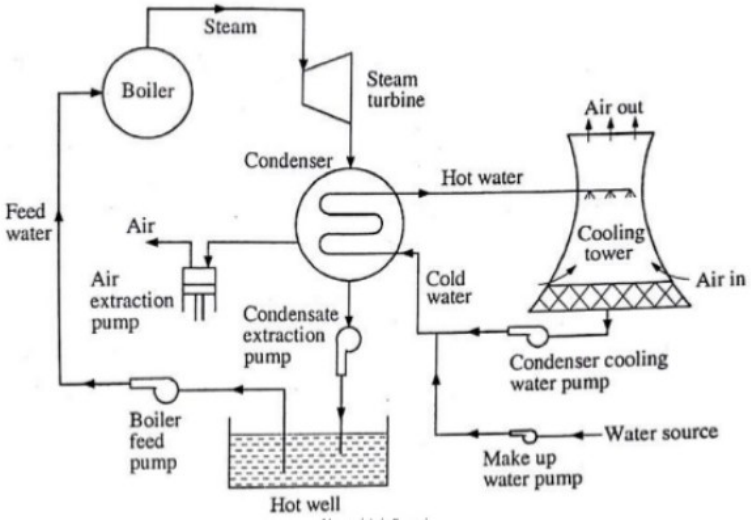
17ME71 (Energy Engineering) Feb. / March 2022

Solutions

1a) With the help of a neat schematic diagram, explain the working principle of a thermal power plant. (8 marks)

Steam is an important medium of producing mechanical energy. Steam has the advantage that it can be raised from water which is available in abundance it does not react much with the materials of the equipment of power plant and is stable at the temperature required in the plant. Steam is used to drive steam engines, steam turbines etc. Steam power station is most suitable where coal is available in abundance. Thermal electrical power generation is one of the major methods. Out of total power developed in India about 60% is thermal. For a thermal power plant the range of pressure may vary from 10 kg/cm^2 to super critical pressures and the range of temperature may be from 250ºC to 650ºC.



A steam power plant must have following equipments:

- A furnace to burn the fuel,
- Steam generator or boiler containing water. Heat generated in the furnace is utilized to convert water into steam.
- Main power unit such as an engine or turbine to use the heat energy of steam and perform work.
- Piping system to convey steam and water.

In addition to the above equipment the plant requires various auxiliaries and accessories depending upon the availability of water, fuel and the service for which the plant is intended.

The thermal power plant consists of the following four main circuits:

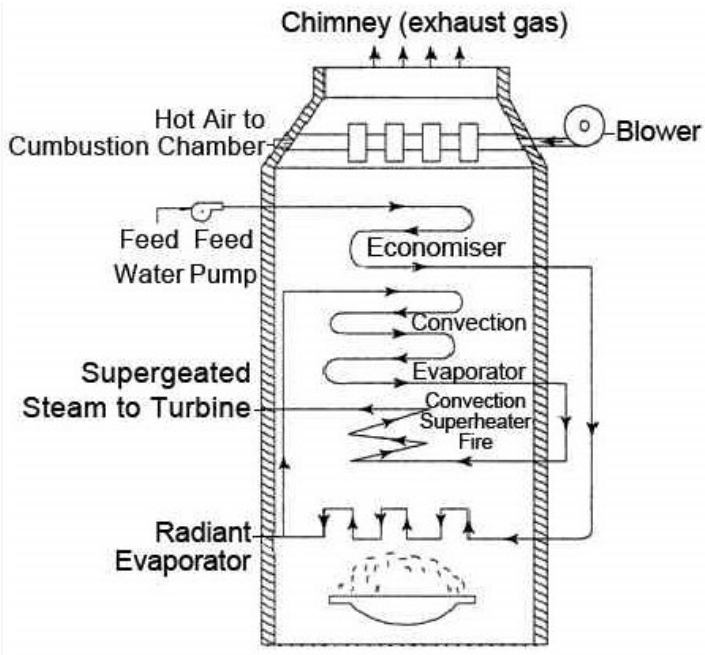
- Feed water and steam flow circuit
- Coal and ash circuit
- Air and gas circuit
- Cooling water circuit.

The different types of systems and components used in steam power plant are as follows:

- High pressure boiler
- Prime mover

- Condensers and cooling towers
- Coal handling system
- Ash and dust handling system
- Draught system
- Feed water purification plant
- Pumping system
- Air pre-heater, economizer, super heater, feed heaters

1b) With a neat sketch, explain the Benson boiler. (7 marks)



Benson Boiler is a high pressure, drumless, supercritical water tube boiler that makes use of forced circulation but has a unique characteristic of the absence of the steam separating drum. Its main principle is that, at the critical pressure, the steam and water coexist at the same density.

The parts of Benson boiler are as follows.

- Feed Pump
- Economizer
- Radiant Parallel tube section
- Transit section
- Convection Superheater
- Steam to the prime mover

Working Principle:

First, the feed water passes through the economizer. The function of economizer is to increases the temperature of the feed water (preheating) by absorbing the heat from the flue gases before they are sent to the atmosphere. The feed water after circulation through the economizer flows through the Radiant parallel tube section to evaporate partly. The steam-water mixture produced then moves to the transit

section where this mixture is converted into steam. The steam is now passed through the Convection superheater and finally supplied to the prime mover in order to drive the turbine. As the superheater is an integral part of the process circulation system, no special starting arrangement for superheating is required. Depending on the size and pressure required, the boiler can be put into service within 10 to 15 minutes.

1c) Write the advantages and disadvantages of using Pulverized coal in thermal power plants. (5 marks)
The advantages of using pulverized coal are as follows

- It becomes easy to burn wide variety of coal. Low grade coal can be burnt easily.
- Powdered coal has more heating surface area. They permit rapid and high rates of combustion.
- Pulverized coal firing requires low percentage of excess air.
- By using pulverized coat, rate of combustion can be adjusted easily to meet the varying load.
- The system is free from clinker troubles.
- It can utilize highly preheated air (of the order of 700F) successfully which promotes rapid flame propagation.
- As the fuel pulverizing equipment is located outside the furnace, therefore it can be repaired without cooling the unit down.
- High temperature can be produced in furnace.

Disadvantages

- It requires additional equipment to pulverize the coal. The initial and maintenance cost of the equipment is high.
- Pulverized coal firing produces fly ash (fine dust) which requires separate fly ash removal equipment.
- The furnace for this type of firing has to be carefully designed to withstand for burning the pulverized fuel because combustion takes place while the fuel is in suspension.
- The flame temperatures are high and conventional types of refractory lined furnaces are inadequate. It is desirable to provide water cooled walls for the safety of the furnaces.
- There are more chances of explosion as coal burns like a gas.
- Pulverised fuel fired furnaces designed to burn a particular type of coal cannot be used to any other type of coal with same efficiency.
- The size of coal is limited. The particle size of coal used in pulverized coal furnace is limited to 70 to 100 microns.

2a) Explain the working of spreader stoker with the help of neat sketch. State advantages and disadvantages. (8 marks)
A spreader stoker is shown in figure below. In this stoker the coal from the hopper is fed on to a feeder which measures the coal in accordance to the requirements. Feeder is a rotating drum fitted with blades. Feeders can be reciprocating rams, endless belts, spiral worms etc. From the feeder the coal drops on to spreader distributor which spread the coal over the furnace. The spreader system should distribute the coal evenly over the entire grate area. The spreader speed depends on the size of coal.

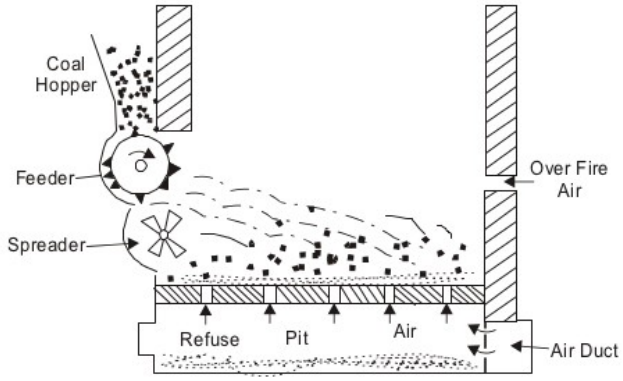
Advantages: The various advantages of spreader stoker are as follows:

- Its operation cost is low.

- A wide variety of coal can be burnt easily by this stoker.
- A thin fuel bed on the grate is helpful in meeting the fluctuating loads.
- Ash under the fire is cooled by the incoming air and this minimises clinkering.
- The fuel burns rapidly and there is little coking with coking fuels.

Disadvantages

- The spreader does not work satisfactorily with varying size of coal.
- In this stoker the coal burns in suspension and due to this fly ash is discharged with flue gases which necessitate efficient dust collecting equipment.



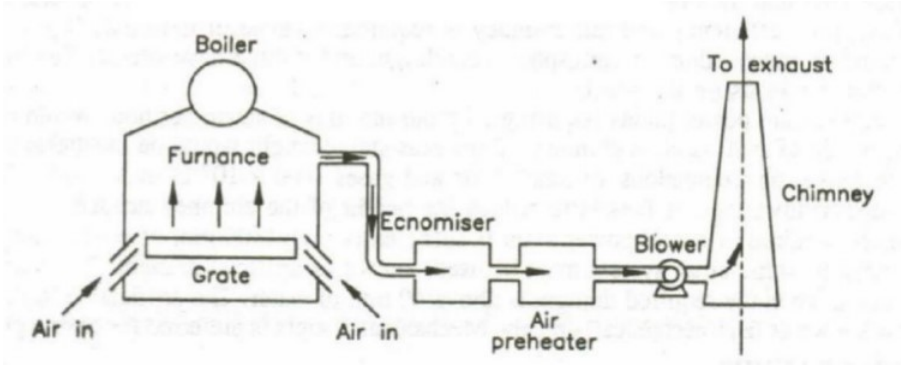
2b) What is draught system? Explain the working of forced and induced draught with the help of a neat sketch. (7 marks)

Draught is defined as the difference between absolute gas pressure (p_{gas}) at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure (p_{at}). Draught is plus if $p_{at} < p_{gas}$ and it is minus $p_{at} > p_{gas}$. Draught is achieved by small pressure difference which causes the flow of air or gas to take place. It is measured in millimetre (mm) of water.

The purpose of draught is as follows:

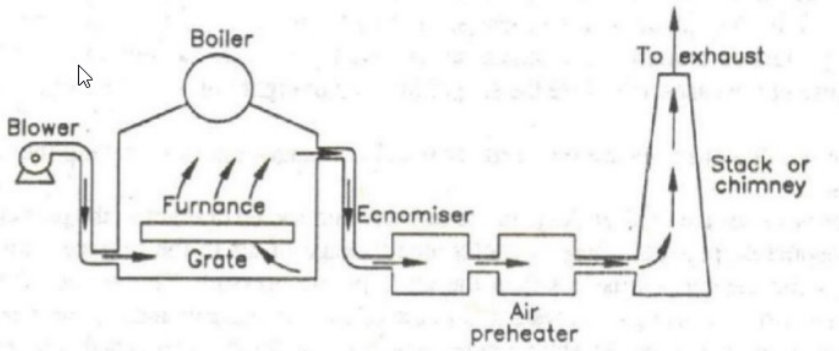
(i) To supply required amount of air to the furnace for the combustion of fuel. The amount of fuel that can be burnt per square foot of grate area depends upon the quantity of air circulated through fuel bed.

(ii) To remove the gaseous products of combustion.



Induced draught system is created by chimney and fan located in the gas passage on the chimney side of the boiler. In this system gas movement is achieved as result of a vacuum. Induced draught is not as simple and direct as forced because fans used in induced draft system operate in gases of much higher temperature (nearly 500 - 904 F). This becomes more expensive.

The fan sucks in gas from the boiler side and discharges it to the chimney (stack). The draught produced is independent of the temperature of the hot gases and, therefore, the gases may be discharged as cold as possible after recovering as much heat possible in air preheater and economiser.



In forced draught system the fan installed near the boiler base supplies the air at a pressure above that of atmosphere and delivers it through air duct to the furnace. Most high rating combustion equipment employs forced draught fans for supplying air to the furnace. Forced draught is used in under fed stokers carrying a thick fuel bed.

2c) Write short note on cooling towers and ponds in thermal power plant. (5 marks)
In a cooling pond, warm condensing water from the condenser is sprayed through nozzles over a pond of large area and cooling effect is mainly due to evaporation from the surface of water. In this system sufficient amount of water is lost by evaporation and windage. Some of the factors which influence the rate of heat dissipation from a cooling pond are as follows:
(i) Area and depth of pond
(ii) Temperature of water entering the pond
(iii) Atmospheric temperature
(iv) Wind velocity
(v) Relative humidity
(vi) Shape and size of water spray nozzles.

Types of Cooling Ponds

- Natural System
- Directed Flow System
- Single Deck System
- Double Deck System

Cooling tower: The cooling towers are desired when positive control on the temperature of water is required, the space occupied by the cooling system is considerable factor and the plant is situated near load centre and far away from the adequate natural resources of cooling water.

Types of cooling tower:
• Natural draft or Atmospheric cooling towers
    a) Natural Draft Spray Filled Tower
    b) Natural Draft Packed Type Tower

c) Hyperbolic Cooling Tower

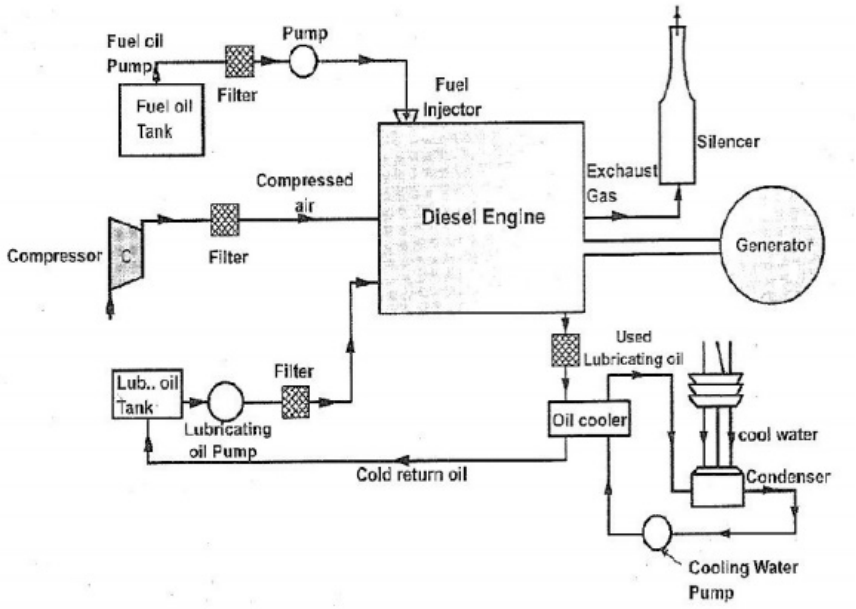
• Mechanical draft towers

a)Forced draft

b)Induced draft.

3a) With the help of a neat sketch, explain the working of diesel engine power plant. (8 marks)

In a diesel power station, diesel engine is used as the prime mover. The diesel burns inside the engine and the products of this combustion act as the working fluid to produce mechanical energy. The diesel engine drives alternator which converts mechanical energy into electrical energy. As the generation cost is considerable due to high price of diesel, therefore, such power stations are only used to produce small power. Although steam power stations and hydroelectric plants are invariably used to generate bulk power at cheaper costs, yet diesel power stations are finding favour at places where demand of power is less, sufficient quantity of coal and water is not available and the transportation facilities are inadequate. This plants are also standby sets for continuity of supply to important points such as hospitals, radio stations, cinema houses and telephone exchanges.



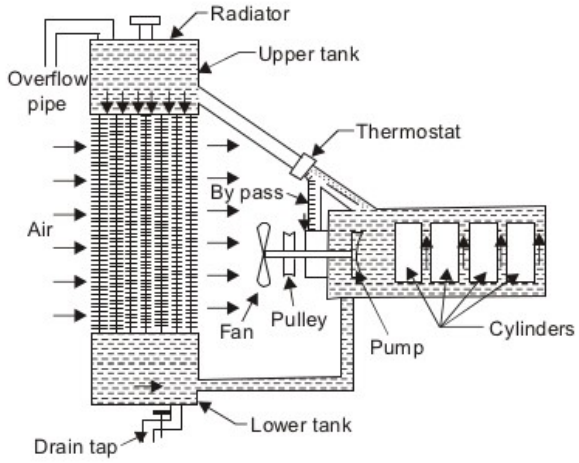
3b) Explain the importance of cooling system in diesel engine. With the help of a neat sketch, explain thermostat cooling. (7 marks)

During combustion process the peak gas temperature in the cylinder of an internal combustion engine is of the order of 2500 K. Maximum metal temperature for the inside of the combustion chamber space are limited to much lower values than the gas temperature by a large number of considerations and thus cooling for the cylinder head, cylinder and piston must therefore be provided. Necessity of engine cooling arises due to the following facts:

- During the combustion period, the heat fluxes to the chamber walls are very high. The flux varies substantially with location. The regions of the chamber that are contacted by rapidly moving high temperature gases generally experience the highest fluxes. In region of high heat flux, thermal stresses must be kept below levels that would cause fatigue cracking. So temperatures must be

less than about 400°C for cast iron and 300°C for aluminium alloy for water cooled engines. For air-cooled engines, these values are 270°C and 200°C respectively.

- The gas side surface temperature of the cylinder wall is limited by the type of lubricating oil used and this temperature ranges from 160°C to 180°C. Beyond these temperature, the properties of lubricating oil deteriorates very rapidly and it might even evaporates and burn, damaging piston and cylinder surfaces. Piston seizure due to overheating resulting from the failure of lubrication is quite common.
- The volumetric and thermal efficiency and power output of the engines decrease with an increase in cylinder and head temperature.



Thermostat cooling system consists of pump, water jacket in the cylinder, radiator, fan and a thermostat. The coolant (water or synthetic coolant) is circulated through the cylinder jacket with the help of a pump, which is usually a centrifugal type, and driven by the engine. The function of thermostat, which is fitted in the upper hose connection initially, prevents the circulation of water below a certain temperature (usually up to 85°C) through the radiation so that water gets heated up quickly. Standby diesel power plants up to 200 kVA use this type of cooling. In the case of bigger plant, the hot water is cooled in a cooling tower and re-circulated. There is a need of small quantity of cooling make-up water.

3c) What are the advantages and disadvantages of diesel power plant? (5 marks)

Advantages:

- It is easy to design and install these electric stations.
- They are easily available in standard capacities
- They can respond to load changes without much difficulty.
- There are less standby losses.
- They can be started and stopped quickly.

Following are some of the disadvantages in installing diesel units for power generation.

- High operating cost
- High maintenance and lubrication cost.
- Capacity is restricted. They cannot be of very big size.
- They produce a lot of noise during regular operation.

4b) Differentiate the following with reference to hydroelectric power plant: (7 marks)

- Base and peak load plants

  Base Load plants: These plants supply constant power to the grid without any interruption. They work throughout the day. Base load plants are often remote controlled with which least staff required for such plants. Run –of-river plants without pondage may sometimes work as base load plant but the capacity is less.

  Peak load plats: They supply power only during the certain hours of the day when the load is more than the average. Thermal power plants work with hydel plants in tandem to meet the base load and peak load during various seasons. Some of such plants supply the power during the average load but also supply peak load as and when it is there. The run-off river plants may be made for peak load by providing pondage.

- Pondage and storage

  Pondage may be defined as a regulating body of water in the form of a relatively small pond or reservoir provided at the plant. The pondage is used to regulate the variable water flow to meet power demand. It takes care of short term fluctuations which may occur due to

  - Sudden increase or decrease of load on the turbine.
  - Sudden changes in the flow of water, say by breaches in the conveyance channel
  - Change of water demand by turbines and the natural flow of water from time to time.

  Pondage increases the capacity of a river over a short time, such as a week. The following figure shows the location of the pondage with respect to the power house.

  Storage may be defined as storing of considerable amount of excess run off during seasons of surplus flow for use in dry seasons. This accomplished by constructing the dam across the stream at suitable site and building a storage reservoir on the upstream side of the dam. Storage increases the capacity of the river over an extended period of 6 months as much as 2 years. The following figure shows the location of the storage with respect to the power house.

4c) Give a brief note on the following (5 marks)

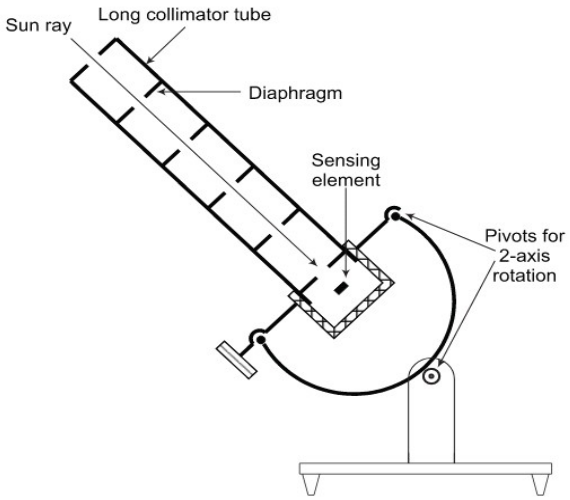
(i) Hydrograph,

Hydro graph is plot of discharge through a river versus time for specified period. The time period for discharge may be day, week, or month. Each hydrograph has a reference to a particular site. Besides the variation in flow indicated by a hydrograph, it also indicates the power available from the stream at different times of the day, week, month or year.

(ii)Flow duration curve

A flow duration curve is another useful form to represent the run off data for the given time. This curve is plotted between the flow available during a period versus the fraction of time. The flow may be expressed in the form cubic meters per second per week or any other convenient unit of time knowing the available head of water, total energy of flow can be computed. By changing the ordinate to power instead of discharge, the power duration curve is obtained and the area under the curve would then represent the average yield of power from hydro power project. Thus by flow duration curve it is possible to know the total power available at the site.

5a) With the help of neat sketch, explain the working principle of pyrheliometer for measuring beam radiation. (8 marks)

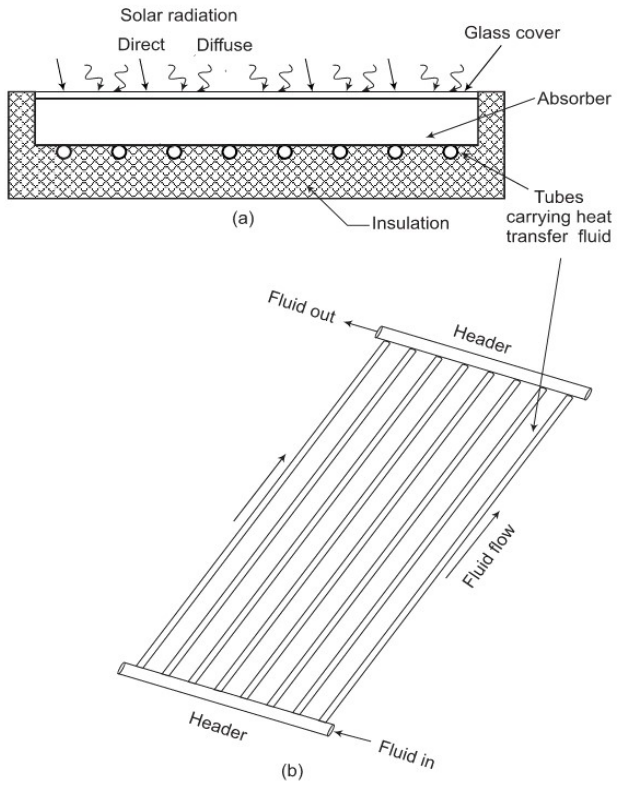


Solar radiation propagating in a straight line and received at the earth's surface without change of direction, i.e., in line with sun is called beam or direct radiation.

The pyrheliometer uses a long collimator tube to collect beam radiation whose field of view is limited to a solid angle of 5.5° (generally) by appropriate diaphragms inside the tube. The inside of the tube is blackened to absorb any radiation incident at angles outside the collection solid angle. The tube is sealed with dry air to eliminate absorption of beam radiation within the tube by water vapor. A tracker is needed if continuous readings are desired. It contains a thermopile whose sensitive surface consists of circular, blackened, hot junctions, exposed to the sun and cold junctions are completely shaded. The temperature difference between the hot and cold junctions is the function of radiation falling on the sensitive surface.

5b) Explain construction and working of a flat plate collector. (7 marks)

The constructional details of a simple flat plate collector are shown below. The basic elements in a majority of these collectors are: (i) transparent cover (one or two sheets) of glass or plastic (ii) blackened absorber plate usually of copper, aluminum or steel, (iii) tubes, channels or passages, in thermal contact with the absorber plate. In some designs, the tubes form integral part of absorber plate (iv) weather tight, insulated container to enclose the above components A liquid, most commonly, water is used as heat transport medium from collector to next stage of the system. However, sometimes mixture of water and ethylene glycol (antifreeze mixture) are also used if the ambient temperatures are likely to drop below 0°C during nights. As solar radiation strikes on specially treated metallic absorber plate, it is absorbed and raises its temperature. The absorber plate is usually made from a metal sheet ranging in thickness from 0.2 to 1 mm. The heat is transferred to heat transfer liquid circulating in the tube (or channels), beneath the absorber plate and in intimate contact with it. The metallic tubes range in diameter from 1 to 1.5 cm. These are soldered, brazed, welded or pressure bonded to the absorber plate with a pitch ranging from 5 to 12 cm. In some designs, the tubes are bonded to the top of absorber plate or in line with and integral to absorber plate.



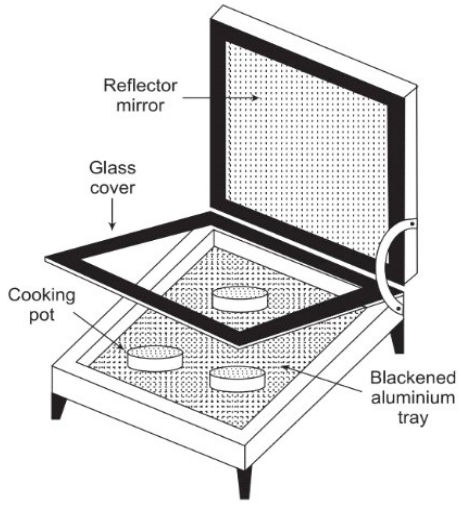
5c) Write a short note on solar cooker. (5 marks)

Thermal energy requirements for cooking purpose forms a major share of total energy consumed, especially in rural areas. Variety of fuels like coal, kerosene, cooking gas, firewood, dung cakes and agricultural wastes are being used to meet the requirement.

Fossil fuel is a fast depleting resource and need to be conserved, firewood for cooking causes deforestation and cow dung, agricultural waste, etc., may be better used as a good fertilizer. Harnessing solar energy for cooking purpose is an attractive and relevant option. A variety of solar cookers have been developed, which can be clubbed in four types of basic designs:

- box type solar cooker,
- dish type solar cooker,
- community solar cooker,
- advance solar cooker.

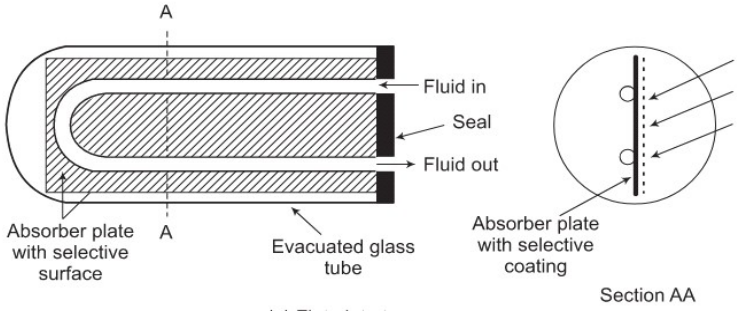
The box type solar cooker is simple in construction and operation. An insulated box of blackened aluminum contains the utensils with food material. The box receives direct radiation and also reflected radiation from a reflector mirror fixed on inner side of the box cover hinged to one side of the box. The angle of reflector can be adjusted as required. A glass cover consisting of two layers of clear window glass sheets serves as the box door. The glass cover traps heat due to greenhouse effect.



6a) Explain evacuate tubular collector with a neat sketch. (8 marks)

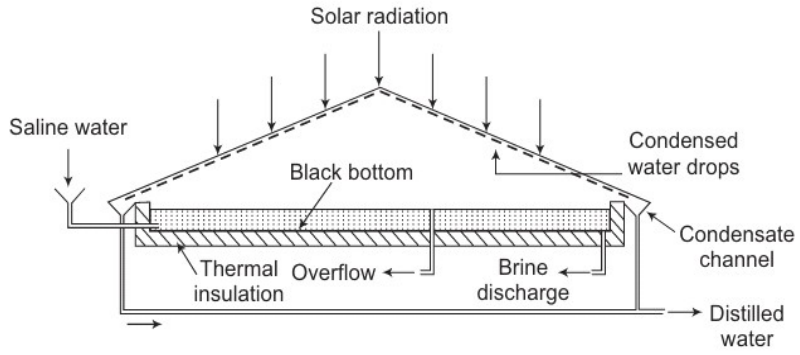
The performance of a flat plate collector can be improved by suppressing or reducing the heat lost from the collector by convection and conduction. This is done by having vacuum around the absorber. As a consequence, it becomes essential to use a glass tube as the cover because only a tubular surface is able to withstand the stresses introduced by the pressure differences as a result of vacuum. The collector consists of a number of long tubular modules stacked together.

The absorber plate has a selective surface coating on it. The two tubes are joined at the other end inside the glass cover and form a "U" path for the fluid, with one tube acting as inlet tube while the other as outlet tube. Glass to metal seal is provided between the absorber tubes and the end cover of the vacuum tube. Also special precaution is required to reduce thermal contact between absorber tubes and outer tube though the seal.

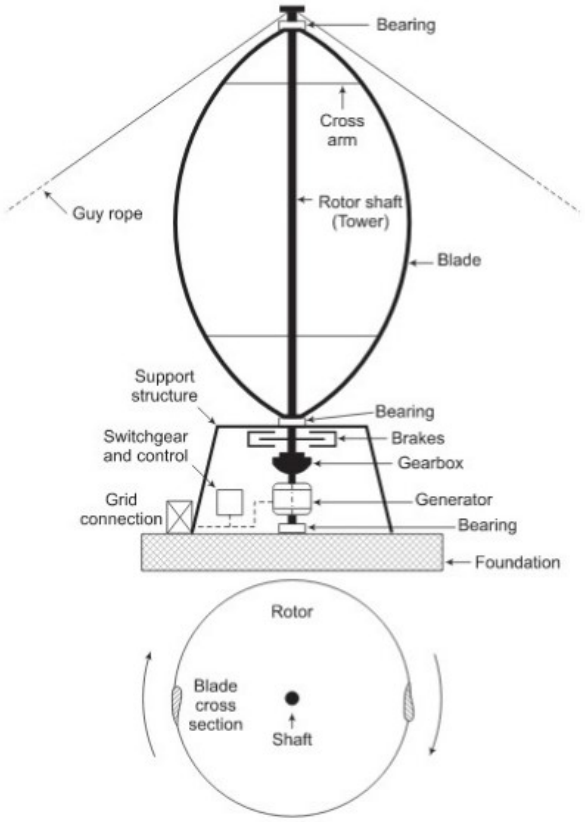


6c) Explain solar distillation process. (5 marks)

A simple basin type solar still consists of a shallow blackened basin filled with saline or brackish water to be distilled. The depth of water is kept about 5-10 cm. It is covered with sloppy transparent roof. Solar radiation, after passing through the roof is absorbed by the blackened surface of the basin and thus increasing the temperature of water. The evaporated water increases the moisture content, which gets condensed on the cooler underside of the glass. The condensed water slips down the slope and is collected through the condensate channel attached to the glass. The construction is schematically shown below.



7a) Explain with neat sketch vertical axis type wind mill. (8 marks)



The constructional details of a vertical axis wind turbine (Darrieus type rotor) are shown below. The details of main components are as follows:

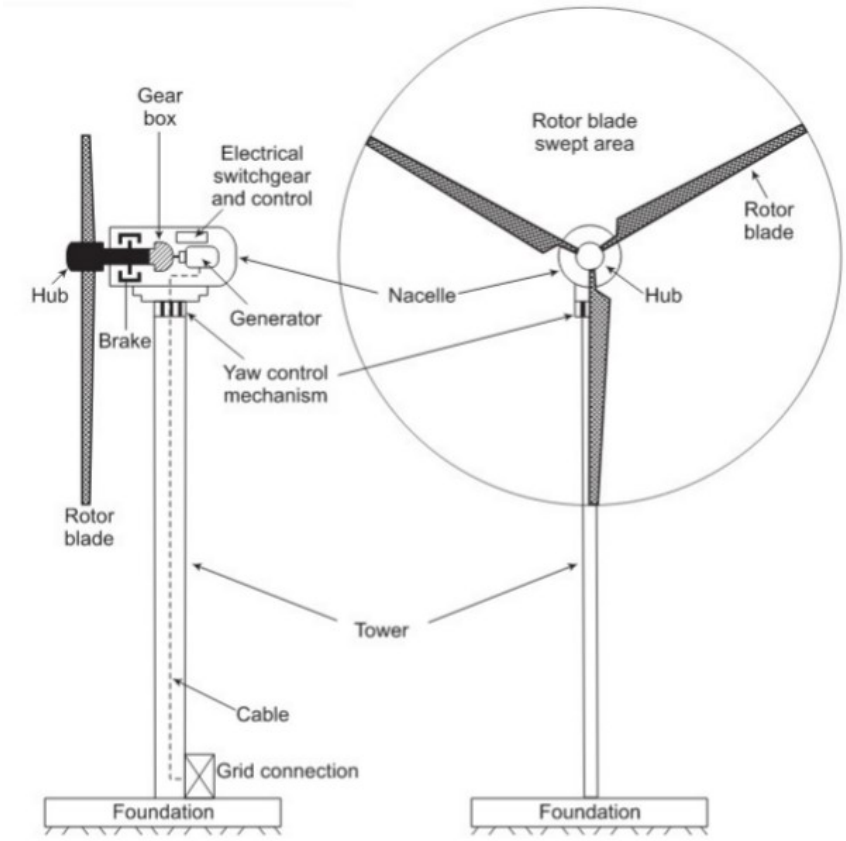
(a) Tower (or Rotor Shaft): The tower is a hollow vertical rotor shaft, which rotates freely about vertical axis between top and bottom bearings. It is installed above a support structure. In the absence of any load at the top, a very strong tower is not required, which greatly simplifies its design. The upper part of the tower is supported by guy ropes. The height of the tower of a large turbine is around 100 m.

(b) Blades: It has two or three thin, curved blades shaped like an eggbeater in profile, with blades curved in a form that minimizes the bending stress caused by centrifugal forces-the so-called "Troposkien"

profile. The blades have airfoil cross section with constant chord length. The pitch of the blades cannot be changed. The diameter of the rotor is slightly less than the tower height.
(c) Support Structure: Support structure is provided at the ground to support the weight of the rotor. Gearbox, generator, brakes, electrical switchgear and controls are housed within this structure.

7b) With neat sketch, explain construction of horizontal axis wind machine. (7 marks)

The constructional details of most common, three-blade rotor, horizontal axis wind turbine are shown in figure. Main parts are as follows:



(a) Turbine Blades: Turbine blades are made of high-density wood or glass fiber and epoxy composites. They have airfoil type cross-section. The blades are slightly twisted from the outer tip to the root to reduce the tendency to stall. Diameter of a typical, MW range, modern rotor may be of the order of 100 m.
(b) Hub: The central solid portion of the rotor wheel is known as hub. All blades ate attached to the hub. Mechanism for pitch angle control is also provided inside the hub.
(c) Nacelle: The rotor is attached to nacelle, mounted at the top of a tower. It contains rotor brakes, gearbox, generator and electrical switchgear and control. Brakes are used to stop the rotor when power generation is not desired. Gearbox steps up the shaft rpm to suit the generator. Protection and control functions are provided by switchgear and control block. The generated electrical power is conducted to ground terminals through a cable.

(d) Yaw Control Mechanism: The mechanism to adjust the nacelle around vertical axis to keep it facing the wind is provided at the base of nacelle.
(e) Tower: Tower supports nacelle and rotor. For medium and large sized turbines, the tower is slightly taller than the rotor diameter. In case of small sized turbine, the tower is much larger than the rotor diameter as the air is erratic at lower heights. Both steel and concrete towers are being used. The construction can be either tubular or lattice type.

7c) Explain site selection criterion for wind mill. (5 marks)
The characteristics of a good wind power site may be summarized as follows:

- A site should have a high annual wind speed.
- There should be no tall obstructions for a radius of 3km.
- An open plain or an open shore line may be a good location.
- The top of a smooth, well rounded hill with gentle slopes lying on a flat plain or located in an island in a lake or sea is a good site.
- A mountain gap which produces wind funnelling is good.

8a) Explain the principle of harnessing energy from the following sources of energy: (8 marks)
(i) Tidal energy:

The principle used for harnessing the energy consisted of a pond filled through sluice (rapid controlled gates) when tides are high and emptying it during low tides via an undershot waterwheel, producing mechanical power.

Main components of a tidal plant are:

(a) Dam, barrage or dyke: a barrier constructed to hold water,

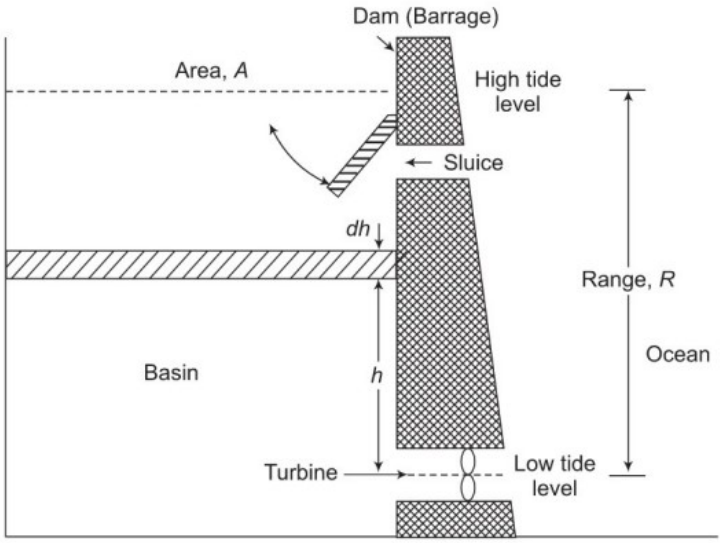
(b) Sluice ways: rapid controlled gates, used to fill basin during high tides or emptying it during low tides and

(c) A special, bulb type power turbine-generator set: steel shell containing an alternator and special Kaplan turbine with variable pitch blades.

(ii) Ocean thermal energy

Ocean thermal energy exists in the form of temperature difference between the warm surface water and the colder deep water. A heat engine generates power utilizing well established thermodynamic principle, where heat flows from high temperature source to low temperature sink through engine, converting a part of the heat into work. In the present case the surface water works as heat source and deep water as heat sink to convert part of the heat to mechanical energy and hence into electrical energy. The facility proposed to achieve this conversion is known as OTEC (ocean thermal energy conversion). A minimum temperature difference of 20°C is required for practical energy conversion.

8b) Explain the fundamental characteristics of Tidal power plant selection. (7 marks)



Consider water trapped at high tide in a basin of area A, and allowed to run out through a turbine at low tide as shown. Potential energy in the mass of water stored in incremental head *dh* above head h:

$$dW = dm \cdot gh$$

$$\text{but } dm = \rho \cdot A \cdot dh$$

$$\text{Thus } dW = \rho \cdot A \cdot g \cdot h \cdot dh$$

Thus, total potential energy of the water stored in the basin is:

$$W = \int_0^R \rho.\, A.\, g.\, h.\, dh$$

$$W = \frac{1}{2} \rho.\, A.\, g.\, R^2 \quad \text{Joules}$$

Here, ρ = density of water; g = gravitational constant; and R = tidal range
Thus tidal power developed is directly proportional to (i) area of basin and (ii) square of the tidal range.

8c) What are the advantages and disadvantages of tidal power plant. (5 marks)
Advantages:

- It is free from pollution as it does not use any fuel.
- The tides are totally independent on nature's cycle of rainfall.
- This will not produce any waste like green house gases, ash, atomic refuse which entails heavy removal cost.

Main limitations of the tidal energy are:

- Economic recovery of energy from tides is feasible only at those sites where energy is concentrated in the form of tidal range of about 5 m or more, thus it is site specific,
- The turbines are required to operate at variable heads.
- Tidal plant disrupts marine life at the location and can cause potential harm to ecology,

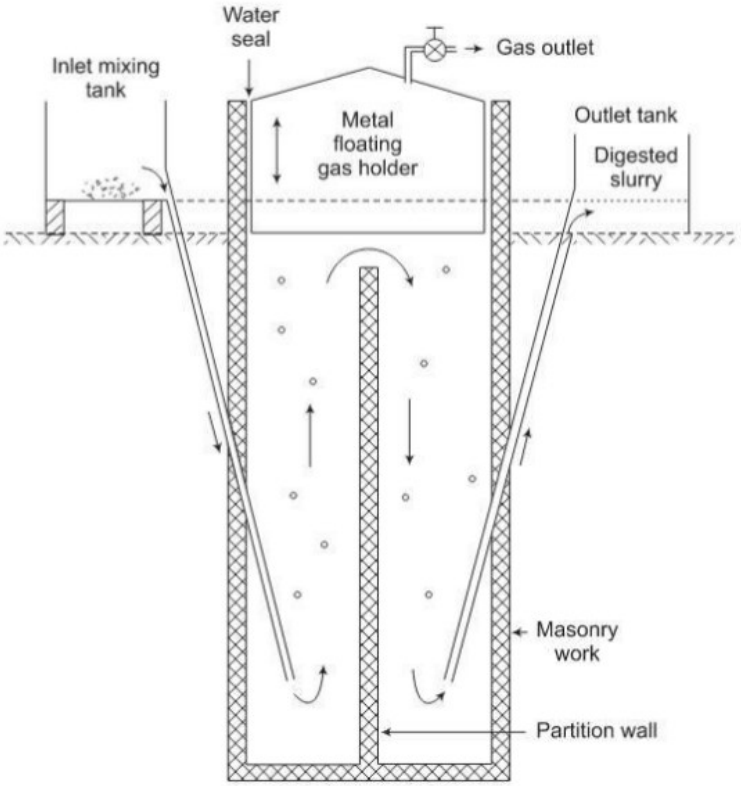
- It requires very large capital cost at most potential installations, and the location of sites may be distant from the demand centres.

9a) With a neat sketch, explain the construction and working of KVIC digester. (8 marks)

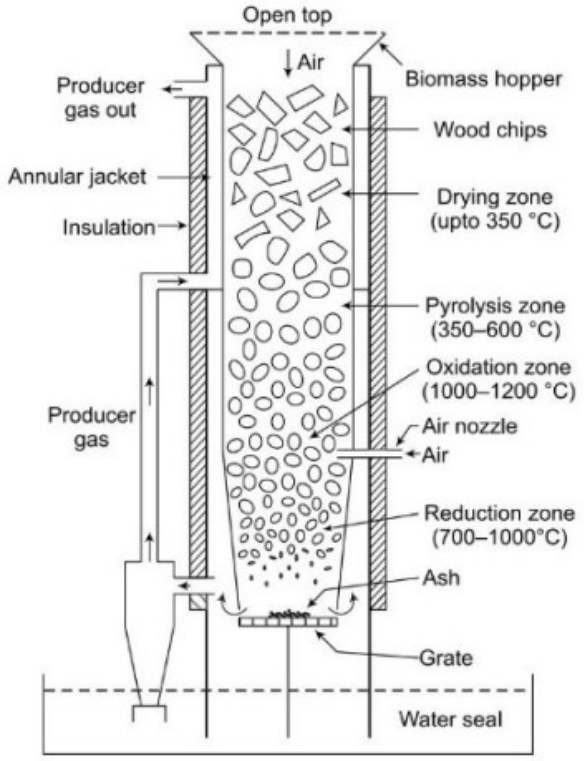
Numerous models of floating drum type biogas plants are developed in various countries. Most representative of this type is the KVIC model (Khadi Village Industries Commission), developed in India.

It has an inverted mild steel drum to work as gasholder. This is the most expensive component of the plant. The drum floats either direct on fermentation slurry or in a water jacket of its own. Most Indian plants now have a pair of central guide pipes. The gasholder is free to rise or fall depending on the production and use of gas. It is also free to rotate on its axis. Gasholder rotation will also be useful as a device to break the scum in the digester. A flexible hosepipe is attached at the top of the gasholder for gas dispersion. The gas passes through a moisture trap before supplying to the utility/house.

The digester is a deep circular pit or a well, built of bricks, mortar and plaster, with a partition wall. The bifurcation of digestion chamber through partitioning wall provides optimum conditions for growth of acid formers and methane formers as the requirement of pH values for these bacteria are different. Therefore, this plant operates very well with good biogas yield. The underground structure helps minimize the heat loss from the plant and the cylindrical shape has better structural strength.



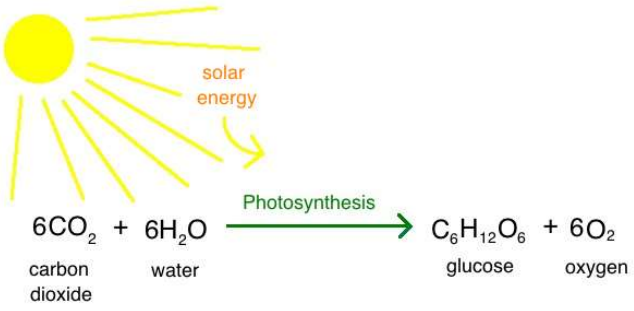
9b) Explain the working principle of downdraft gasifier with neat sketch. (7 marks)



In steady state operation, heat from the combustion zone (oxidation zone), near the air nozzle is transferred upwards by radiation, conduction and convection causing wood chips to pyrolyse and lose 70 to 80 per cent of their weight. These pyrolysed gases burn with air to from CO, CO2, H2 and H2O, thereby raises the temperature to 1000-1200 °C. The product gases from combustion zone further undergo reduction reaction with char to generate combustible products like CO, H2 and CH4. Generally, 40 to 70 per cent air is drawn through open top depending on the pressure drop conditions due to size of wood chips and gas flow rate. This flow of air opposite to flame front helps in maintaining homogeneous air/gas flow across the bed. Combining the open top with air nozzle towards the bottom of the reactor helps in stabilizing the combustion zone by consuming the uncovered char left and also by preventing the movement of the flame front to the top. As a consequence, the high temperature zone spreads above the air nozzle by radiation and conduction, aided by airflow from the top. The tar thus is eliminated in the best possible way by creating a high temperature-oxidizing atmosphere in the reactor itself. The gas produced is withdrawn from an exit at the bottom and reintroduced in the annular jacket for heat recovery.

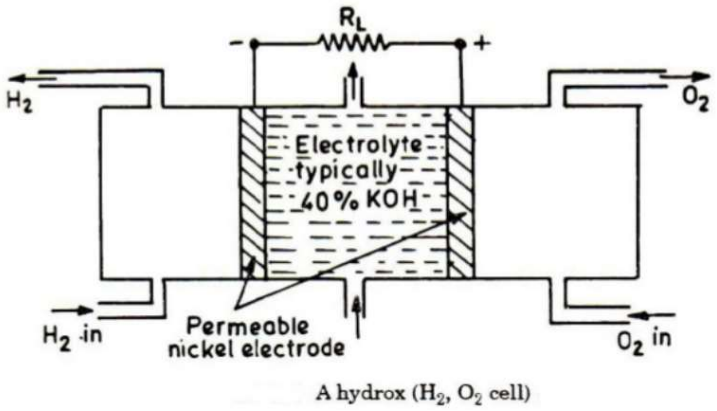
9c) Write a short note on photosynthesis. (5 marks)

Solar radiation incident on green plants and other photosynthetic organisms performs two basic functions: (i) temperature control for chemical reactions to proceed and (ii) photosynthesis process. The fundamental conversion process in green plants is photosynthesis, which is the process of combining CO_2 from the atmosphere with water plus light energy to produce oxygen and carbohydrates (sugars, starches, celluloses and hemicelluloses). They are ultimate source of most of our foods and other necessities of daily life such as clothes (in the form of cotton), furniture (in the form of wood) etc.



10a) What is fuel cell? What are the classifications of fuel cells? (8 marks)

Fuel cell is a cell or combination of cells capable of generating an electric current by converting the chemical energy of a fuel directly into electrical energy. It consists of positive and negative electrodes with an electrolyte between them. Fuel in suitable form is supplied to the negative electrode and oxygen, often from air, to the positive electrode. When the cell operates, the fuel is oxidized and the chemical reaction provides the energy that is converted in to electricity.



Hydrogen oxygen fuel cell

Classification of fuel cells:

(a) Based on the type of electrolyte:

- Phoshphoric acid fuel cell
- Alkaline fuel cell
- Solid Oxide fuel cell
- Molten carbonate fuel cell

(b) Based on the types of the fuel and oxidant:

- Hydrogen Oxygen fuel cell
- Ammonia Air fuel cell
- Synthetic gas air fuel cell
- Hydrocarbon air fuel cell

(c) Based on Operating temperature:

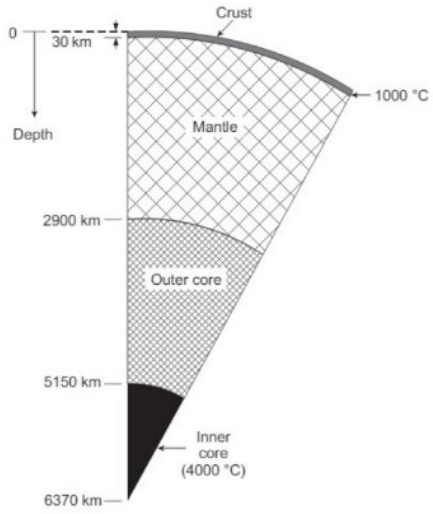
- Low temperature fuel cell (below 150ºC)
- Medium temperature fuel cell (150ºC - 250ºC)
- High temperature fuel cell (250ºC - 800ºC)

- Very high temperature fuel cell (800ºC - 1100ºC)

(d) Based on chemical nature of electrolyte:

- Acidic electrolyte type
- Alkaline electrolyte type
- Neutral electrolyte type

10b) Write a short note on geothermal energy. (5 marks)



Cross section of the Earth

Geothermal energy is the heat that originates from the core of the earth, where temperatures are about 4000°C. The core is surrounded by a region, known as mantle, which consists of semi-fluid material called the magma. The mantle is finally covered by the outermost layer known as crust, which has average thickness of about 30 km. The temperature in the crust increases with depth at a rate of 30°C/km. The temperature at the base of crust is about 1000 °C and then increases slowly into the core of the earth. A section through the earth is shown in figure. There are regions in which hot molten rock (magma) of the mantle has pushed up through faults and cracks towards the surface. In an active volcano, the magma actually reaches the surface, but more often “hot spots” occur at moderate depths (within 2 to 3 km), where the heat of the magma is being conducted upward through an overlaying rock layer. The extraction and practical utilization of this heat requires technology, which depends on the nature of resource.