Hall Ticket Number: **14EE 501**

III/IV B.Tech (Regular\Supplementary) DEGREE EXAMINATION

November, 2019 **Electrical and Electronics Engineering**

Fifth Semester **Generation of Electrical Power**

Time: Three Hours **Maximum:** 60 Marks

Answer Question No.1 compulsorily. (1X12 = 12 Marks)

Answer ONE question from each unit. (4X12=48 Marks)

1. Answer all questions (1X12=12 Marks)
   a) Define two part tariff.
   b) Write the importance of diversity factor and load factor?
   c) What are the causes of low power factor
   d) List any two merits and demerits of hydroelectric power stations.
   e) Describe the functions of super heater & economizer?
   f) What is a pumped storage plant? What is its purpose?
   g) What are the properties of reactor control rods?
   h) How the biogas plants are classified
   i) What is boiling water reactor(BWR)
   j) Write down the principle involved in the solar energy conversion.
   k) Define solar constant
   l) What is a fuel cell

UNIT I

2	a)	Define power factor? Explain the methods of improving the power factor	6M
	b)	A generating station has a connected load of 43MW and a maximum demand of 20 MW; the units generated being 61•5 × 106 per annum. Calculate (i) the demand factor and (ii) load factor.	6M
		(OR)	
3	a)	Describe the different types of tariff with necessary equations.	6M
	b)	The maximum demand of a consumer is 20 A at 220 V and his total energy consumption is 8760 kWh. If the energy is charged at the rate of 20 paise per unit for 500 hours use of the maximum demand per annum plus 10 paise per unit for additional units, calculate: (i) annual bill (ii) equivalent flat rate.	6M

UNIT II

4.	a)	What are the important factors to be considered for selection of site for a hydroelectric power plant?	6M
	b)	A steam power station spends Rs. 30 lakhs per annum for coal used in the station. The coal has a calorific value of 5000 kcal/kg and costs Rs. 300 per ton. If the station has thermal efficiency of 33% and electrical efficiency of 90%, find the average load on the station?	6M
		(OR)	
5.	a)	Explain principle of operation of Thermal Power station with neat diagram.	6M
	b)	Explain different parts in thermal power plant?	6M

UNIT III

6.	a)	Explain the operation of pressurized water reactor.	6M
	b)	Discuss the advantages and disadvantages of fixed dome type and floating drum type plant.	6M
		(OR)	
7.	a)	Explain with a neat sketch the various parts of a nuclear reactor.	6M
	b)	Draw a sketch to illustrate the constructional features of biogas plant and describe its operation.	6M

UNIT IV

8.	a)	Draw the schematic diagram of solar thermal power plant used for power production and explain the operation of this system in detail.	6M
	b)	Describe various methods of extracting energy from geothermal sources of energy.	6M
		(OR)	
9.	a)	Explain principle and operation of wind energy conversion.	6M
	b)	Explain the principle of operation of a fuel cell. What are the electrochemical principles and thermodynamics involved in the working of a fuel cell?	6M

1. Answer all questions.

a) **Two part form.** It is sometimes convenient to give the annual cost of energy in two part form. In this case, the annual cost of energy is divided into two parts *ie:* a fixed sum per kW of maximum demand *plus* a running charge per unit of energy.

   Total annual cost of energy = Rs. (A kW + B kWh)

b) **Load factor** means how efficiently we use energy. It is the measure of the utilization of electrical energy during a given period to the maximum energy which would have been utilized in that period.

   Diversity factor. The ratio of the sum of individual maximum demands to the maximum demand on power station is known as **diversity factor.**

   The **diversity factor** normally has a value greater than unity and is only equal to unity if all the individual demands occur simultaneously.

c) The lagging reactive power is responsible for the low power factor. It is clear from the power triangle that smaller the reactive power component, the higher is the power factor of the circuit.

$$\text{kVAR} = \text{kVA} \sin\phi = \frac{\text{kW}}{\cos\phi}\sin\phi$$

d) Advantages of Hydroelectric Energy
   1. Renewable
   2. Green
   3. Reliable
   4. Flexible
   5. Safe

   Disadvantages of Hydroelectric Energy

   1. Environmental Consequences
   2. Expensive
   3. Droughts
   4. Limited Reservoirs

e) **Superheater** is the heat exchanger where steam is superheated so placed in such place where maximum heat transfer can take place.
   In **economiser**, feed water is preheated to improve overall efficiency.

f) **Pumped-storage hydroelectricity** (**PSH**), or **pumped hydroelectric energy storage** (**PHES**), is a type of hydroelectric energy storage used by electric power systems for load balancing. The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation.
   During periods of high electrical demand, the stored water is released through turbines to produce electric power.

g) **Control rods** are used in **nuclear reactors** to **control** the fission rate of uranium and/or plutonium. Their compositions includes chemical elements such as boron, cadmium, silver, and/or indium, that are capable of absorbing many neutrons without themselves fissioning

h)

CLASSIFICATION

Classification of biogas plants depends upon the plants design and mode of working. One common way to classify them is

BIOGAS PLANT

- **Batch type plant**
- **Continuous type plant**
  - **Floating Gas Holder Biogas Plant:**
  - **Fixed Dome Biogas Plant**

i) A boiling water reactor is a type of light water nuclear reactor used for the generation of electrical power. It is the second most common type of electricity-generating nuclear reactor after the pressurized water reactor.

j) When certain materials are exposed to light, they absorb photons and release free electrons. This phenomenon is called as the photoelectric effect.

k) Solar constant, the total radiation energy received from the Sun per unit of time per unit of area on a theoretical surface perpendicular to the Sun. the constant is approximately 1.366 kilowatts per square meter.

l) a cell producing an electric current direct from a chemical reaction. (OR) A **fuel cell** produces electricity through a chemical reaction, but without combustion. It converts hydrogen and oxygen into water, and in the process also creates electricity.

UNIT I

2 a) The cosine of angle between voltage and current in an a.c. circuit is known as **power factor.**

Normally, the power factor of the whole load on a large generating station is in the region of 0·8 to 0·9. However, sometimes it is lower and in such cases it is generally desirable to take special steps to improve the power factor. This can be achieved by the following equipment:

1. Static capacitors. 2. Synchronous condenser. 3. Phase advancers.

1. **Static capacitor.** The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static capacitor) draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load. For three-phase loads, the capacitors can be connected in delta or star as shown in Fig.1. Static capacitors are invariably used for power factor improvement in factories.

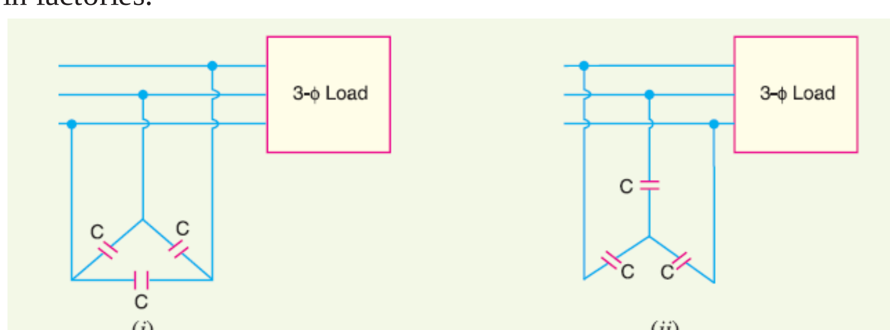


Fig 1.

2. Synchronous condenser. A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as *synchronous condenser.* When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of the load. Thus the power factor is improved.

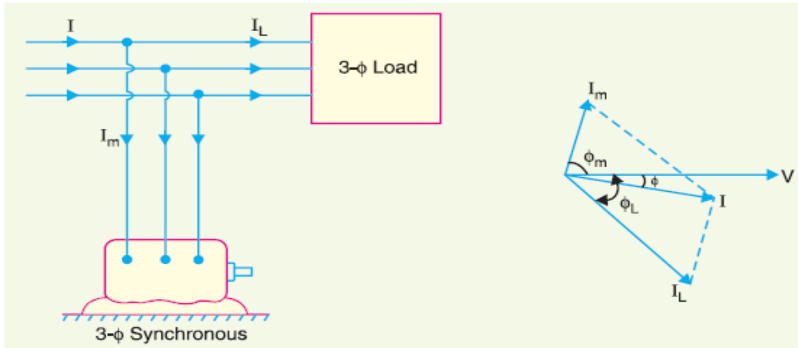


Fig. 2.

2. **Phase advancers.** Phase advancers are used to improve the power factor of induction motors. The low power factor of an induction motor is due to the fact that its stator winding draws exciting current which lags behind the supply voltage by 90o. If the exciting ampere turns can be provided from some other a.c. source, then the stator winding will be relieved of exciting current and the power factor of the motor can be improved. This job is accomplished by the phase advancer which is simply an a.c. exciter. The phase advancer is mounted on the same shaft as the main motor and is connected in the rotor circuit of the motor. It provides exciting ampere turns to the rotor circuit at slip frequency. By providing more ampere turns than required, the induction motor can be made to operate on leading power factor like an over-excited synchronous motor.

b)

A generating station has a connected load of 43MW and a maximum demand of 20 MW; the units generated being 61·5 × 10^6 per annum. Calculate (i) the demand factor and (ii) load factor.

Solution.

(*i*) $$\text{Demand factor} = \frac{\text{Max. demand}}{\text{Connected load}} = \frac{20}{43} = 0{\cdot}465$$

(*ii*) $$\text{Average demand} = \frac{\text{Units generated / annum}}{\text{Hours in a year}} = \frac{61{\cdot}5\times 10^6}{8760} = 7020 \text{ kW}$$

$$\therefore \quad \text{Load factor} = \frac{\text{Average demand}}{\text{Max. demand}} = \frac{7020}{20\times 10^3} = 0{\cdot}351 \text{ or } 35{\cdot}1\%$$

3. a) There are several types of tariff. However, the following are the commonly used types of tariff :

1. **Simple tariff.** When there is a fixed rate per unit of energy consumed, it is called a simple tariff or uniform rate tariff.

2. **Flat rate tariff**. When different types of consumers are charged at different uniform per unit rates, it is called a flat rate tariff.

3. **Block rate tariff.** When a given block of energy is charged at a specified rate and the succeeding blocks of energy are charged at progressively reduced rates, it is called a block rate tariff.

4. **Two-part tariff**. When the rate of electrical energy is charged on the basis of maximum demand of the consumer and the units consumed, it is called a two-part tariff.

5. Maximum demand tariff. It is similar to two-part tariff with the only difference that the maximum demand is actually measured by installing maximum demand meter in the premises of the consumer.

6. Power factor tariff. The tariff in which power factor of the consumer's load is taken into consideration is known as **power factor tariff**.

(*i*) *k VA maximum demand tariff* :

(*ii*) *Sliding scale tariff* :

(*iii*) *kW and kVAR tariff* :

7. Three-part tariff. When the total charge to be made from the consumer is split into three parts viz., fixed charge, semi-fixed charge and running charge, it is known as a **three-part tariff**. i.e.,

$$\text{Total charge} = \text{Rs } (a + b \times kW + c \times kWh)$$

b)

The maximum demand of a consumer is 20 A at 220 V and his total energy consumption is 8760 kWh. If the energy is charged at the rate of 20 paise per unit for 500 hours use of the maximum demand per annum plus 10 paise per unit for additional units, calculate : (i) annual bill (ii) equivalent flat rate.

Solution.

Assume the load factor and power factor to be unity.

$$\therefore \quad \text{Maximum demand} = \frac{220 \times 20 \times 1}{1000} = 4 \cdot 4 \text{ kW}$$

(*i*) Units consumed in 500 hrs = $4{\cdot}4 \times 500 = 2200$ kWh

Charges for 2200 kWh = Rs $0{\cdot}2 \times 2200 =$ Rs 440

Remaining units = $8760 - 2200 = 6560$ kWh

Charges for 6560 kWh = Rs $0{\cdot}1 \times 6560 =$ Rs 656

$\therefore$ Total annual bill = Rs $(440 + 656) =$ **Rs. 1096**

$$(ii) \quad \text{Equivalent flat rate} = \text{Rs } \frac{1096}{8760} = \text{Re } 0 \cdot 125 = \textbf{12.5 paise}$$

4.a) Choice of Site for Hydro-electric Power Stations The following points should be taken into account while selecting the site for a hydro-electric power station :

(*i*) *Availability of water*. Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water, such plants should be built at a place (*e.g.*, river, canal) where adequate water is available at a good head.

(*ii*) *Storage of water*. There are wide variations in water supply from a river or canal during the year. This makes it necessary to store water by constructing a dam in order to ensure the generation of power throughout the year. The storage helps in equalising the flow of water so that any excess quantity of water at a certain period of the year can be made available during times of very low flow in the river. This leads to the conclusion that site selected for a hydro-electric plant should provide adequate facilities for erecting a dam and storage of water.

(*iii*) *Cost and type of land.* The land for the construction of the plant should be available at a reasonable price. Further, the bearing capacity of the ground should be adequate to withstand the weight of heavy equipment to be installed.

(*iv*) *Transportation facilities.* The site selected for a hydro-electric plant should be accessible by rail and road so that necessary equipment and machinery could be easily transported. It is clear from the above mentioned factors that ideal choice of site for such a plant is near a river in hilly areas where dam can be conveniently built and large reservoirs can be obtained.

4.b)

A steam power station spends Rs. 30 lakhs per annum for coal used in the station. The coal has a calorific value of 5000 kcal/kg and costs Rs. 300 per ton. If the station has thermal efficiency of 33% and electrical efficiency of 90%, find the average load on the station.

Solution.

$$\text{Overall efficiency, } \eta_{overall} = 0{\cdot}33 \times 0{\cdot}9 = 0{\cdot}297$$

$$\text{Coal used/annum} = 30 \times 10^5/300 = 10^4 \text{ tons} = 10^7 \text{ kg}$$

$$\text{Heat of combustion} = \text{Coal used/annum} \times \text{Calorific value}$$

$$= 10^7 \times 5000 = 5 \times 10^{10} \text{ kcal}$$

$$\text{Heat output} = \eta_{overall} \times \text{Heat of combustion}$$

$$= (0{\cdot}297) \times (5 \times 10^{10}) = 1485 \times 10^7 \text{ kcal}$$

$$\text{Units generated/annum} = 1485 \times 10^7/860 \text{ kWh}$$

$$\therefore \quad \text{Average load on station} = \frac{\text{Units generated / annum}}{\text{Hours in a year}} = \frac{1485 \times 10^7}{860 \times 8760} = \mathbf{1971\ kW}$$

5.a) A generating station which converts heat energy of coal combustion into electrical energy is known as a **steam power station.**

A steam power station basically works on the Rankine cycle. Steam is produced in the boiler by utilising the heat of coal combustion. The steam is then expanded in the prime mover (i.e., steam turbine) and is condensed in a condenser to be fed into the boiler again. The steam turbine drives the alternator which converts mechanical energy of the turbine into electrical energy. This type of power station is suitable where coal and water are available in abundance and a large amount of electric power is to be generated.

Advantages

(*i*) The fuel (*i.e.*, coal) used is quite cheap.

(*ii*) Less initial cost as compared to other generating stations.

(*iii*) It can be installed at any place irrespective of the existence of coal. The coal can be transported

to the site of the plant by rail or road.

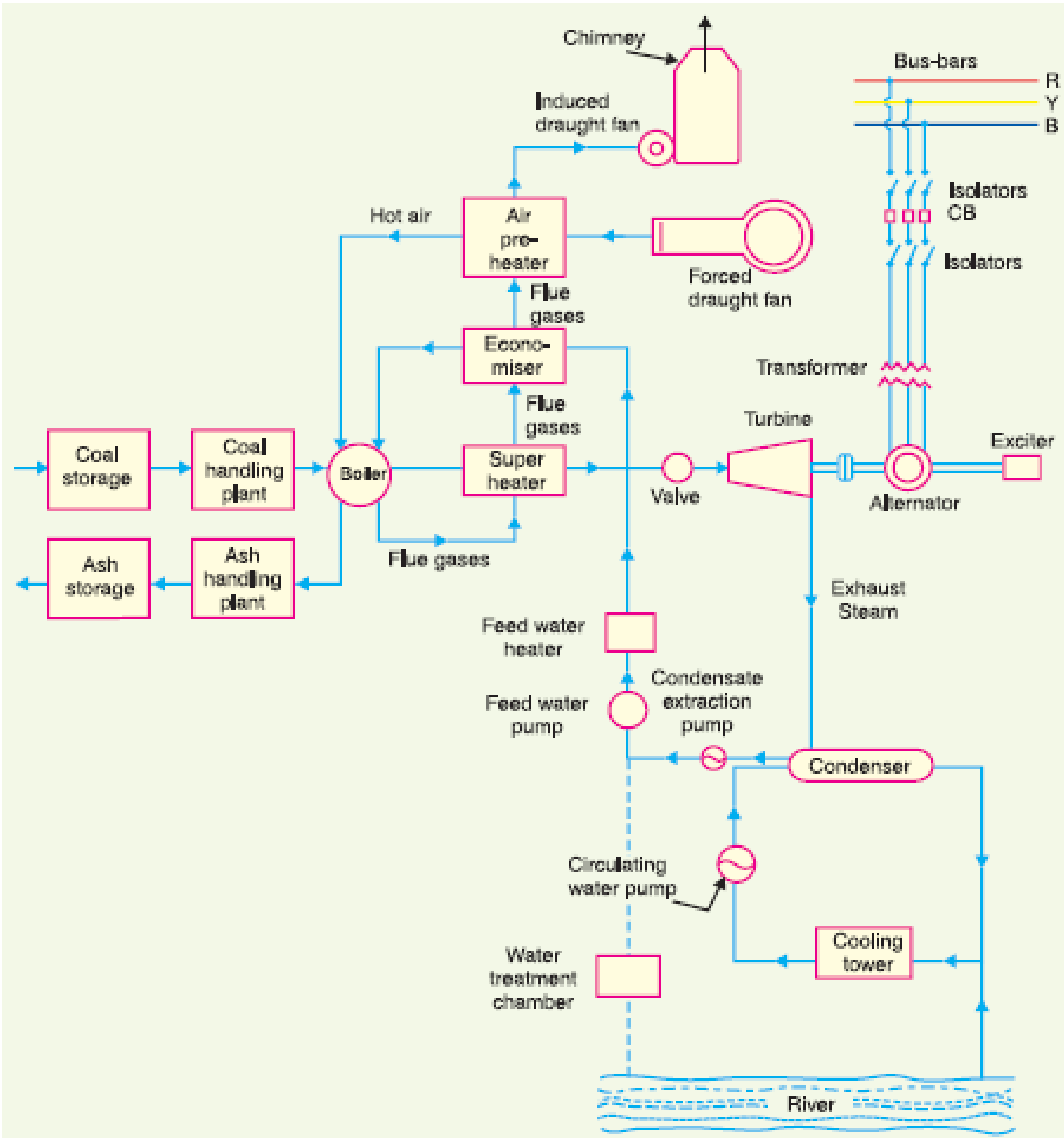
(*iv*) It requires less space as compared to the hydroelectric power station.

(*v*) The cost of generation is lesser than that of the diesel power station.

Disadvantages

(*i*) It pollutes the atmosphere due to the production of large amount of smoke and fumes.

(*ii*) It is costlier in running cost as compared to hydroelectric plant.



Schematic arrangement of Steam Power Station

Although steam power station simply involves the conversion of heat of coal combustion into electrical energy, yet it embraces many arrangements for proper working and efficiency. The schematic arrangement of a modern steam power station is shown in Fig. The whole arrangement can be divided into the following stages for the sake of simplicity :

1. Coal and ash handling arrangement **2.** Steam generating plant

3. Steam turbine **4.** Alternator

5. Feed water **6.** Cooling arrangement

1. Coal and ash handling plant. The coal is transported to the power station by road or rail and is stored in the coal storage plant. Storage of coal is primarily a matter of protection against coal strikes, failure of transportation system and general coal shortages. From the coal storage plant, coal is delivered to the coal handling plant where it is pulverised (*i.e.*, crushed into small pieces) in order to increase its surface exposure, thus promoting rapid combustion without using large quantity of excess air. The pulverised coal is fed to the boiler by belt conveyors. The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant and then delivered to the ash storage plant for disposal. The removal of the ash from the boiler furnace is necessary for proper burning of coal.

2. Steam generating plant. The steam generating plant consists of a boiler for the production of steam and other auxiliary equipment for the utilisation of flue gases.

(*i*) *Boiler*. The heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature and pressure. The flue gases from the boiler make their journey through superheater, economiser, air pre-heater and are finally exhausted to atmosphere through the chimney.

(*ii*) *Superheater.* The steam produced in the boiler is wet and is passed through a superheater where it is dried and superheated (*i.e.*, steam temperature increased above that of boiling point of water) by the flue gases on their way to chimney. Superheating provides two principal benefits. Firstly, the overall efficiency is increased. Secondly, too much condensation in the last stages of turbine (which would cause blade corrosion) is avoided. The superheated steam from the superheater is fed to steam turbine through the main valve.

(*iii*) *Economiser.* An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of heat of flue gases to increase the feed water temperature.

(*iv*) *Air preheater.* An air preheater increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air preheater before supplying to the boiler furnace. The air preheater extracts heat from flue gases and increases the temperature of air used for coal combustion. The principal benefits of preheating the air are : increased thermal efficiency and increased steam capacity per square metre of boiler surface.

3. Steam turbine. The dry and superheated steam from the superheater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy. After giving heat energy to the turbine, the steam is exhausted to the *condenser* which condenses the exhausted steam by means of cold water circulation.

4. Alternator. The steam turbine is coupled to an alternator. The alternator converts mechanical energy of turbine into electrical energy. The electrical output from the alternator is delivered to the bus bars through transformer, circuit breakers and isolators.

5. Feed water. The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external source. The feed water on its way to the boiler is heated by water heaters and economiser. This helps in raising the overall efficiency of the plant.

6. Cooling arrangement. In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed* by means of a condenser. Water is drawn from a natural source of supply such as a river, canal or lake and is circulated through the condenser. The circulating water takes up the heat of the exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river. In case the availability of water from the source of supply is not assured throughout the year, *cooling towers* are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

6.a) **Pressurised Water Reactor(PWR)**

• PWR is the most common type of nuclear reactor, representing about 60% of all nuclear power reactors in the world.

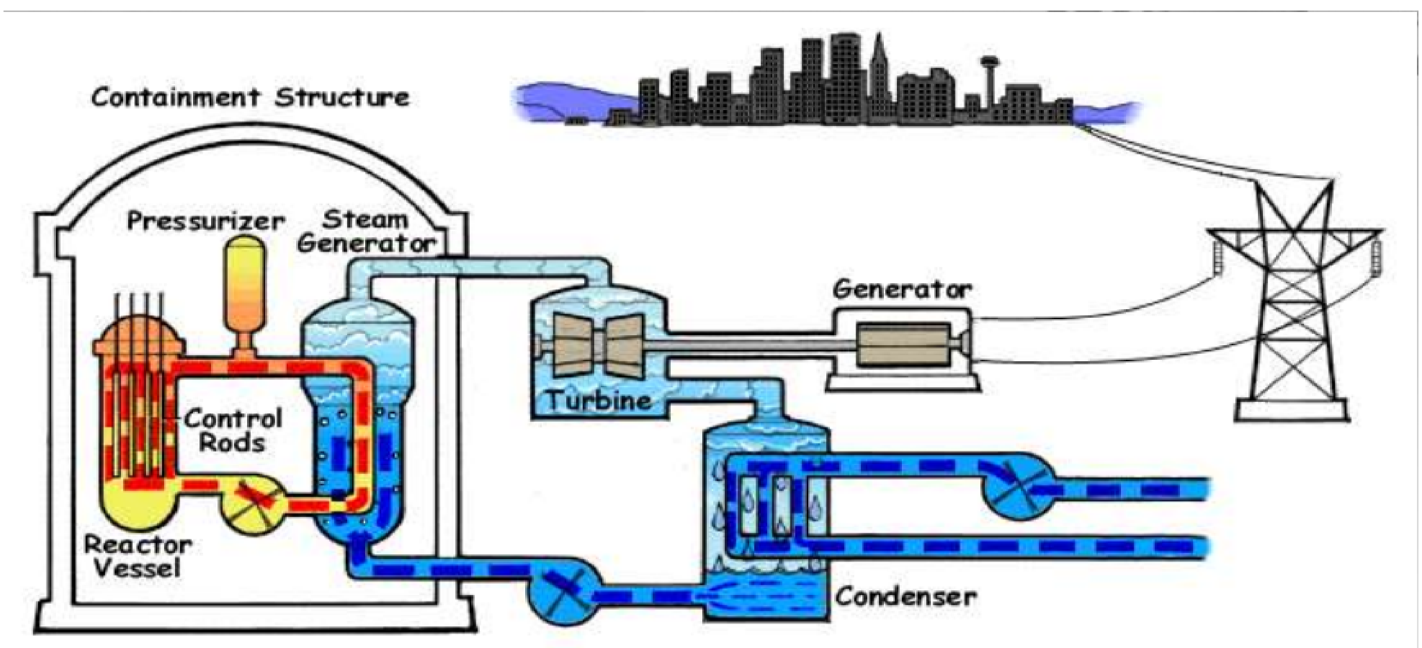
• PWRs keep water under pressure so that it heats, but does not boil.

• Water from the reactor and the water in the steam generator that is turned into steam never mix. In this way, most of the radioactivity stays in the reactor area.

• Light Water Cooled

Working Of PWR In a typical design concept of a commercial PWR the following process occurs:

1. The core inside the reactor vessel creates heat.
2. Pressurized water in the primary coolant loop carries the heat to the steam generator.
3. Inside the steam generator, heat from the primary coolant loop vaporizes the water in a secondary loop, producing steam.
4. The steam line directs the steam to the main turbine, causing it to turn the turbine generator, which produces electricity.

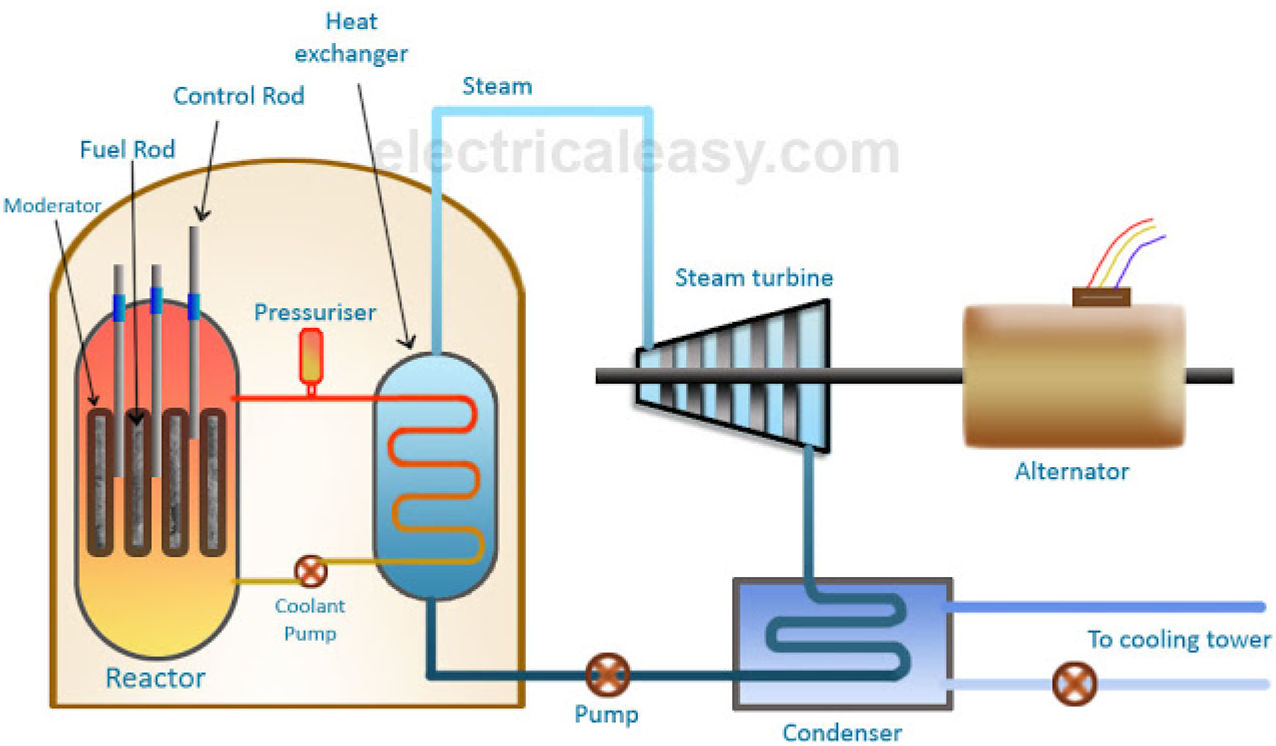


6.b)

Properties	Fixed Dome Type Biogas Plant	Fixed Dome with Expansion Chamber Type Biogas Plant
Experimental Setup	Digester of this plant is a shallow well shaped masonry structure. No partition wall is provided.	Digester id made of two segments of two spheres one each for the top and Bottom.
Biogas Holder	Gas holders the integral part of the masonry structure of the plant. Slurry from the gas storage portion is displaced out of the digester with the formation of gas and comes back when it is used.	The structure described above includes digester and the gas storage chamber. Gas is stored in the same way as in the F.D type plant.
Gas Pressure	Varies from 0-90 cm of water.	Varies from 0-75 cm of water.
Maintenance	Cost of maintenance is low.	Cost of maintenance is low.
Life Span	Life span is comparatively long.	Life span is between the other two plants.
Extra features	Space above the gas holder can be used.	Ther is no moving part so no recurring expenditure.
Required work place	Requires more excavation work.	Requires high excavation work.
Construction	A trained mason using locally available materials can build entire plant.	Entire plant can be build by a trained mason using locally available materials.
Installation Cost	It is Cheaper then previous and the plant costs about Rs.5400.00 (Indian Currency)	It is much Cheaper than both plants and its plant design costs Rs.4000.00 (Indian Currency).

7.a) Heavy elements such as Uranium (U^{235}) or Thorium (Th^{232}) are subjected to nuclear fission reaction in a nuclear reactor. Due to fission, a large amount of heat energy is produced which is transferred to the reactor coolant. The coolant may be water, gas or a liquid metal. The heated coolant is made to flow through a heat exchanger where water is converted into high-temperature steam. The generated steam is then allowed to drive a steam turbine. The steam, after doing its work, is converted back into the water and recycled to the heat exchanger. The steam turbine is coupled to an alternator which generates electricity. The generated electrical voltage is then stepped up using a transformer for the purpose of long distance transmission.

The image below shows **basic components and layout of a nuclear power station**.



Fuel. Uranium is the basic fuel. Usually pellets of uranium oxide (UO_2) are arranged in tubes to form fuel rods. The rods are arranged into fuel assemblies in the reactor core.* In a 1000 MWe class PWR there might be 51,000 fuel rods with over 18 million pellets.

Moderator. Material in the core which slows down the neutrons released from fission so that they cause more fission. It is usually water, but may be heavy water or graphite.

Control rods. These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction, or to halt it.* In some PWR reactors, special control rods are used to enable the core to sustain a low level of power efficiently. (Secondary control systems involve other neutron absorbers, usually boron in the coolant – its concentration can be adjusted over time as the fuel burns up.) PWR control rods are inserted from the top, BWR cruciform blades from the bottom of the core

Coolant. A fluid circulating through the core so as to transfer the heat from it. In light water reactors the water moderator functions also as primary coolant.

Pressure vessel or pressure tubes. Usually a robust steel vessel containing the reactor core and moderator/coolant, but it may be a series of tubes holding the fuel and conveying the coolant through the surrounding moderator.

Steam generator. Part of the cooling system of pressurised water reactors (PWR & PHWR) where the high-pressure primary coolant bringing heat from the reactor is used to make steam for the turbine, in a secondary circuit. Essentially a heat exchanger like a motor car radiator

Heat Exchanger

In the heat exchanger, the primary coolant transfers heat to the secondary coolant (water). Thus water from the secondary loop is converted into steam. The primary system and secondary system are closed loop, and they are never allowed to mix up with each other. Thus, heat exchanger helps in keeping secondary system free from radioactive stuff. Heat exchanger is absent in boiling water reactors.

Steam Turbine

Generated steam is passed through a steam turbine, which runs due to pressure of the steam. As the steam is passed through the turbine blades, the pressure of steam gradually decreases and it expands in volume. The steam turbine is coupled to an alternator through a rotating shaft.

Alternator

The steam turbine rotates the shaft of an alternator thus generating electrical energy. Electrical output of the alternator is the delivered to a step up transformer to transfer it over distances.

Condenser

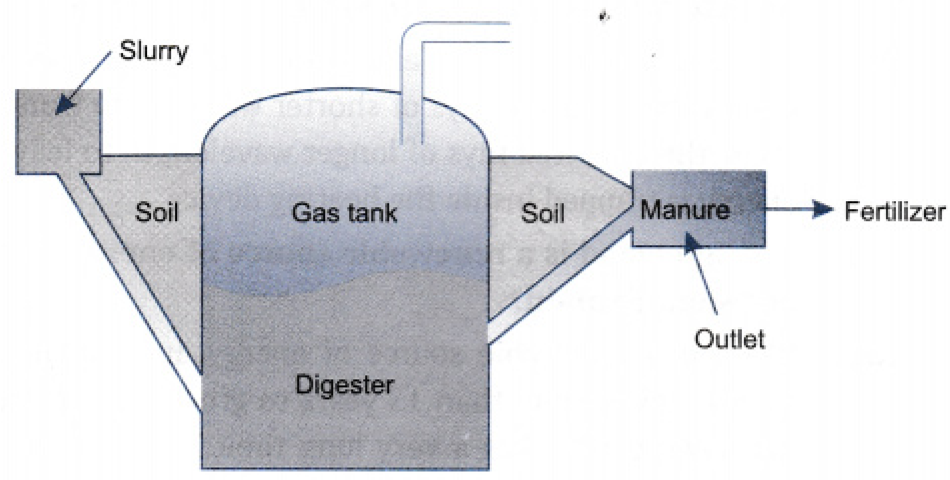
The steam coming out of the turbine, after it has done its work, is then converted back into water in a condenser. The steam is cooled by passing it through a third cold water loop.

7.b)

Biogas is a mixture of methane, carbon dioxide, hydrogen and hydrogen sulphide. The major constituent of biogas is methane.

Biogas is produced by the anaerobic degradation of animal wastes like cow-dung or plant wastes in the presence of water.

The biogas plant has a dome-like structure built with bricks. A slurry of cow-dung and water is made in the mixing tank from where it is fed into the digester. The digester is a sealed chamber in which there is no oxygen. Anaerobic micro-organisms that do not require oxygen decompose or break down complex compounds of the cow-dung slurry. It takes a few days for the decomposition process to be complete and generate gases. The biogas is stored in the gas tank above the digester from which they are drawn through pipes for use.



Fixed dome type biogas plant

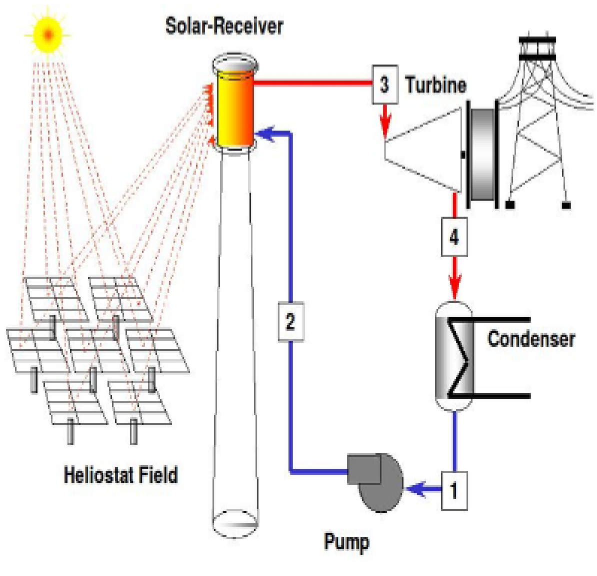
Structure of a biogas (gobar gas) plant:

The biogas plant is a dome-like structure made of bricks and cement. It consists of the following five compartments:

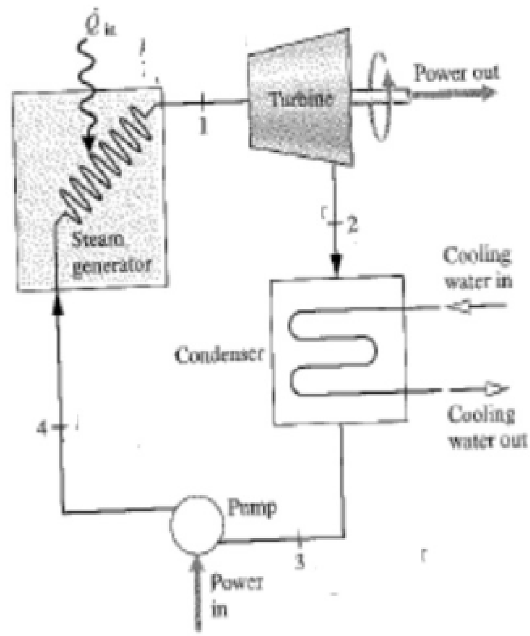
- Mixing tank: Present above the ground level.
- Inlet chamber/tank: The mixing tank opens underground into a sloping inlet chamber.
- Digester: The inlet chamber opens from below into the digester. The digester is a huge tank with a dome-like ceiling. The ceiling of the digester has an outlet with a valve for the supply of biogas.

- Outlet chamber/tank: The digester opens from below into an outlet chamber.
- Overflow tank: The outlet chamber opens from the top into a small overflow tank.

8.a)



Scheme of the Rankine-cycle based solar power plant



Solar thermal power systems use concentrated solar energy

Solar thermal power (electricity) generation systems collect and concentrate sunlight to produce the high temperature heat needed to generate electricity. All solar thermal power systems have solar energy collectors with two main components: *reflectors* (mirrors) that capture and focus sunlight onto a *receiver*. In most types of systems, a heat-transfer fluid is heated and circulated in the receiver and used to produce steam. The steam is converted into mechanical energy in a turbine, which powers a generator to produce electricity. Solar thermal power systems have tracking systems that keep sunlight focused onto the receiver throughout the day as the sun changes position in the sky.

Solar thermal power systems may also have a thermal energy storage system component that allows the solar collector system to heat an energy storage system during the day, and the heat from the storage system is used to produce electricity in the evening or during cloudy weather. Solar thermal power plants may also be hybrid systems that use other fuels (usually natural gas) to supplement energy from the sun during periods of low solar radiation.

Types of concentrating solar thermal power plants

There are three main types of concentrating solar thermal power systems:

- Linear concentrating systems, which include parabolic troughs and linear Fresnel reflectors
- Solar power towers
- Solar dish/engine systems

Linear concentrating systems

Linear concentrating systems collect the sun's energy using long, rectangular, curved (U-shaped) mirrors. The mirrors focus sunlight onto receivers (tubes) that run the length of the mirrors. The concentrated sunlight heats a fluid flowing through the tubes. The fluid is sent to a heat exchanger to boil water in a conventional steam-turbine generator to produce electricity.

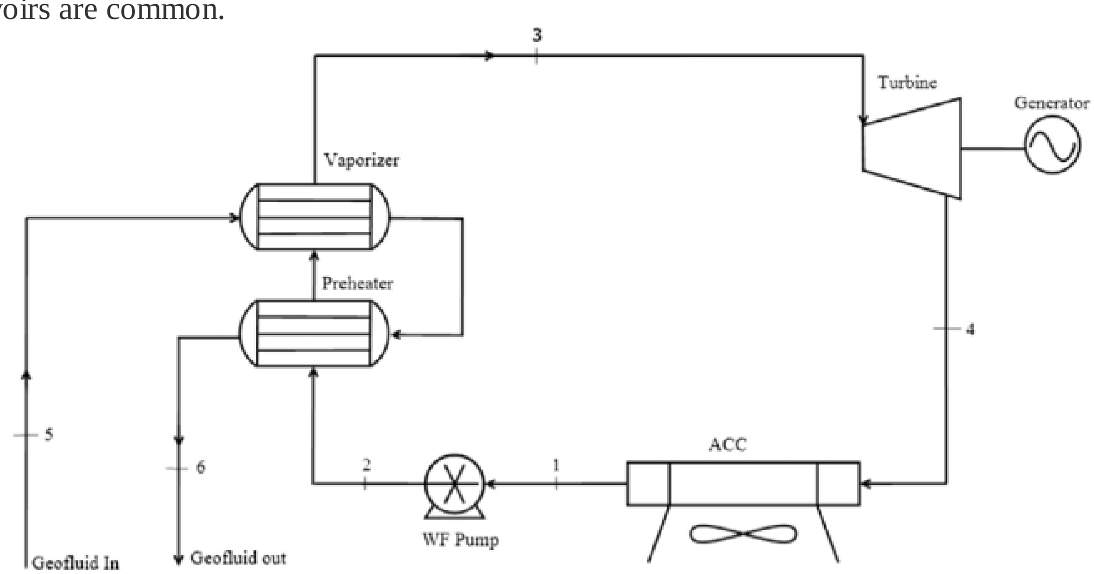
Parabolic troughs

A parabolic trough collector has a long parabolic-shaped reflector that focuses the sun's rays on a receiver pipe located at the focus of the parabola. The collector tilts with the sun to keep sunlight focused on the receiver as the sun moves from east to west during the day.

Linear Fresnel reflectors
Linear Fresnel reflector (LFR) systems are similar to parabolic trough systems in that mirrors (reflectors) concentrate sunlight onto a receiver located above the mirrors. These reflectors use the Fresnel lens effect, which allows for a concentrating mirror with a large aperture and short focal length.
Solar power towers
A solar power tower system uses a large field of flat, sun-tracking mirrors called heliostats to reflect and concentrate sunlight onto a receiver on the top of a tower. Sunlight can be concentrated as much as 1,500 times. Some power towers use water as the heat-transfer fluid.
Solar dish/engines
Solar dish/engine systems use a mirrored dish similar to a very large satellite dish. To reduce costs, the mirrored dish is usually composed of many smaller flat mirrors formed into a dish shape. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to an engine generator
8.b)

Electricity from under the earth

A **geothermal power** plant **works** by tapping into steam or hot water reservoirs underground; the heat is used to drive an electrical generator. Most **geothermal** plants are located in the western United States, where hot water reservoirs are common.



How to Use Geothermal Energy

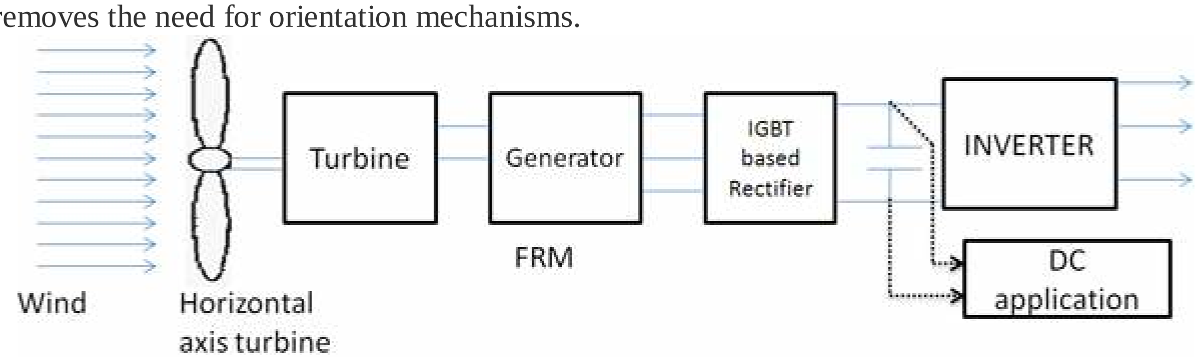
Geothermal energy is used in three main ways: direct use, power generation, and ground source heating and cooling:

- **Direct Use:** The hot water in geothermal reservoirs produces heat and steam, which can be directly used for multiple purposes. In the past, hot springs were directly used for bathing and cleaning purposes. Today, this hot water is extracted by a well and then delivered though piping, a heat exchanger, and controls for its intended purpose. Geothermal hot water has a variety of direct uses, ranging from melting ice on roads and sidewalks to warming fishing farms.
- **Power Generation:** Aside from being used directly, geothermal energy can be used to produce power (similar to solar and wind energy). Geothermal power plants capture deep deposits of geothermal energy, whether steam or hot water, and use this to drive turbines that sequentially produce electricity. There are three different types of geothermal power plants:

    - **Dry Steam Power Plants** are the oldest geothermal plant design. Steam from underground is used to operate the turbine, which produces power. The steam is then either pumped back underground or released into the atmosphere.
    - **Flash Steam Power Plants** are a more sophisticated steam power plant design. Highly pressurized water ranging from 300°-700°F is pumped from the earth's surface and the pressure is then reduced, causing the water to immediately turn to steam. This sudden sporadic change of water "flashing" into steam essentially drives the turbine. The water is then cooled and pumped back underground.
    - **Binary Power Plants** use a different approach than the previous two. Like a flash steam power plant, a binary power plant pumps pressurized hot water to the earth's surface. The tube that does this, however, connects to a second tube that contains water at a lower pressure. Water from the first tube flows into the second one, boiling the water, which sequentially drives the turbine. Water from the first tube is then pumped back underground to restart the process.
- **Ground Source Heating and Cooling** is the most common use for geothermal energy today. As opposed to generally heating an area using heat found in the outside air, a ground source heat pump, or GSHP, taps into the constant temperature found within the earth's surface. The fact that this constant temperature can be captured from almost anywhere in the world allows GSHPs to be one of the most sustainable and efficient technologies used today. This system specifically transfers heat from the earth into a building during the winter season and then transfers heat back into the ground during the summer. The temperature can be controlled with the use of heat from the earth.

9.a)

- A windmill converts wind energy into rotational energy by means of its blades.
- The basic principle of every windmill is to convert kinetic energy of wind into mechanical energy which is used to rotate the turbine of electrical generator to produce electricity.
- They are sometimes used to pump water or to extract groundwater.
  The most commonly seen windmills are Horizontal axis windmills which have their main rotor shaft and electrical generator at the top of a tower arranged in a row, horizontally. Basic parts include blades, rotor, a gear box (which amplifies the energy output of the rotor), and a generator which generates electricity. Sometimes, a tail-vane is also attached to direct the turbine to gather maximum wind energy.
- When the main rotor shaft is set traverse, not necessarily vertical, to the wind, it is a Vertical axis windmill. The main components of these windmills are located at the base of the turbine. The main advantage of this arrangement is that the generator and gearbox are located close to the ground, facilitating service and repair. These windmills do not necessarily be pointed into the wind, which removes the need for orientation mechanisms.

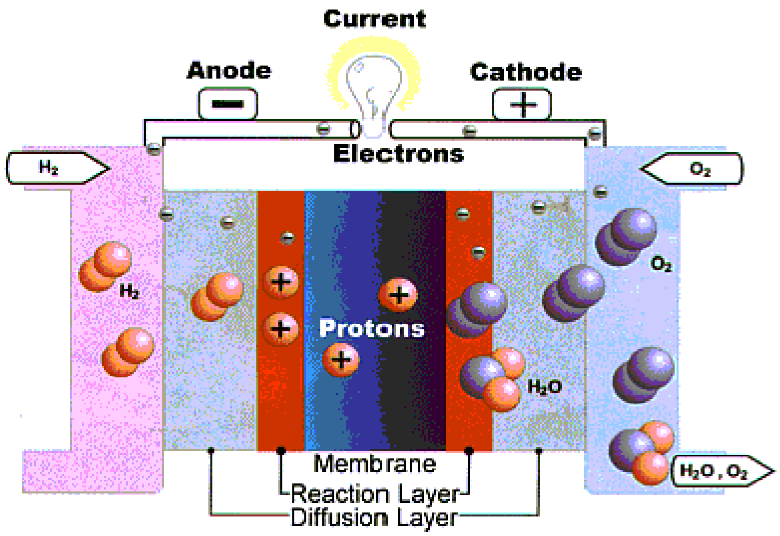


9.b)

Fuel cell operation. The **fuel cell** is an electrochemical devise, which converts chemical energy of the **fuel** to electricity by combining gaseous hydrogen with air in the absence of combustion. At the anode, the reaction releases hydrogen ions and electrons whose transport is crucial to energy production.

Fuel cell operation

The fuel cell is an electrochemical devise, which converts chemical energy of the fuel to electricity by combining gaseous hydrogen with air in the absence of combustion. The basic principles of operation of the fuel cell is similar to that of the electrolyser in that the fuel cell is constructed with two electrodes with a conducted electrolyte between them.



For a better explanation of the fuel cell operation, take a closer look at the **Proton Exchange Membrane (PEM)** fuel cell (click on the picture for animation)

The heart of the cell is the the proton conducting solid **PEM**. It is surrounded by two layers, a diffusion and a reaction layer. Under constant supply of hydrogen and oxygen the hydrogen diffuses through the anode and the diffusion layer up to the platinum catalyst, the reaction layer. The reason for the diffusion current is the tendency of hydrogen oxygen reaction.

Two main electrochemical reactions occur in the fuel cell. One at the anode (anodic reaction) and one at the cathode.

At the anode, the reaction releases hydrogen ions and electrons whose transport is crucial to energy production.

$H_2 \longrightarrow 2H^+ + 2e^-$

The hydrogen ion on its way to the cathode passes through the polymer membrane while the only possible way for the electrons is though an outer circuit. The hydrogen ions together with the electrons of the outer electric circuit and the oxygen which has diffused through the porous cathode reacts to water.

$2H^+ + ½ O_2 + 2e^- \longrightarrow H_2O$

The water resulting from this reaction is extracted from the system by the excess air flow. The reaction is:

$H + ½ O_2 \longrightarrow H_2O$