpm and generated torque is 477464.8293 Nm. Find: (a) Input Power, (b) Output Power and (c) Efficiency.
4. A Steam Power Plant has Coal Consumption of 16300 Kg/hr with Calorific Value of Coal as 17793.9 kJ/kg. If the speed of steam turbine is 1100 rpm, radial distance is 1.5m and generated force is 318309.8862 N. Find: (a) Generated Torque, (b) Input Power , (c) Output Power and (d) Efficiency.
5. Determine the power in the wind if the wind speed is 20 m/s and blade length is 50 Air density ρ = 1.23 kg/m3.

Numericals on pump

1. In a centrifugal pump, work done by impeller is 346kW, If mechanical efficiency is 75% find input power of pump shaft
2. A pump running at an efficiency of 65% delivers an output of 410.4 J/s what is the power consumption

$$\eta_{mech} = \frac{Impeller\ power}{shaft\ power} \times 100$$

$$\eta_{overall} = \frac{output\ power}{shaft\ power} \times 100$$

Numericals on compressor

1. In a single acting single cylinder reciprocating compressor, has indicated power 5.8 kW and brake power 6.25kW find mechanical efficiency
2. Find the mechanical efficiency if the power supplied to reciprocating compressor is 18kW and power actually utilised to run the compressor is 10kW

$$\eta_{mech} = \frac{indicated\ power}{brake\ power} \times 100$$

$$\eta_{mech} = \frac{output\ power}{brake\ power} \times 100$$

Systems In Mechanical Engineering

Unit 1

Energy Conversion Devices

Mr. Girish G Khope

Energy Conversion Devices

- *A device which is used to convert one form of energy into another form of energy is called as "Energy Conversion Device".*

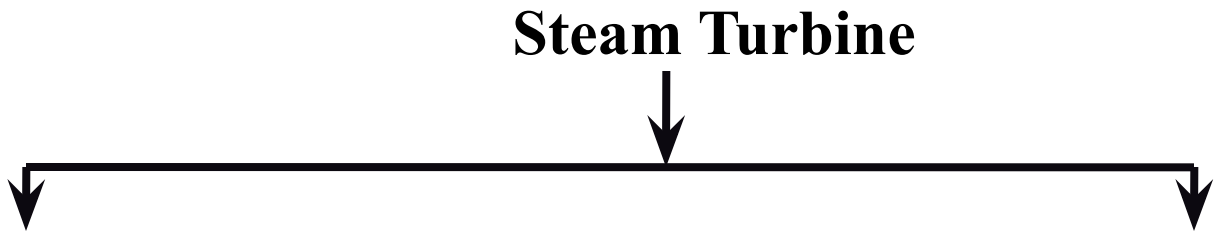
- *According to energy conversion they are classified into two categories.*

  i) ***Power Producing Devices****: Boilers; I.C. Engines; Steam Turbines;*

  ii) ***Power Absorbing Devices****: Compressor, pump, Air conditioner, Refrigerator*

Steam Turbines

Steam Turbines: is rotary machine which is designed to convert the energy of high pressure and high temperature steam into mechanical power



Impulse Turbine

Expansion of Steam takes Place in only one set of Nozzles.

e.g. De-Laval Turbine, Curties Turbine, Rateau Turbine

Reaction Turbine

Expansion of Steam takes place in every set of fixed blades. Fixed Blades acts as Nozzles

e.g. Parson's Turbine

Impulse Turbine

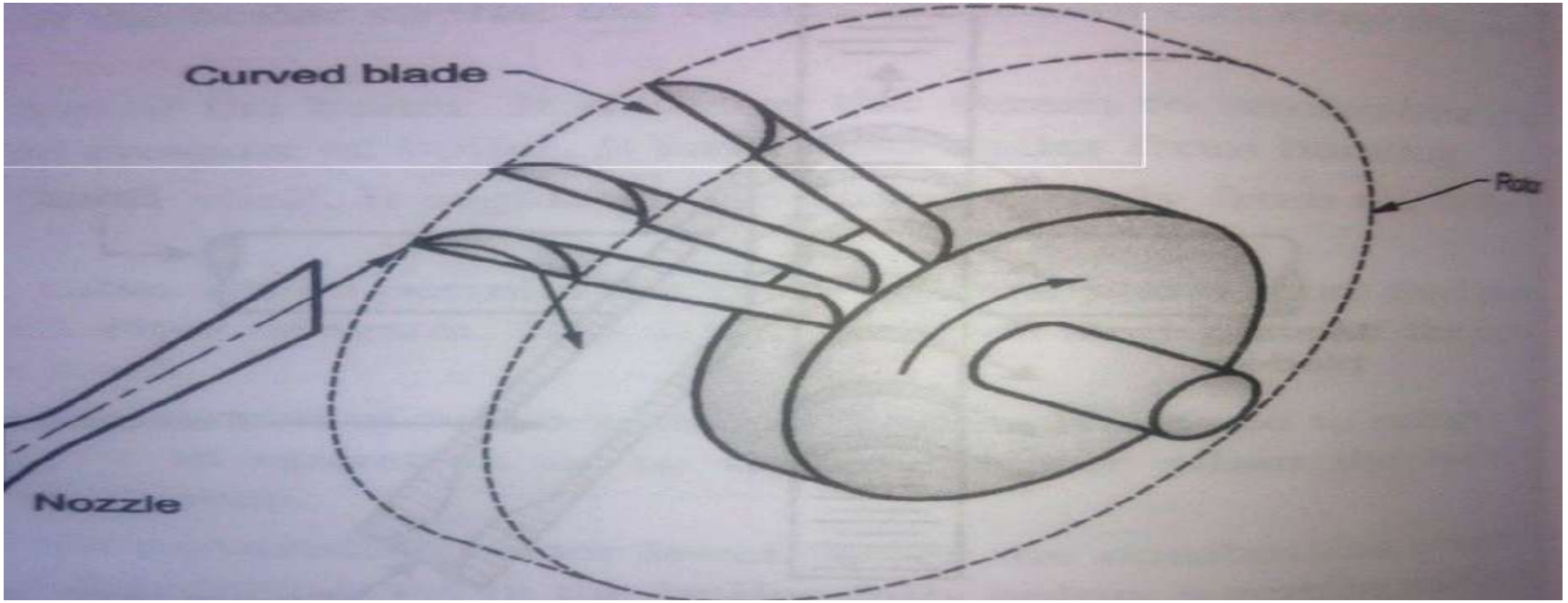
- It carries one set of nozzle, where in the pressure energy of steam is converted into kinetic energy

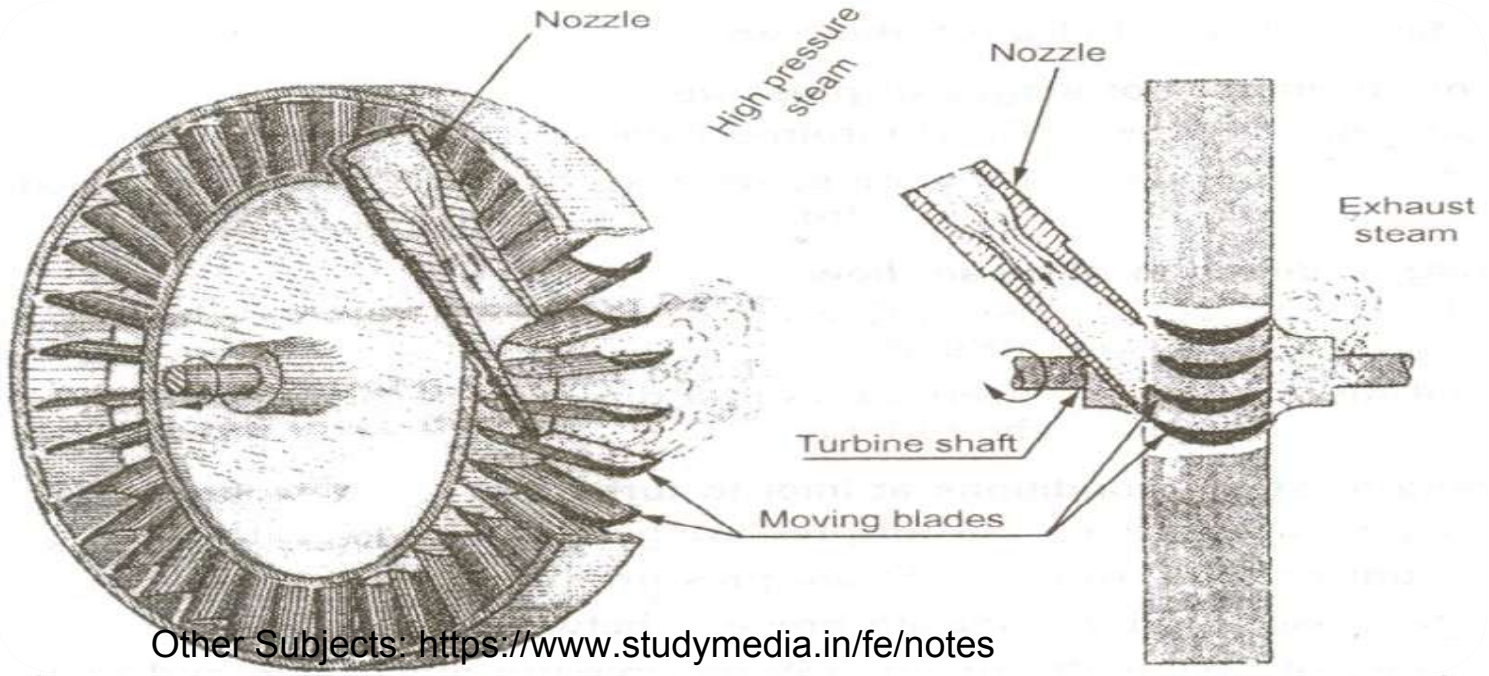
- The high velocity steam is passed over the moving blade. Change in momentum will exerts force on moving blade

- The turbine blades are attached to a rotor mounted on a shaft. The resultant force would cause to rotor to rotate. Thus mechanical power is developed

- Rotor shaft connected to generator shaft, which generates the electricity.

- e.g. De-Laval Turbine, Curties Turbine,Pelton Wheel





Reaction Turbine

- It carries set of alternate fixed and moving blades.

- Fixed blades

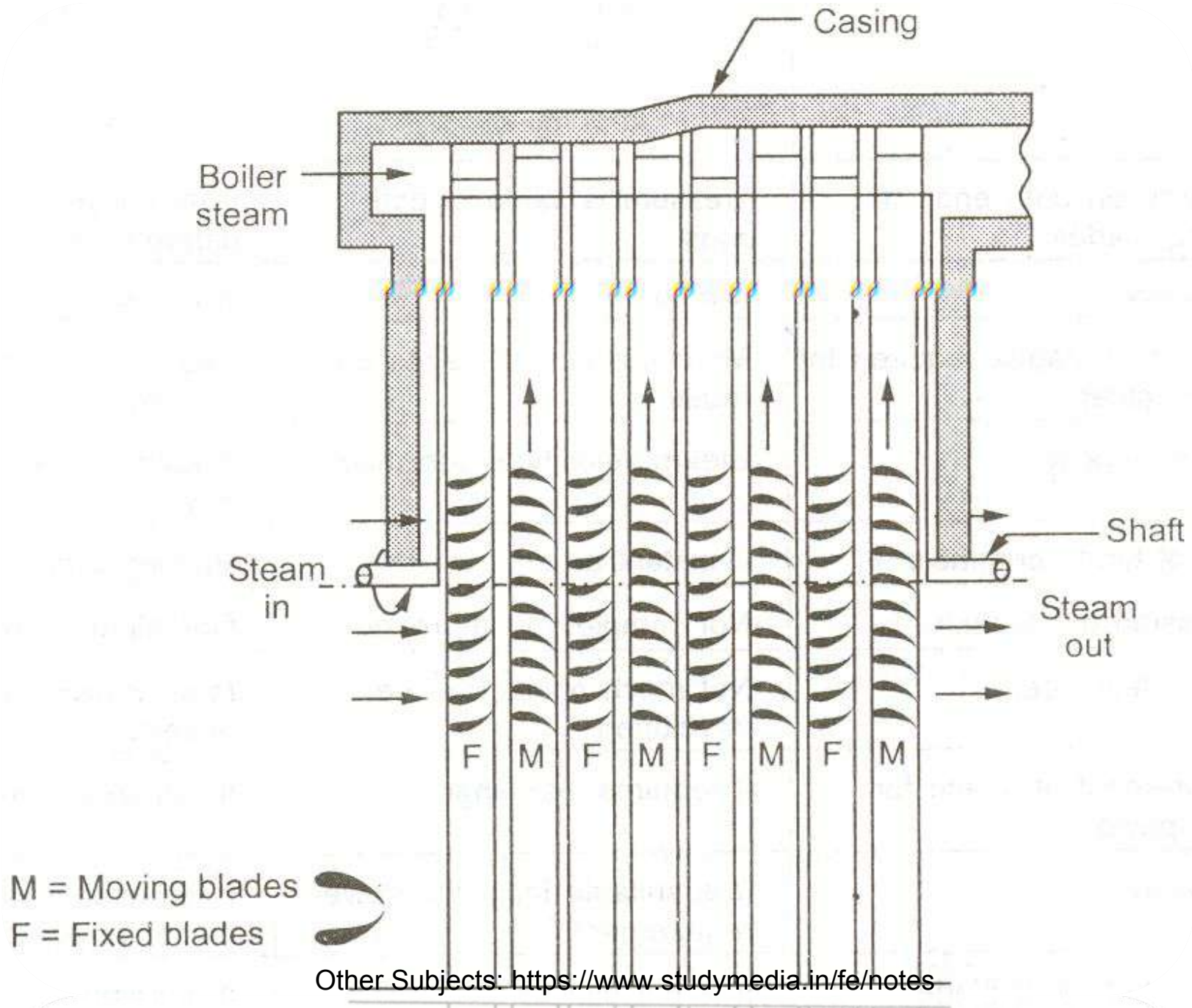
  – it acts as nozzle, which increases velocity of steam by decreasing pressure.

  – it is blades attached to the casing.

- Moving blades – attached over rotor disc.

- Pressure drop takes place when steam strikes to moving blades. in this turbine, Pressure of steam progressively reduces.

- K.E. of steam converted into mechanical energy causes rotation of rotor disc and rotor shaft.



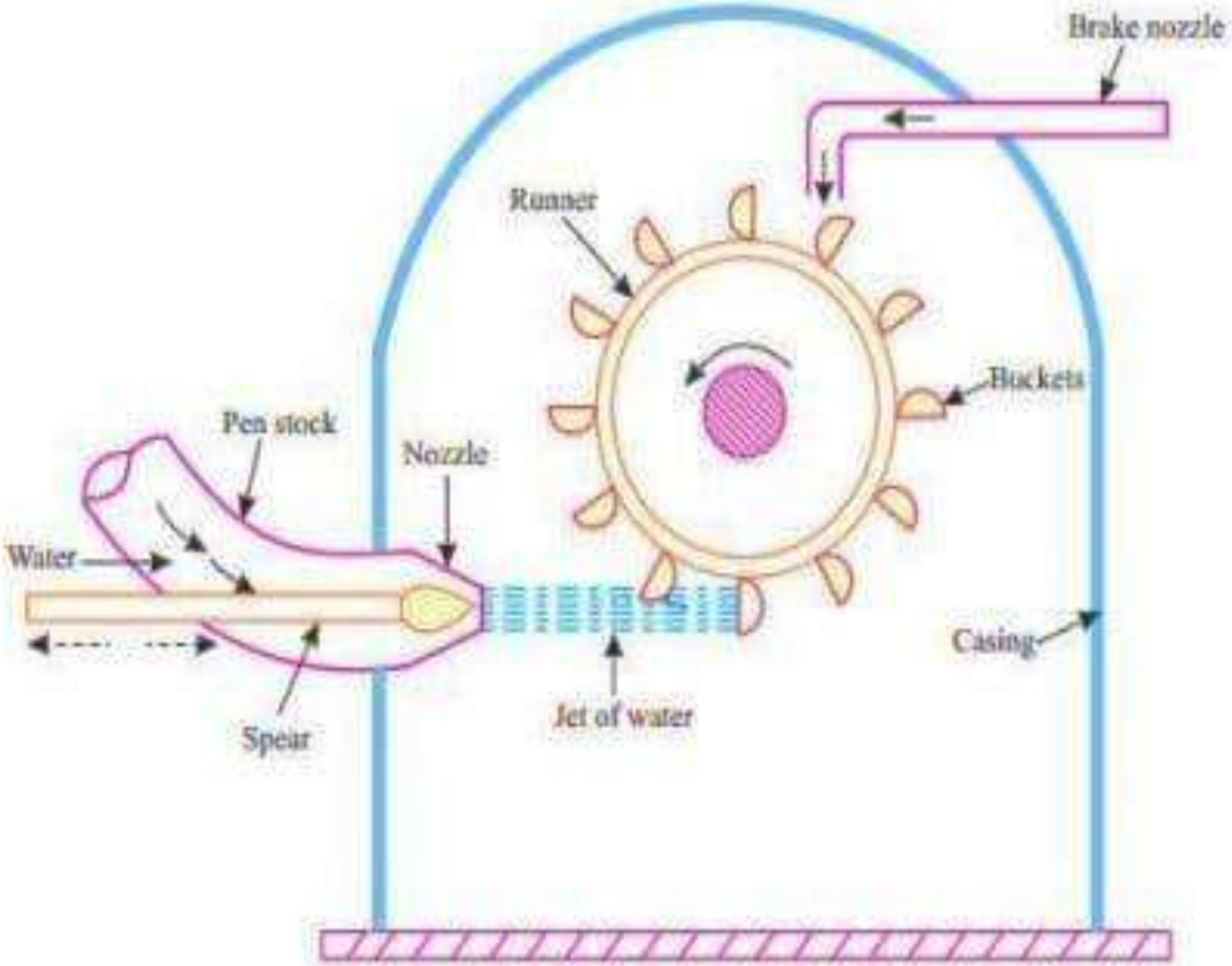
Difference between Impulse and Reaction Turbine

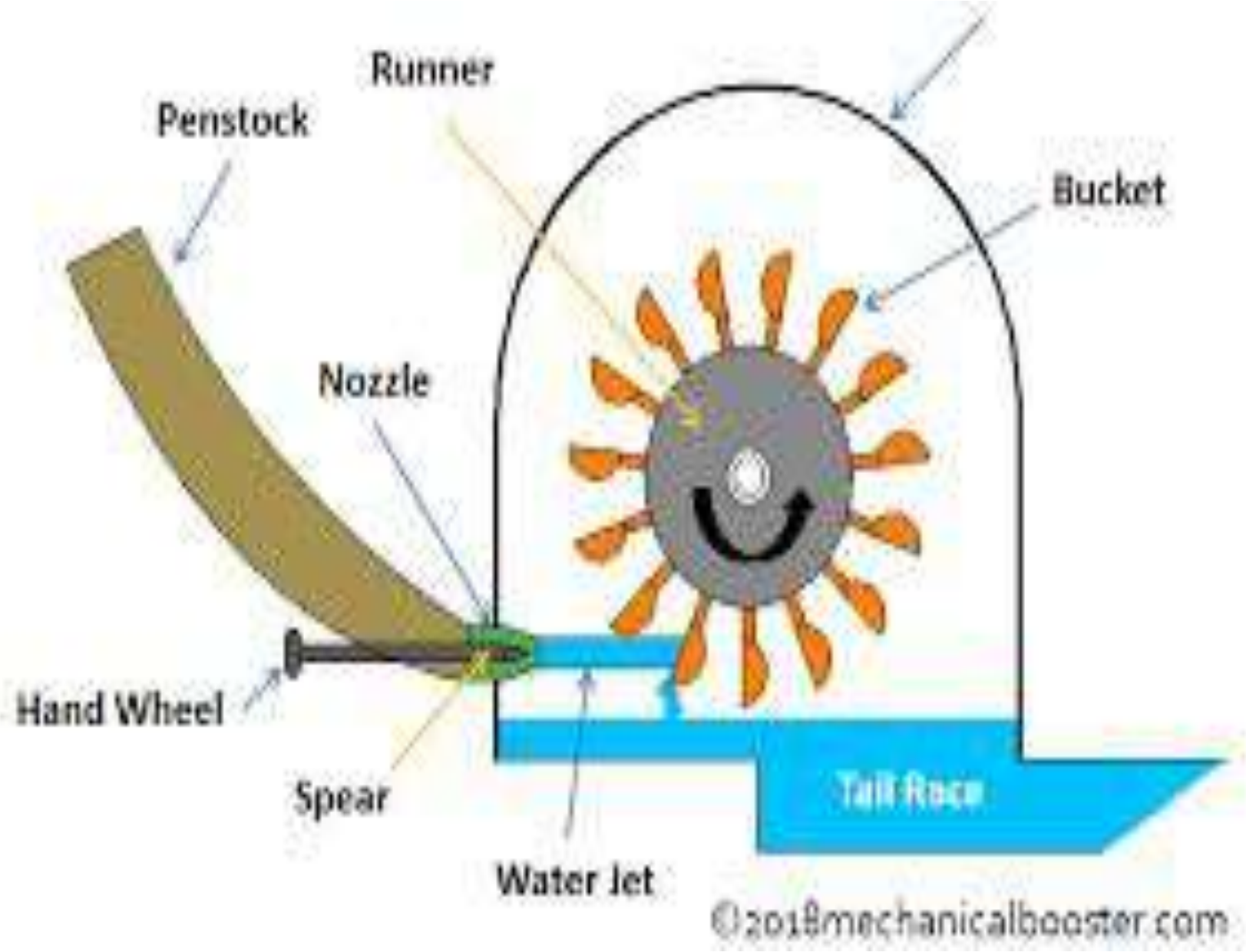
Impulse Turbine	Reaction turbine
Pressure drops only in nozzle and not in moving blades channel.	Pressure drops in nozzle as well as in moving blades channel.
Blades are of profile shape.	Blades are of aerofoil shape.
Blade channel area is constant	It is varying
Power produced using these turbines is comparatively less	More power can be produce.
Velocity of steam is higher.	Velocity of steam is lower
It requires less space	It requires more space for same power output
Blade manufacturing is simple and less costly	Blade manufacturing is difficult and hence costly.

Pelton Wheel Turbine

- The Pelton wheel or Pelton turbine is a tangential flow impulse turbine.

- The main parts of the pelton turbine are: -
  - Nozzle and flow regulating arrangement.
  - Runner and buckets.
  - Casing.
  - Breaking Jet.




Runner
Penstock
Bucket
Nozzle
Hand Wheel
Spear
Water Jet
Tail Race
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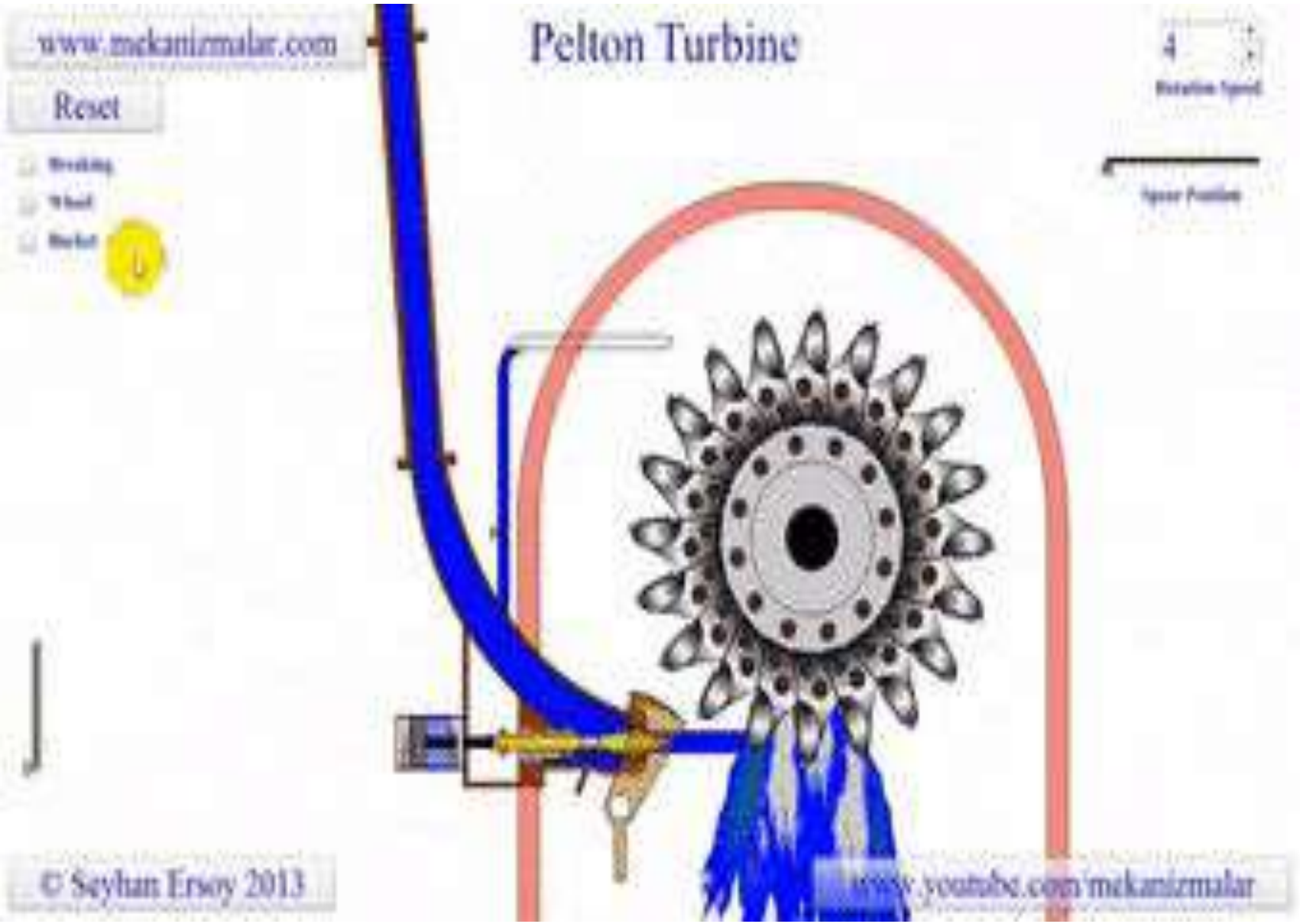
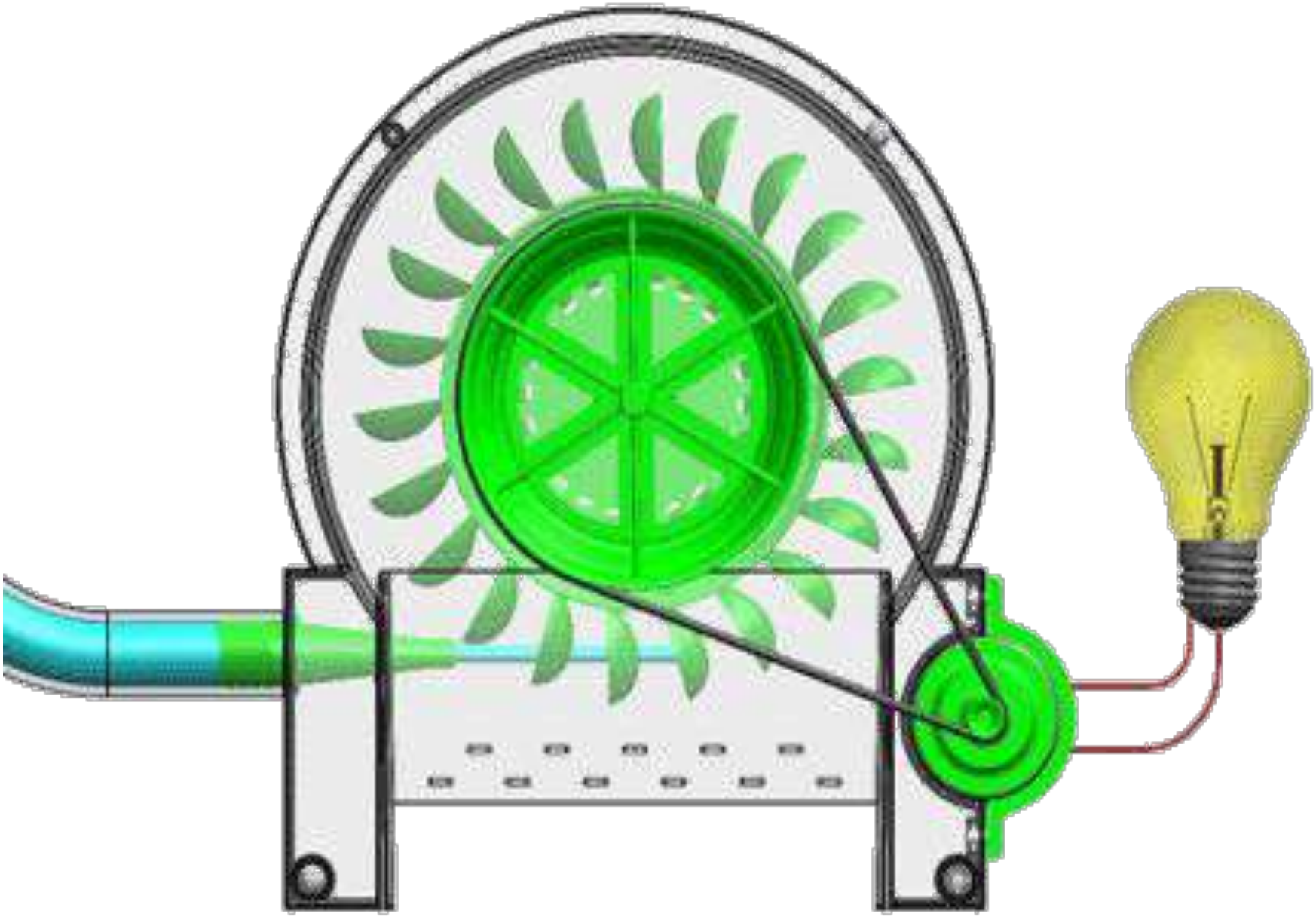




Nozzle and flow regulating arrangement:

- The amount of water striking the buckets of the runner is controlled by providing a spear in the nozzle.
- The spear is a conical needle which is operated either by a hand wheel or automatically in an axial direction depending upon the size of the unit.
- When the spear is pushed forward into the nozzle the amount of water striking the runner is reduced & viceversa.

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.
- Each bucket is divided into two hemispherical parts by a dividing wall which is known as splitter.

Casing:

- The function of the casing is to prevent the splashing of the water and to discharge water to tail race.
- It also acts as a safeguard against accidents. It is made of cast iron or fabricated steel plates.

Breaking Jet:

- When the nozzle is completely closed by moving the spear in the forward direction the amount of water striking the runner reduces to zero.
- But the runner due to inertia goes on revolving for a long time.
- To stop the runner in a short time, a small nozzle is provided which directs the Jet of water on the back of the buckets. This Jet of water is called breaking Jet.

Working of Pelton wheel Turbine:

- The water from the reservoir flows through the penstocks at the outlet of which a nozzle is fitted.
- The nozzle increases the kinetic energy of the water flowing through the penstock by converting pressure energy into kinetic energy.
- At the outlet of the nozzle, the water comes out in the form of a Jet and strikes on the splitter, which splits up the jet into two parts.
- The buckets are shaped in such a way that buckets rotates, runner of the turbine rotates and thus hydraulic energy of water gets converted into mechanical energy on the runner of turbine which is further converted into electrical energy in a generator/alternator

Francis Turbine

- **Francis Turbine**: - The inward flow reaction turbine having radial discharge at outlet is known as Francis turbine, after the name of J.B Francis an American engineer who in beginning designed inward radial flow reaction turbine.
- The main parts of the Francis turbine are: -
  - Penstock
  - Casing
  - Guide mechanism
  - Runner
  - Draft tube

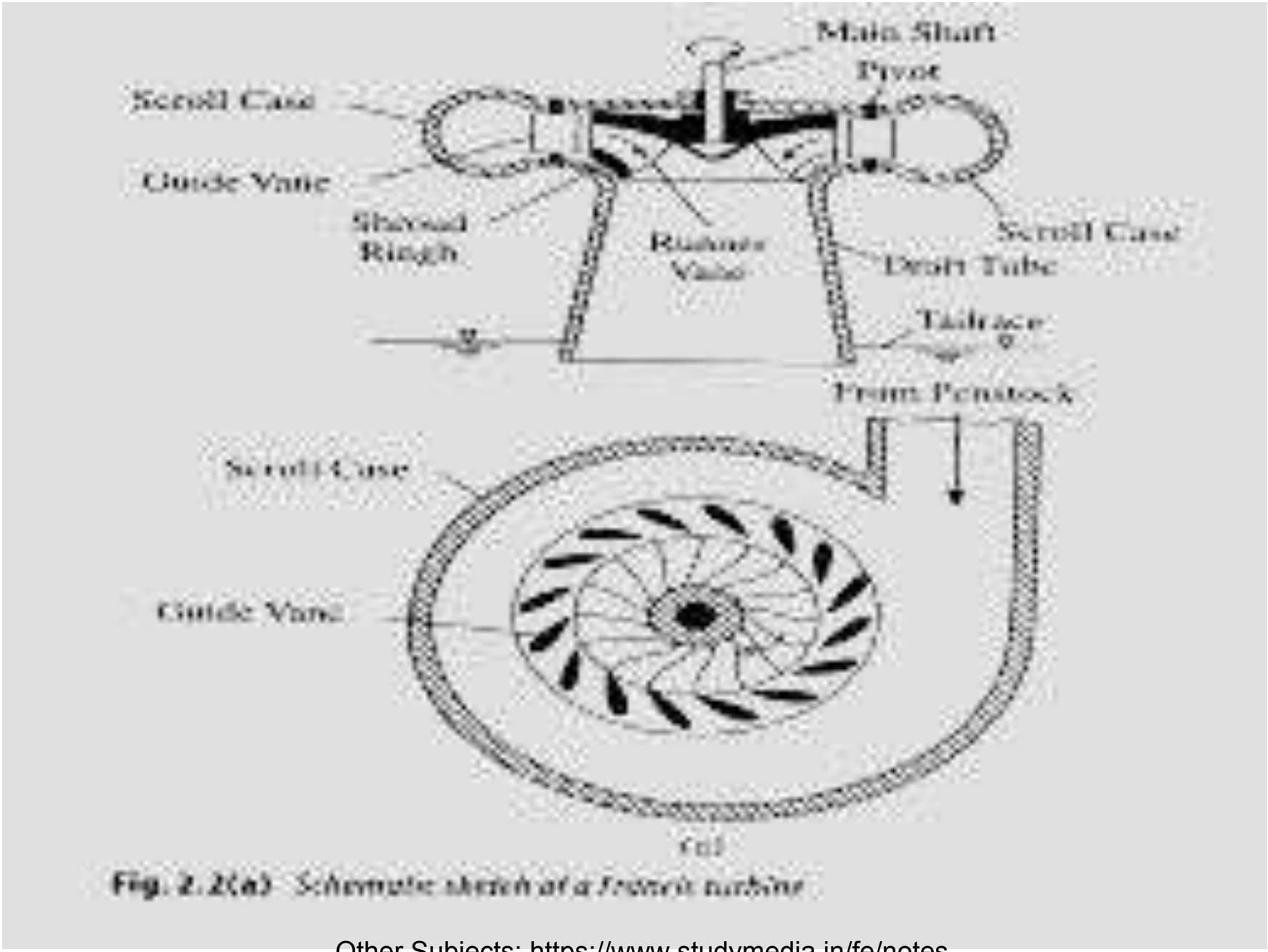
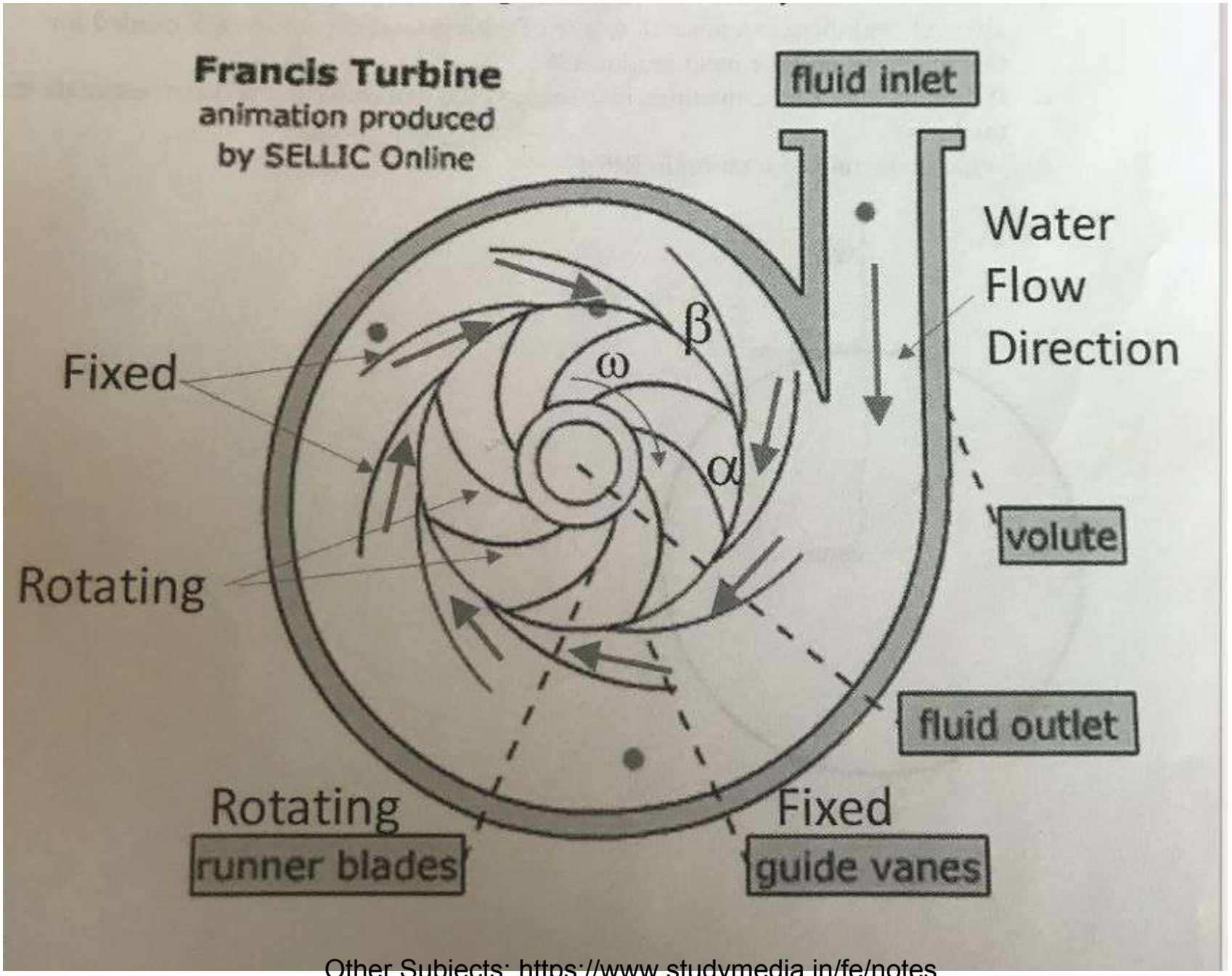


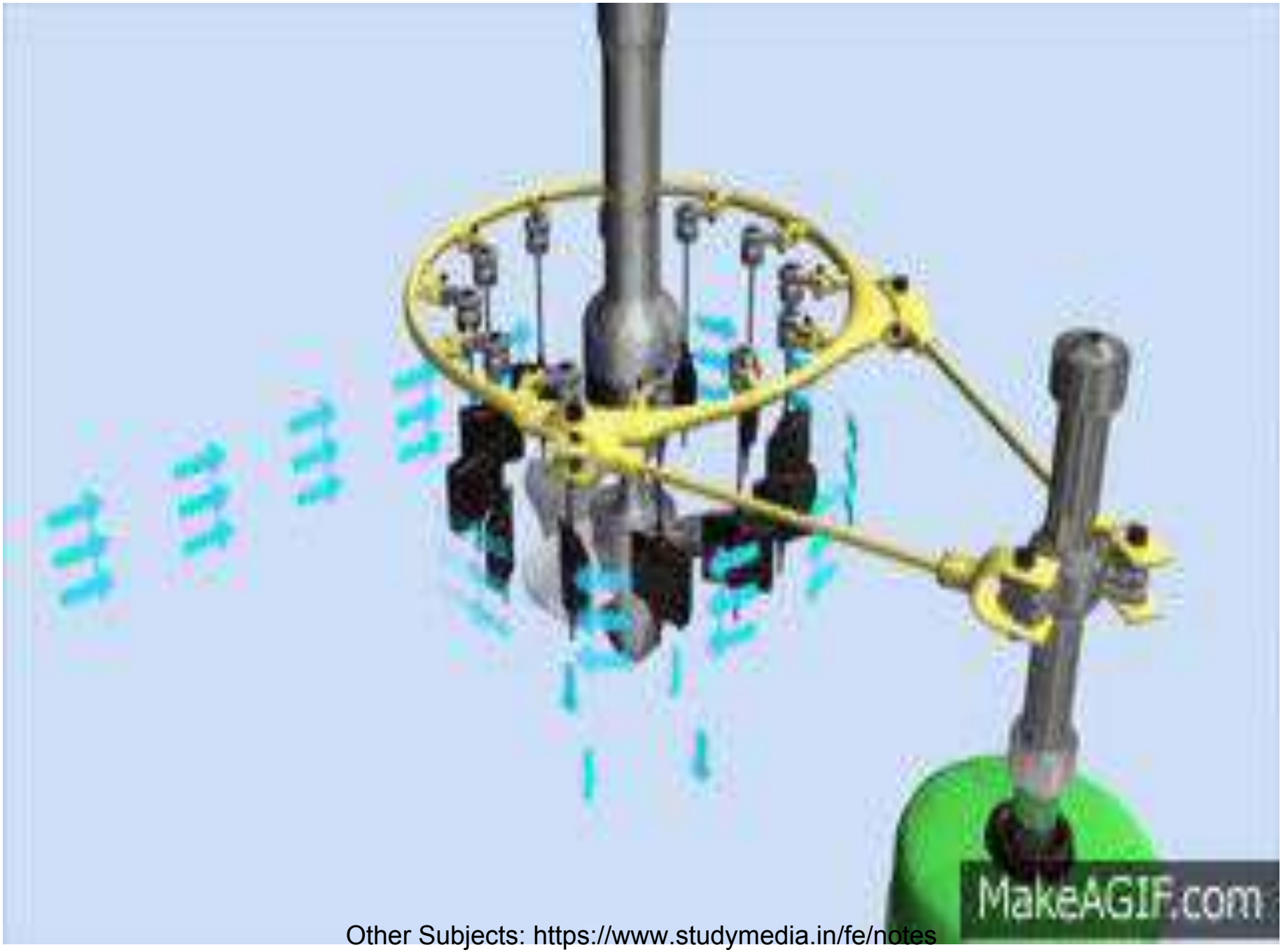
Fig. 2.2(a) Schematic sketch of a Francis turbine




MakeAGIF.com

- **Penstock:** -
  - It is a long pipe at the outlet of which a nozzle is fitted.
  - The water from reservoir flows through the penstock.
  - The nozzle increases the kinetic energy of water flowing through the penstock.

- **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.
  - The casing is made of spiral shape, so that the water may enter the runner at constant velocity through out the circumference of the runner.
  - The casing is made of concrete or cast steel.



- **Guide Mechanism**: -

- It consists of a stationary circular wheel all round the runner of the turbine.
- 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 shake at inlet.
- Also by a suitable arrangement, the width between two adjacent vanes of a guide's mechanism can be altered so that the amount of water striking the runner can vary.

- **Runner: -**

- It is a circular wheel on which a series of radial curved vanes are fixed.
- The surface of the vanes is made very smooth.
- The radial curved vanes are so shaped that the water enters and leaves the runner without shock.
- The runners are made of cast steel, cast iron or stainless steel. They are keyed to the shaft.

Draft tube: -

- The pressure at the exit of the runner of a reaction turbine is generally less than atmosphere pressure.
- The water at exit cannot be directly discharged to the tail race.
- A tube or pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race.
- This tube of increasing area is called draft tube.

Pumps

- Pumps are hydraulic machines which converts mechanical energy into hydraulic energy of a liquid.

- Basic function of pumps is to lift quantity of liquid from lower level to higher level.

- For lifting liquid from lower level to higher level external power is required to perform the work.

Single Acting Reciprocating Pump

Liquid remains in contact with only one side of piston.

Crank & Connecting Rod Mechanism

- Crank mounted on crank shaft & is driven either by I.C. engine or electric motor.
- Crank is connected to the piston by connecting rod. Rotary motion of crank converts into reciprocating motion

Piston and Cylinder

- Piston reciprocates inside the cylinder and cylinder creates a space for working medium.

Suction Pipe

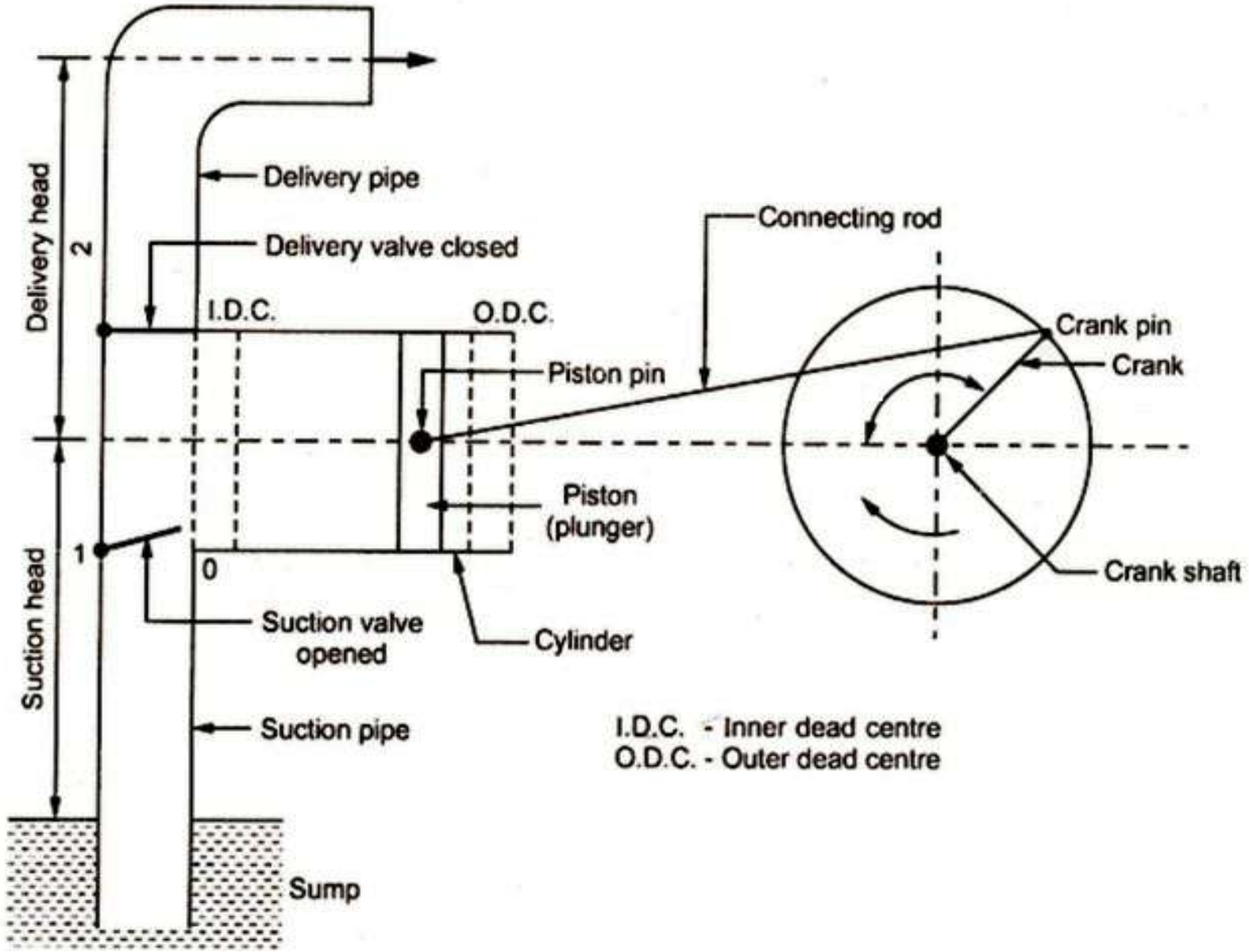
- Pipe connected to the suction of pump,through which the liquid will be sucked from the sump into the cylinder.
- It is provided with non-return valve.

Sump

- Reservoir of liquid from which water will be pumped.

Delivery Valve

- Pipe connected to the discharge end, which delivers liquid at some height from sump at higher pressure.
- It is provided with non-return valve.



Rotary motion of crank is converted into reciprocating motion of piston

Single Acting Reciprocating Pump

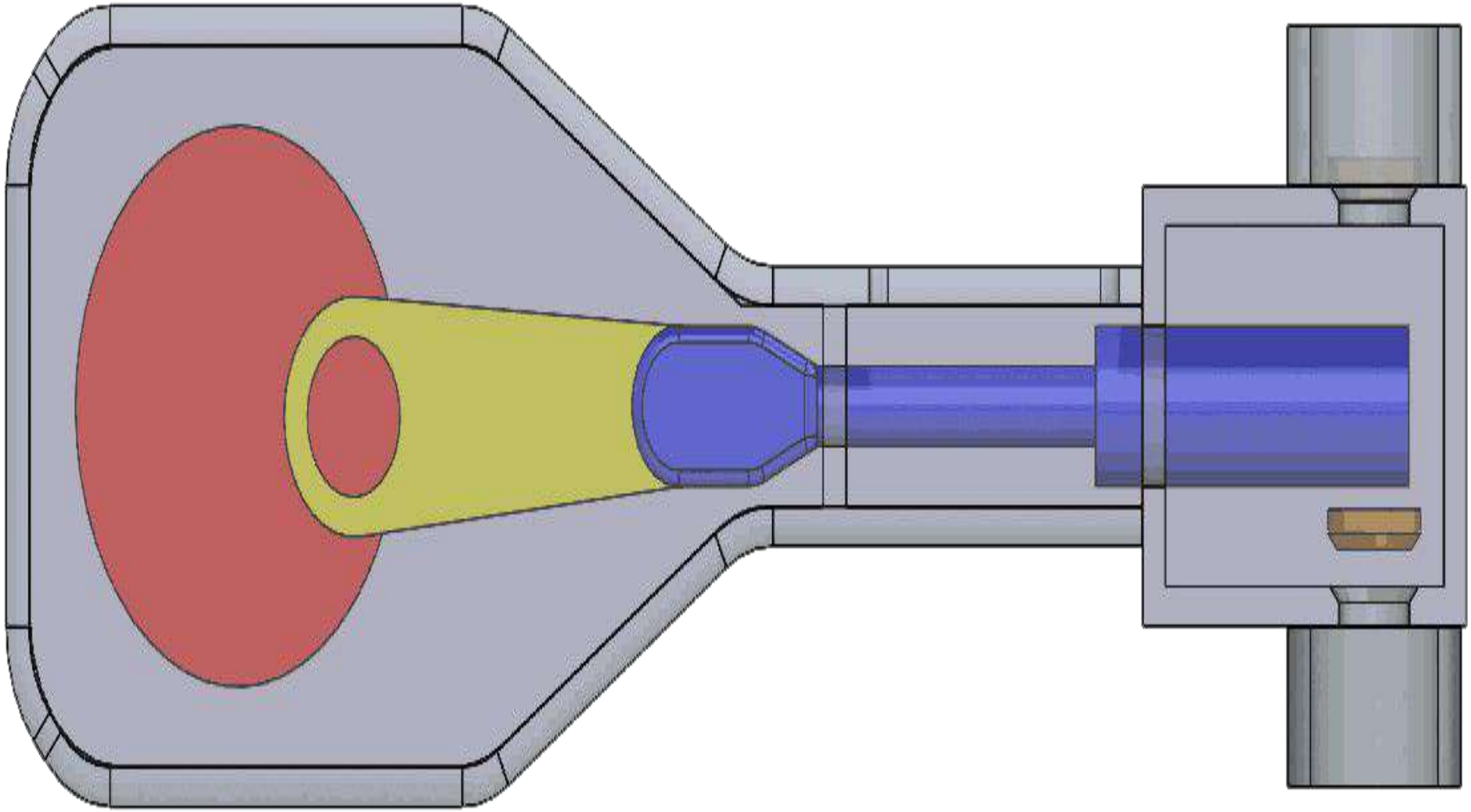
Working:

- **Suction** : Initially crank is at inner dead centre. As crank rotates, piston move toward right and vacuum is created in the cylinder. this vacuum causes the opening of suction valve and simultaneously liquid will be sucked from sump to left side of piston. when crank reaches to O.D.C., the piston is on extreme right position and suction stroke is completed.

- **Compression** When crank rotate from O.D.C to I.D.C., liquid will be compress and high pressure liquid is delivered through delivery valve.

- **Application of Pump:**

- Agricultural and Irrigation purposes.
- In Steam Power Plant to circulate feed water & cooling water.
- Hydraulic control systems (hydraulic jacks) and Pneumatic pressure systems.
- Kerosene pumps, hand operated pumps



Centrifugal Pump

Centrifugal pump: If the mechanical energy is converted into pressure by using centrifugal force acting on the fluid, the hydraulic machine is known as centrifugal pump.

Components:

1.Impeller: it is an wheel or rotor having a series of vanes or blades. Impeller is mounted on shaft which is usually coupled to a motor

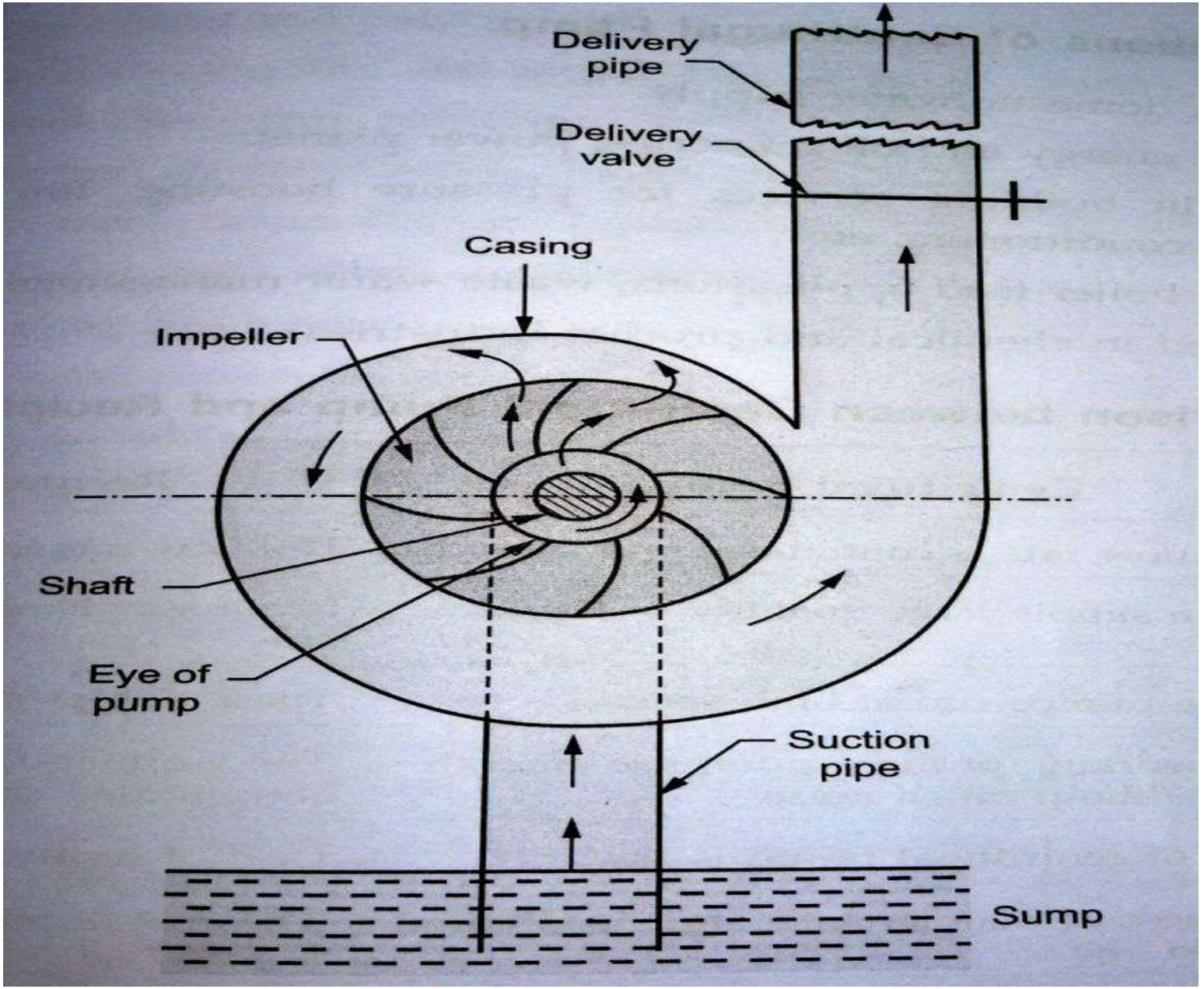
2. Casing. The impeller is enclosed in a water tight casing.

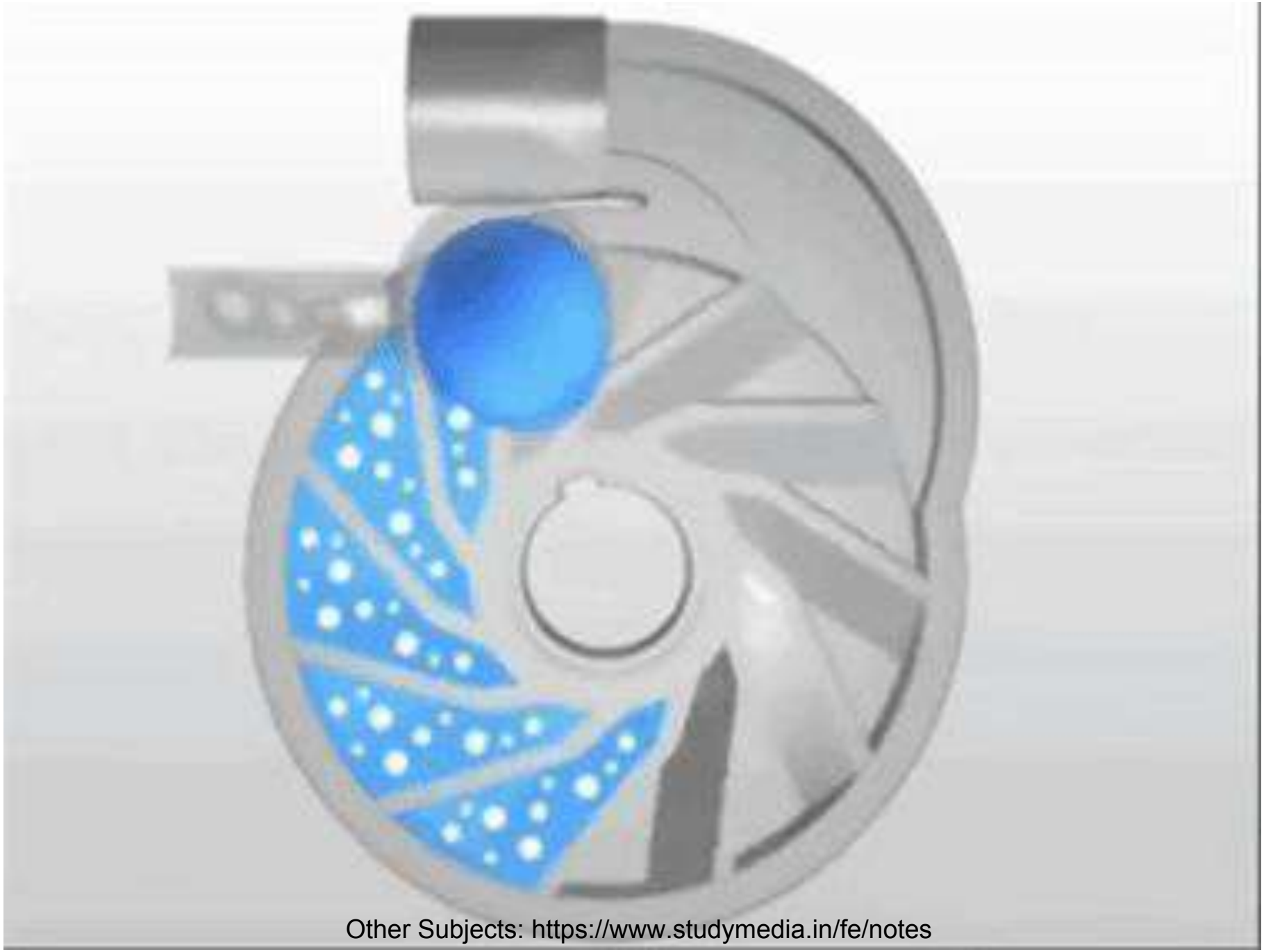
3. Suction pipe: it is pipe which connect the sump to the eye of pump

4. Delivery pipe: pipe which connect outlet of pump to deliver point

Working:

- **Priming**: filling the liquid in suction pipe and casing up to delivery valve so that no air pocket are left in the system
- Pump shaft and impeller is rotated with the help of electric motor.
- Due to rotation of impeller, vacuum is created at the eye of impeller and causes liquid to rise into suction pipe from the sump.
- Speed of impeller should be sufficient to produce centrifugal head.
- Now the delivery valve is opened and the liquid is lifted and discharged through delivery valve due to high pressure





Application:

1. Irrigation purpose
2. Pumping of water in building
3. Agriculture

Difference between Reciprocating and Centrifugal pump

Centrifugal Pump	Reciprocating Pump
The flow rate is continuous and smooth	It is intermittent.
It can supply large quantity of liquid.	It can supply small quantity of liquid only.
These pumps run at high speed	These run at low speed
The working is smooth without much noise	The is noisy.
Low maintenance and installation cost	High maintenance and installation cost
High efficiency	Low efficiency
It requires small floor area	It requires larger floor area

Compressor

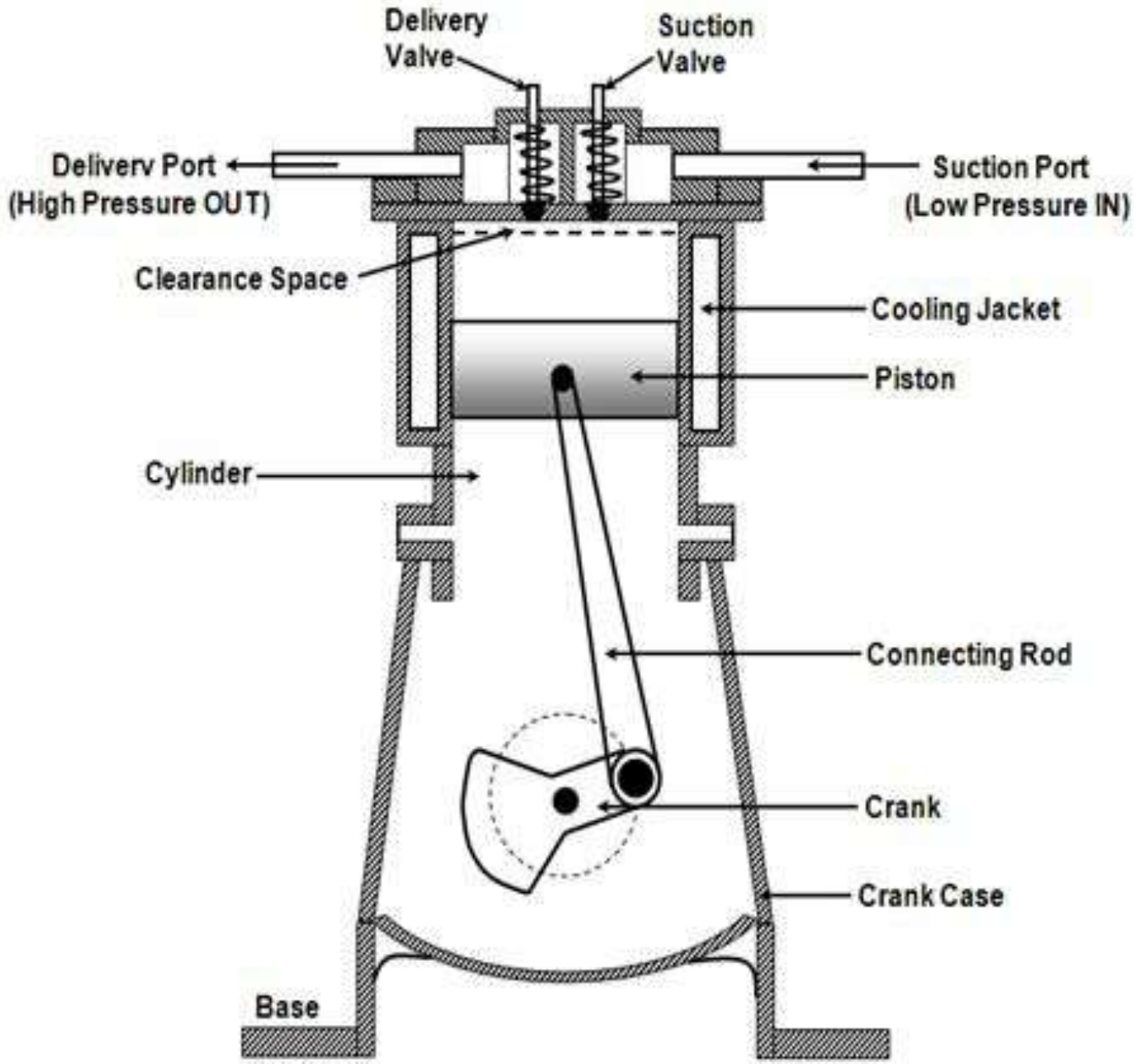
- It is device which compresses atmospheric air and delivers it to higher pressure.

- To compress air at high pressure some external work is required. This external work is provided from electrical motors, I.C. engines or from steam turbines.

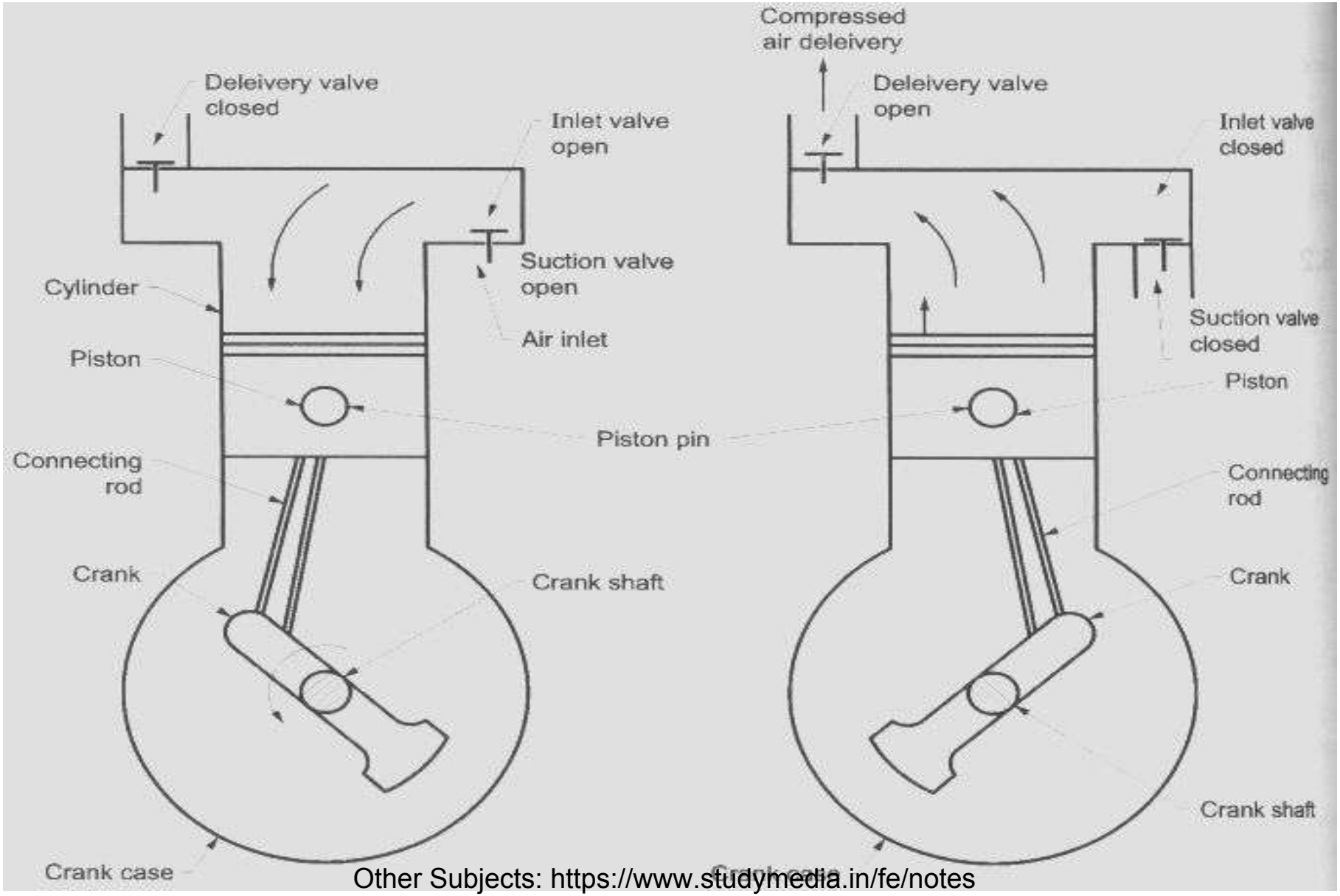
- High pressure developed in compressor is stored in the receiver.

Single Acting Single Stage Reciprocating Compressor

- **Crankshaft :** It is driven by an electric motor.
- **Crank**: Fitted on crankshaft and connects to connecting rod. It can converts rotary motion into reciprocating motion
- **Connecting Rod:** connects Crank & Piston.
- **Piston:** Reciprocates inside the cylinder. it can Creates working volume inside the cylinder.
- **Cylinder:** Closed at one end. Provides working space for air
- **Valves:** Pressure differential type suction and delivery valves
- **Application:** Spray painting,, Gas turbine power plant, Supercharging of IC engines



Working of Single Acting Compressor

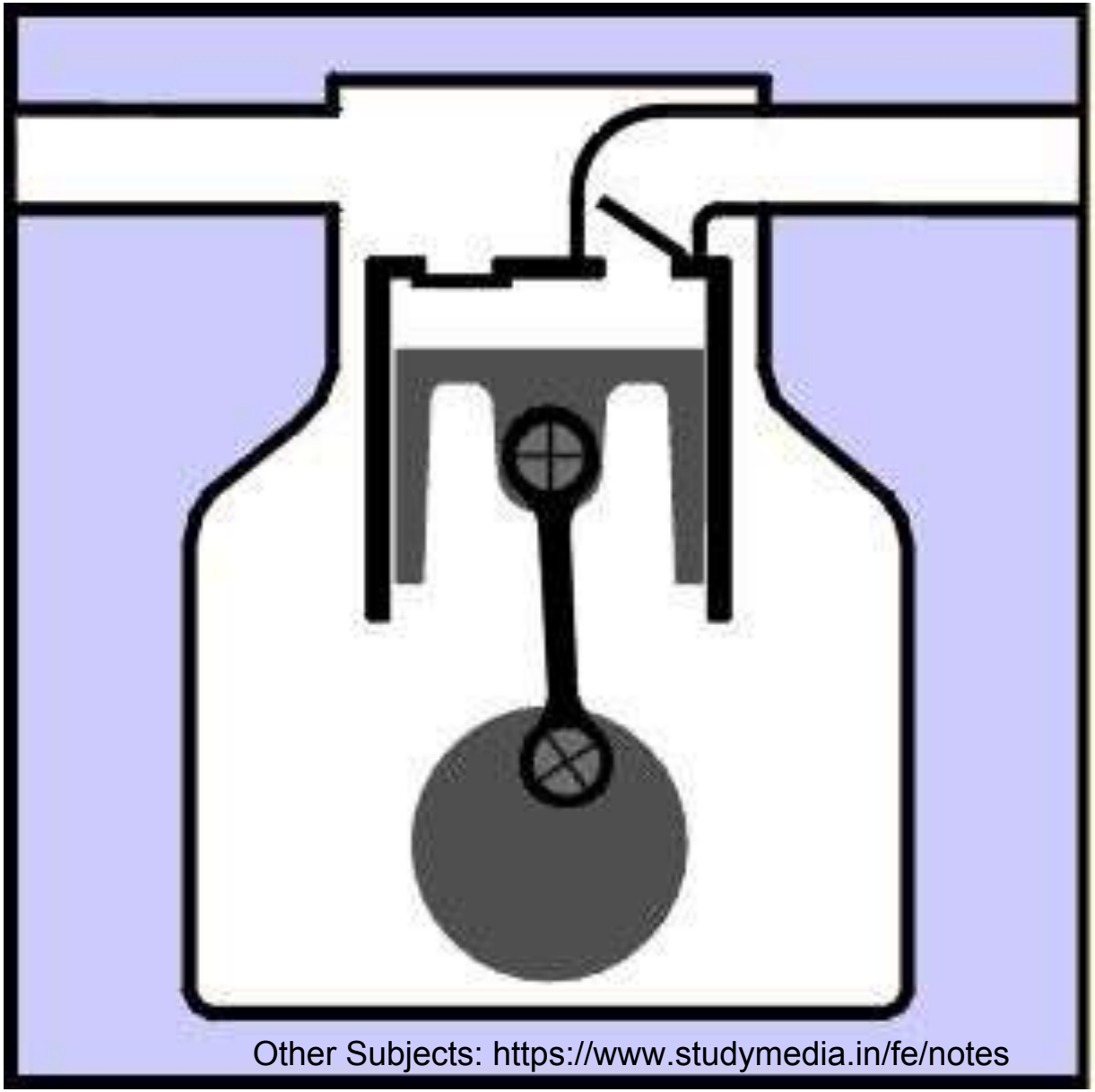


Working of Single Acting Compressor

- **Suction** :When the pressure inside the cylinder fall below atmospheric pressure, the inlet valve open. The atmospheric air is sucked into the cylinder up to end of stroke

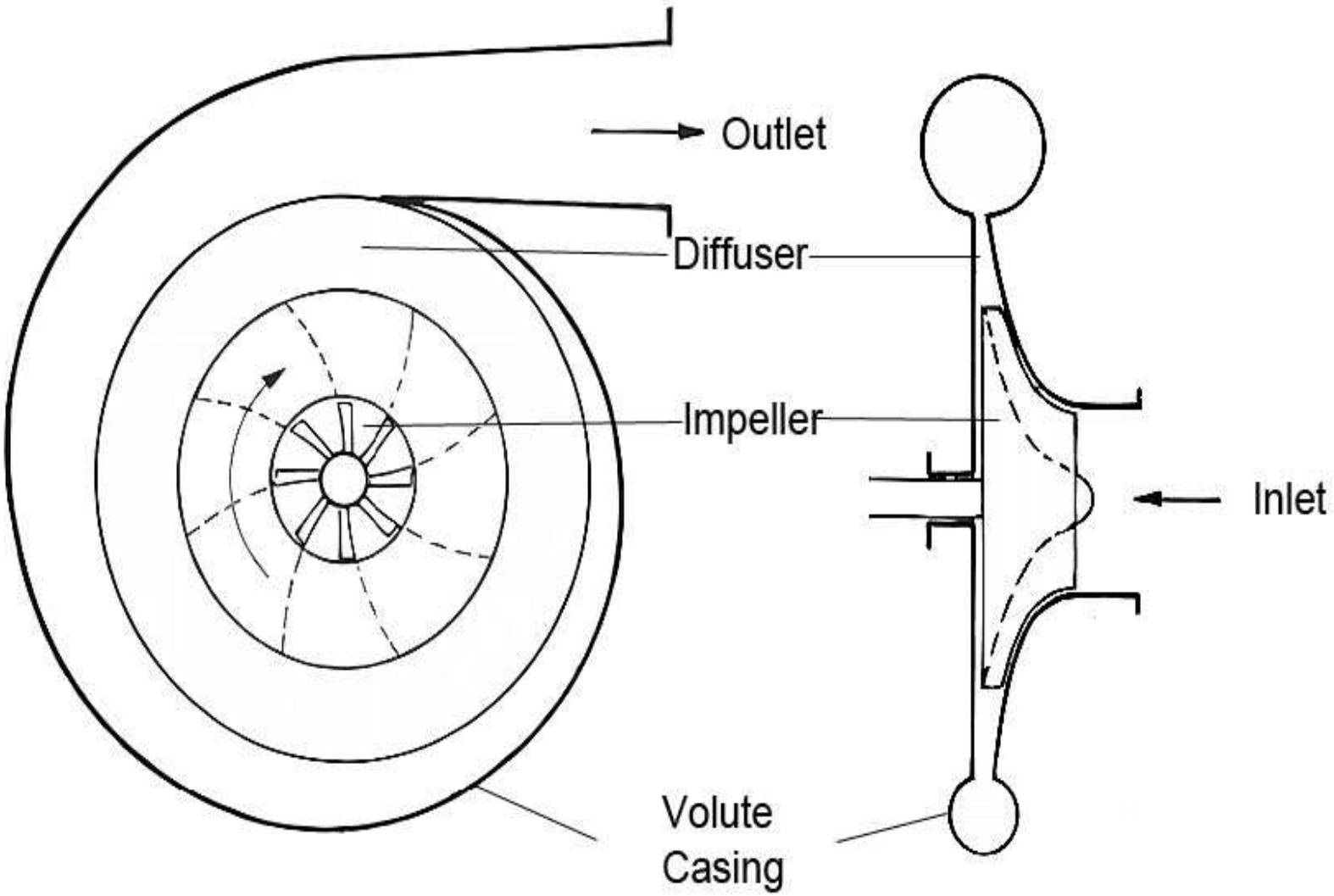
- **Compression and delivery stroke:** when piston is moving upward, suck air is compress due to positive displacement of piston. With further movement of piston upward, air pressure increases. When the pressure inside cylinder reaches above the pressure on deliver side(i.e. receiver pressure), the delivery valve opens. The compressed air from the cylinder is discharged to the receiver.

Reciprocating Compressor Animation

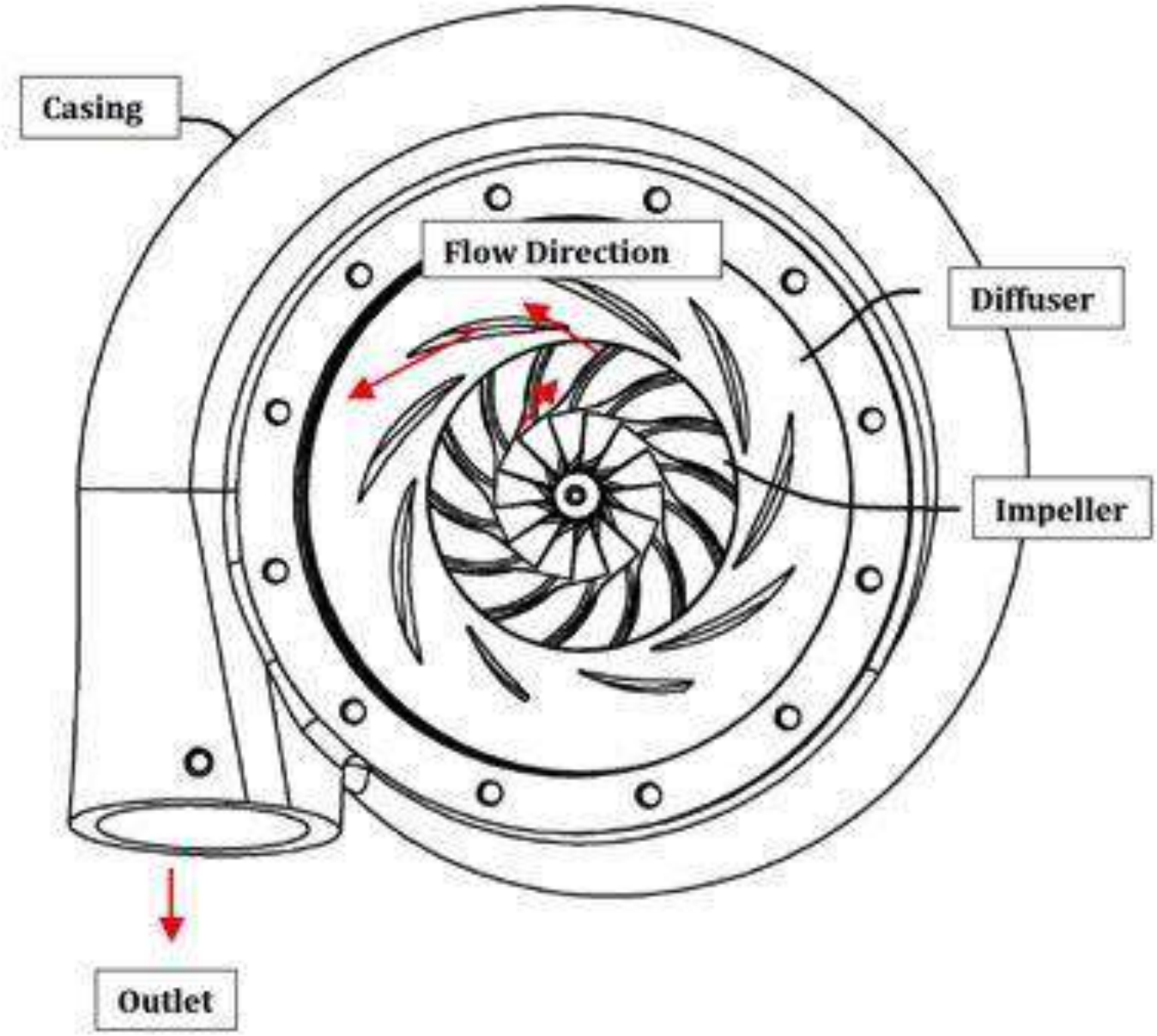


Centrifugal Compressor

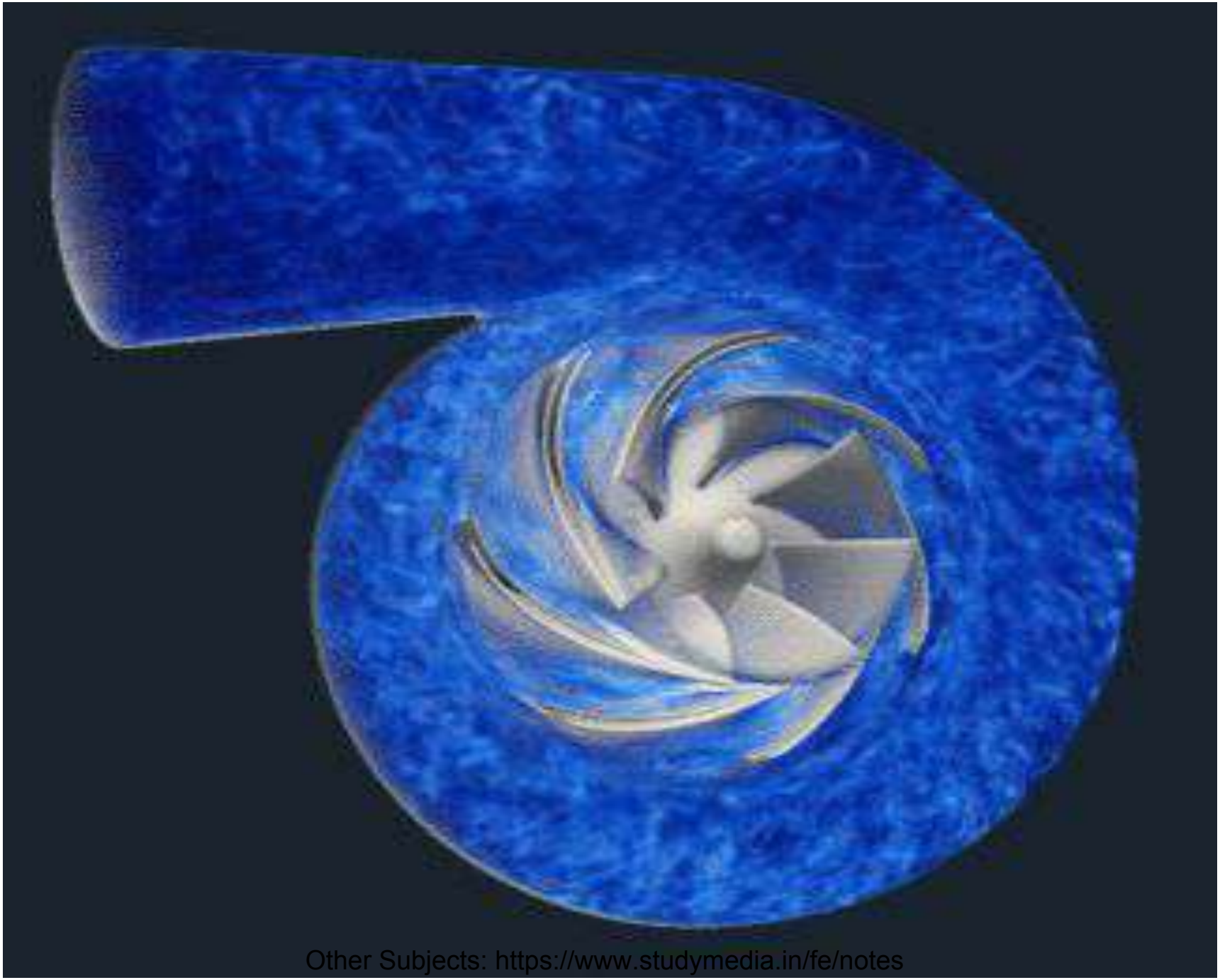
- The centrifugal compressor are used to apply large quantity of air at low pressure.
- The compressor consist of a rotating impeller diffuser and casing.
- The impeller consists of a disc on which radial blades are attached.
- The impeller of a centrifugal compressor can be run at a speed of 20,000 to 30,000 rpm.
- The diffuser is other important part of compressor which surrounds the impeller and delivery passage for air flow.



Centrifugal compressor schematic diagram



- The air coming out from the diffuser is collected in casing and then taken out from outlet.
- The air enters with low velocity and atmospheric pressure.
- The air moves radially outwards passing through the impeller, increases the momentum of air flowing through it. Causing rise in pressure and temperature of air.
- The air leaving due impeller enters diffuser where its velocity is reduced by providing more cross- sectional for flow.
- The part of K.E is converted into pressure energy and pressure of air further increased.
- nearly half of the total pressure rise is achieved by impeller and remaining half in diffuser.



Thank U