USN 1CA14ME086 **10ME754**

Seventh Semester B.E. Degree Examination, Dec.2017/Jan.2018
Non Conventional Energy Sources

Time: 3 hrs. Max. Marks:100

Note: ***Answer FIVE full questions, selecting at least TWO questions from each part.***

PART – A

1 a. With neat sketch, explain the production of oil from oil shale and Tar sands. **(12 Marks)**
b. Explain the advantages and limitations of use of non-conventional sources of energy. **(08 Marks)**

2 a. With a neat sketch, explain the working principle of an instrument used to measure Global radiation. **(10 Marks)**
b. With the help of appropriate sketch, explain altitude, zenith angle and solar azimuth angle. **(10 Marks)**

3 a. With a neat sketch, explain the working principle and applications of solar pond. **(12 Marks)**
b. With a neat sketch, explain thermal storage wall and roof storage with respect to passive solar heating system. **(08 Marks)**

4 a. Briefly explain the effect of various parameters on performance of liquid flat plate collectors. **(10 Marks)**
b. Data for a flat plate collector used for heating the building are given below :

Sl No	Factor	Specification
1	Location and latitude	– Baroda, 22°N
2	Day and time	– January 1, 11:30 to 12:30 (IST)
3	Annual average intensity of solar radiation.	– 0.5 Langley/min
4	Collector tilt	– Latitude + 15°
5	Number of glass covers	– 02
6	Heat removal factor for collector	– 0.810
7	Transmittance of the glass	– 0.88
8	Absorptance of the glass	– 0.90
9	Top loss coefficient for collector	– 7.88W/m^2°C [6.80 Kcal/hrm^2°C]
10	Collector fluid temperature	– 60°C
11	Ambient Temperature	– 15°C

Calculate:
i) Solar altitude angle
ii) Incident angle
iii) Collector efficiency. **(10 Marks)**

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

PART – B

5 a. With a neat sketch, explain the working principle of horizontal axis wind turbine using two aerodynamic blades. (10 Marks)

b. Describe the main considerations in selecting a site for wind generators. (10 Marks)

6 a. With a neat sketch, explain single and double basin tidal power plant. (10 Marks)

b. Briefly explain the various factors which affect the operational and environmental problems with respect to Geothermal energy. (10 Marks)

7 a. With a neat sketch, explain the Indian bio-gas-plant. (10 Marks)

b. What are the applications of Bio-gas? Explain the modifications needed for C.I. engine using Biogas. (10 Marks)

8 a. Discuss briefly the four methods of hydrogen storage. (10 Marks)

b. What are the various routes of hydrogen production? Explain the hydrogen production through electrolysis of water with simple sketch. (10 Marks)

Seventh Sem ~~B.Tech~~ B.E Degree Exam
Dec 2017/ Jan 2018

Non-Conventional Energy Sources
(Answer Key)

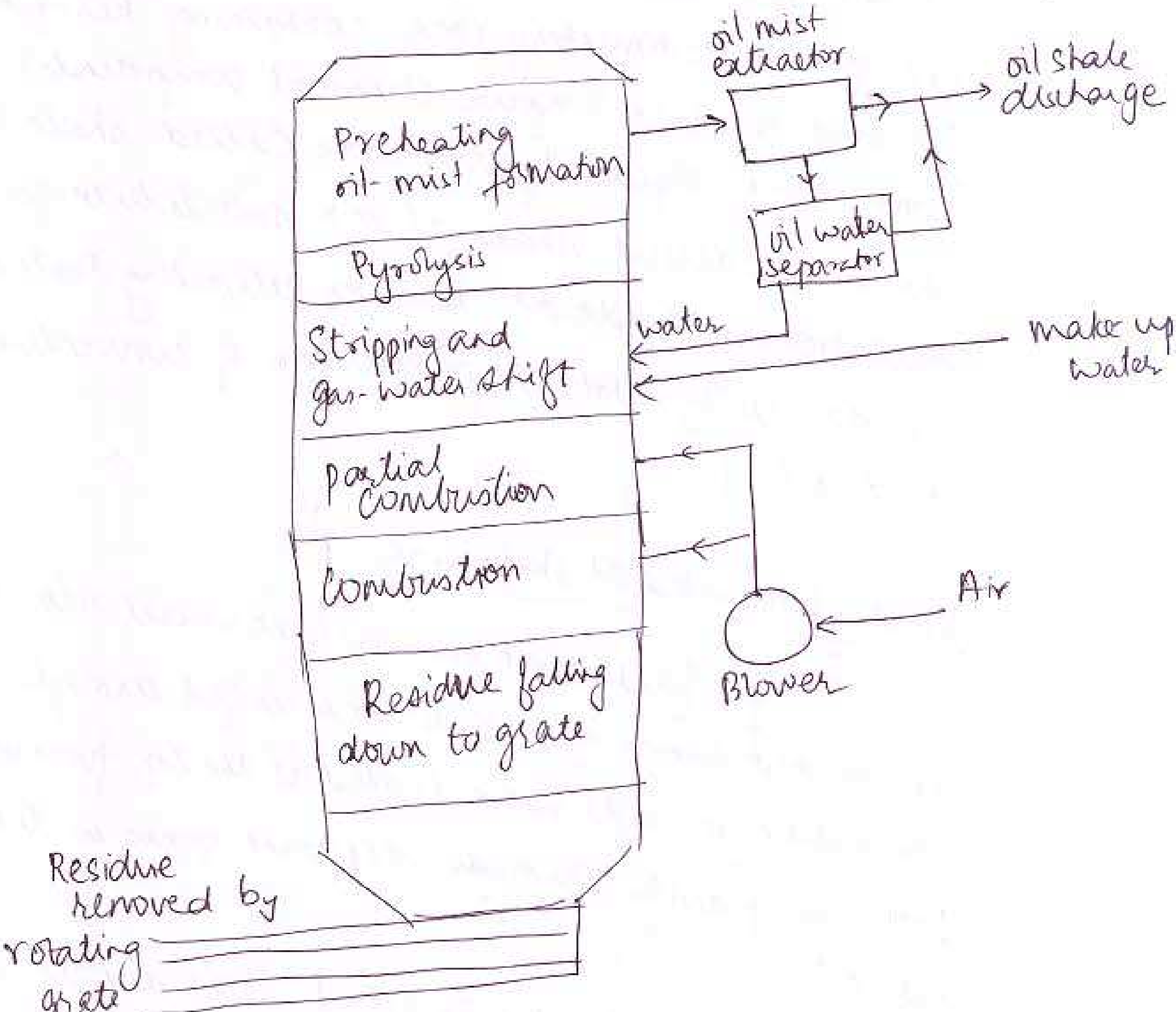
1
(a) Oil shale, also known as Kerogen shale, is an organic-rich fine grained sedimentary rock containing kerogen (a solid mixture of organic chemical compounds) from which liquid hydrocarbons called shale oil can be produced. Shale oil is a substitute for conventional crude oil; however extracting shale oil is more costly that the production of conventional crude oil.

Retorting Excavated oil shale rock

The gas fired retort is a vertical vessel into which the crushed lumps of oil shale rock is fed through a non-return gas tight valve located at the top, from where it falls by gravity through different zones in the retort.

The vessel is heated to about 700°F and the rock is fed into it. As the rock passes through the first zone, of the retort, it is met by the hot gases moving upwards from the combustion area. Here, the shale is preheated, and some oil mist is formed. As the shale falls down the retort through the next zone, it is subjected to pyrolysis- anaerobic combustion removing the kerogen and leaving a char. This falls down into the combustion zone where along with produced gas and combustion air, temperature rises upto ~~to~~ around 900°F.

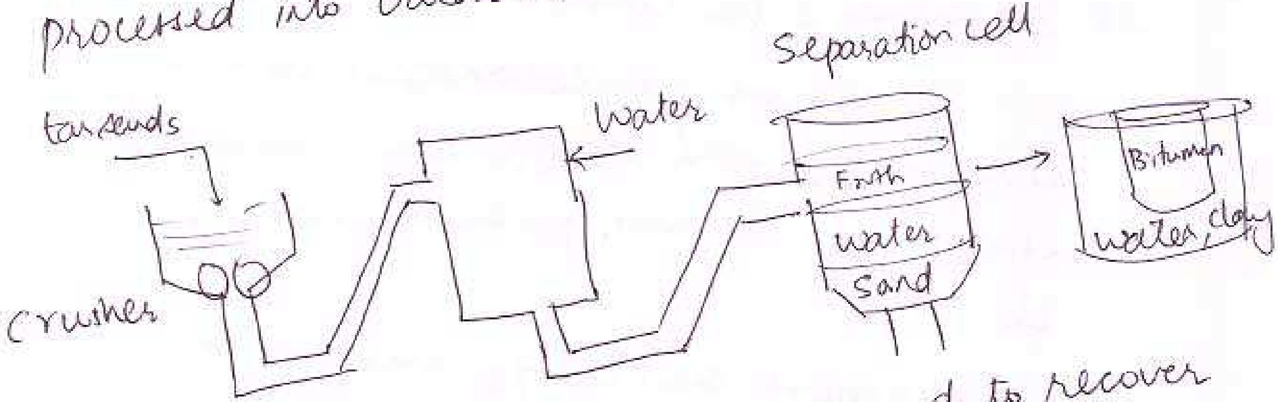
The residue then falls to the bottom of the retort where it is cooled by air and falls onto a rotating grate arrangement where it is removed to the residue storage site.



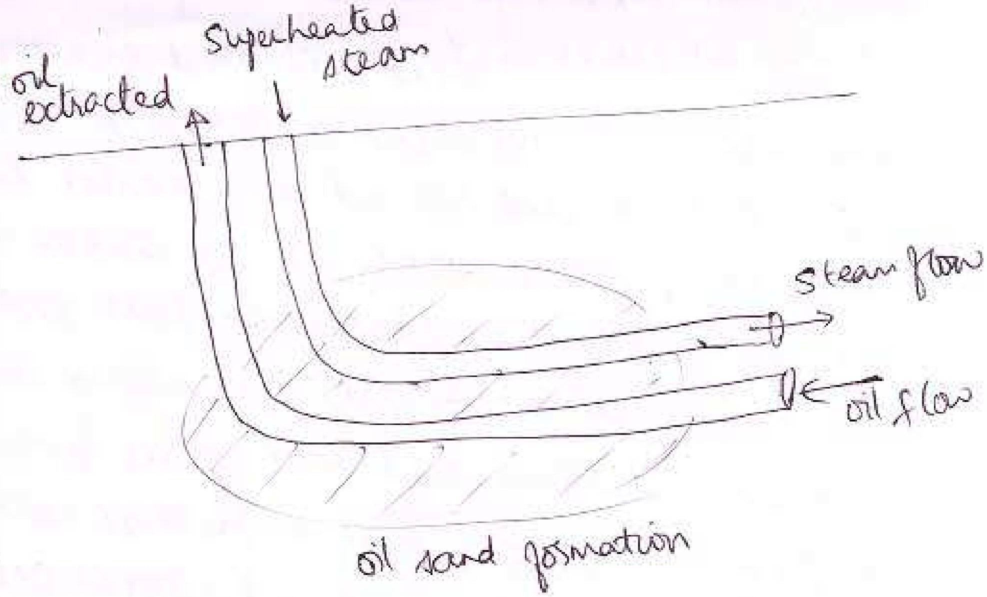
<u>Tar Sands</u> : Tar sands, also known as oil sands or crude bitumen or more technically bituminous sands are either loose sands or partially consolidated sandstone containing a naturally occurring mixture of sand, clay and water, saturated with a dense and extremely viscous form of petroleum.

There are two main ways of extracting crude oil from tar sands. These are explained below

(1) <u>open pit mining</u> → Land is cleared to expose sand containing ~~[illegible]~~ semi-solid petroleum or bitumen. The tar sands are loaded to trucks and poured into a crusher to break up lumps and remove rocks. The tar sand is then mixed with hot water to create a slurry mixture and transported by pipeline to an extraction plant. The slurry enters a separation cell, where sand settles to the bottom and bitumen and tiny air bubbles form a froth at the top. The bitumen froth is skimmed off, mixed with solvent and spun into a centrifuge to remove water and clay solids. It can be processed into crude oil.



<u>Steam injection</u> - This method may be used to recover bitumen that lies too deep beneath the surface for mining. This method requires the drilling of two horizontal wells through the oil deposit. Heated steam is injected into the upper well, where the build-up of pressure and heat melts the bitumen and causes it to flow downward to the second ~~[illegible]~~ horizontal well, from which it is pumped to the surface. Water is injected into the deposit to maintain stability after the bitumen is removed.



1(b) Advantages of Non-conventional Energy Sources

The various non-conventional energy sources are solar energy, wind energy, tidal energy, wave energy, energy from biomass, geothermal energy, tar sands, oil shales, etc.

→ In general, these energy sources are available free of cost (except tar sands and oil shale). They produce no or very little pollution. Thus, they are environmentally friendly.

→ They are inexhaustible.

→ Do not deplete natural resources.

→ Have low gestation period and takes less construction time compared to non-renewable energy plants.

→ Can supply energy for many generations

→ manage rural energy crisis.

Disadvantages/Limitations:

→ Continous supply of energy cannot be provided because of intermittent nature of availability of energy sources such as solar, wind, tidal etc.

→ Available in dilute form in nature, although available in large quantities. they are concentrated only in certain regions.

→ Though available freely in nature, cost of harnessing energy is very high.

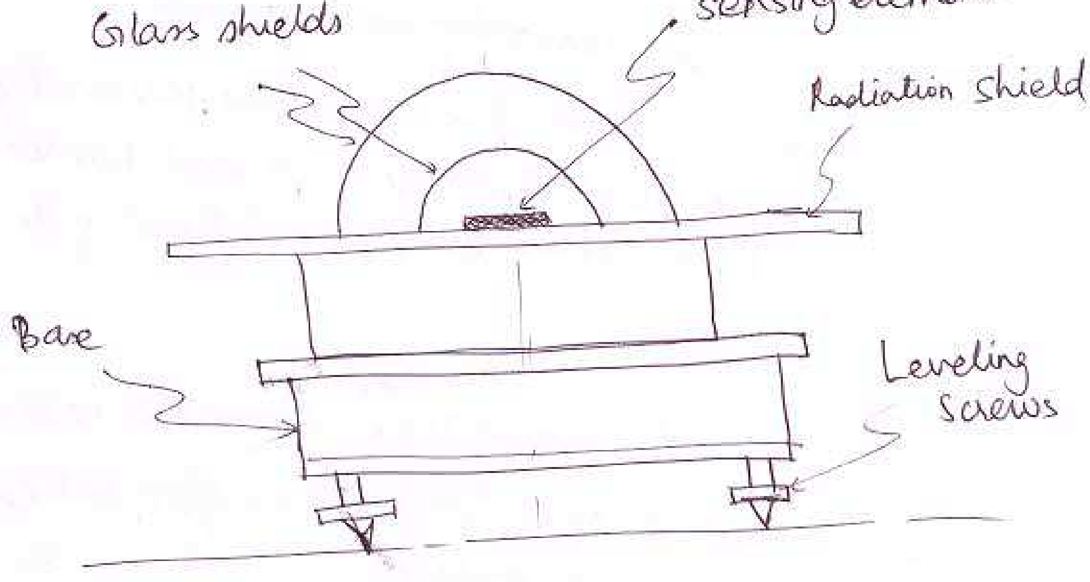
→ High initial cost since advanced technologies are required such as solar cells, automatic tracking system for solar concentrators etc.

→ Difficulty in transporting such sources.

→ To harness energy from renewable sources depends on various natural phenomenon beyond human control such as local atmospheric conditions, time of the day etc.

2(a) Pyranometer: A pyranometer is designed to measure global radiation, usually on a horizontal surface, but can also be used on an inclined surface.

A precision pyranometer is designed to respond to radiation of all wavelengths and hence measures accurately the total power in the incident spectrum. It contains a thermophile (a collection of thermocouples arranged in series) whose sensitive surface consists of circular, blackened, hot junctions, exposed to the sun, while the cold junctions are completly shaded. The temperature difference between the hot and cold junctions is a function of radiation falling on the sensitive surface. The sensing ~~element~~ element is covered by two concentric hemispherical glass domes to shield it from rain and wind. This also reduces the convection currents. A radiation shield, surrounding the outerdome and coplanar with ~~sensing~~ sensing element, prevents direct solar radiation from heating the base of the instrument.



Schematic of pyranometer

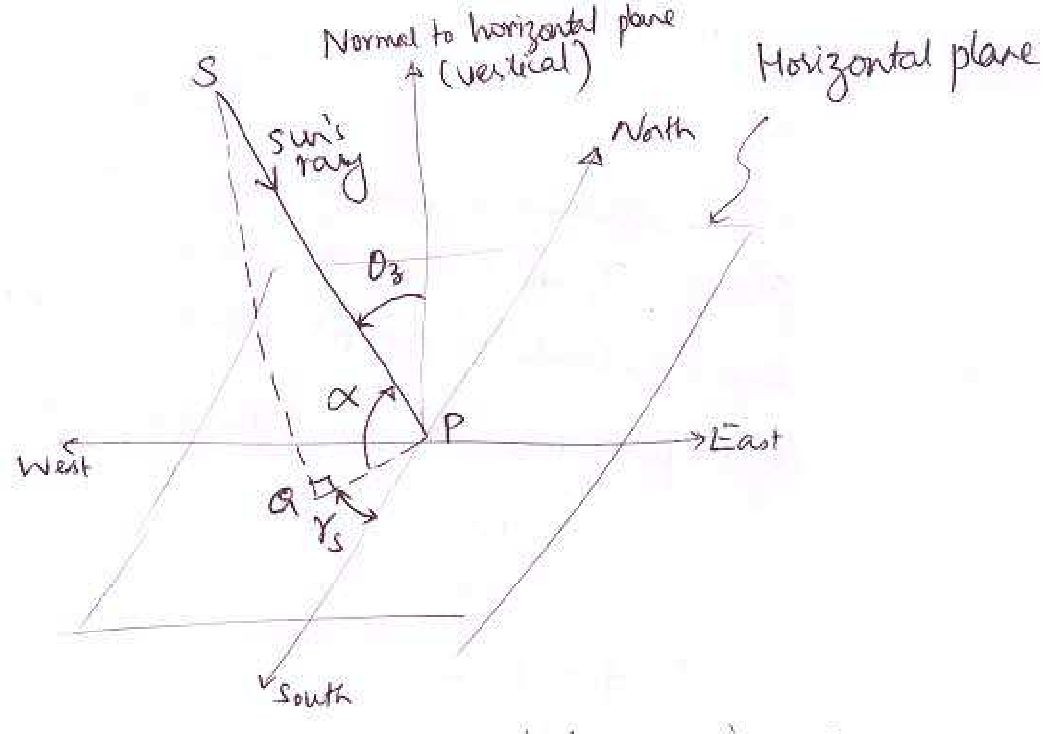
The pyranometer, when provided with a shadow band prevents beam radiation from reaching the sensing element, measures the diffused radiation only.

2(b) Inclination angle (altitude)(α):

It is the angle between the sun's rays and its projection on a horizontal surface.

Zenith angle (θ_z): It is the angle between the sun's rays and the perpendicular (normal) to the horizontal plane.

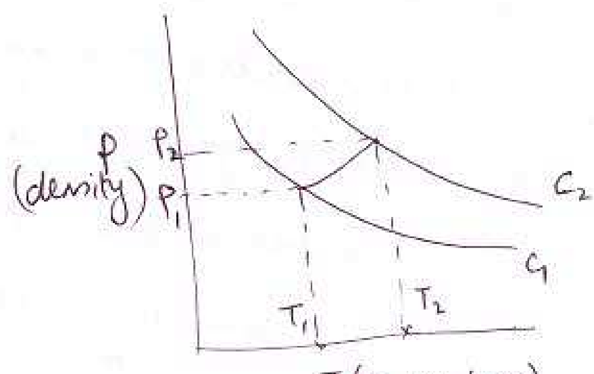
Solar Azimuth Angle(γ_s): It is the angle on a horizontal plane, between the line due south and the projection of the sun's ray on the horizontal plane. It is taken as positive when measured from south towards west.



QP → Horizontal projection of sun's rays

3(a) **Solar Pond** : An artificially constructed pond in which significant temperature rises are caused to occur in the lower regions by preventing convection is called a solar pond. The usual method adopted to prevent convection is to dissolve a salt in the water and to maintain a concentration gradient.

consider a pond of depth L having salts dissolved in water. The concentration C_1 at top is less that that C_2 at bottom. Thus, a concentration gradient exists from top to bottom.



The variation of density with temperature is shown in the fig above. T_1 and ρ_1 are the temperature and density of the top layer of water, (point A), while T_2 and ρ_2 are for the bottom layer (point B). For no convection to occur,

$$\left(\frac{d\rho}{dx}\right) > 0$$

$$\because \rho = \rho(C, T)$$

$$\frac{d\rho}{dx} = \left(\frac{\partial \rho}{\partial C}\right)_T \left(\frac{dC}{dx}\right) + \left(\frac{\partial \rho}{\partial T}\right)_C \left(\frac{dT}{dx}\right) > 0$$

So, the condition of stability is

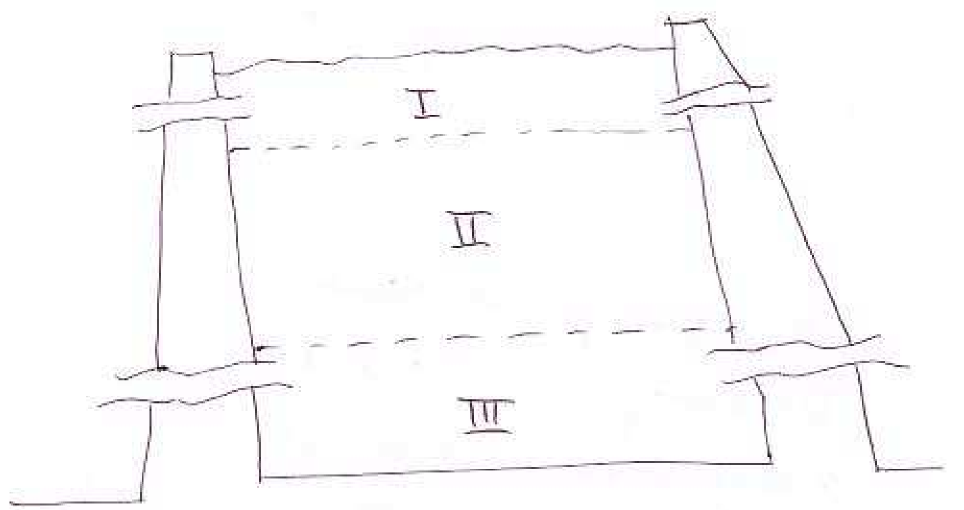
$$\left(\frac{dC}{dx}\right) > \frac{-\left(\frac{\partial \rho}{\partial T}\right)_C \left(\frac{dT}{dx}\right)}{\left(\frac{\partial \rho}{\partial C}\right)_T}$$

A more sophisticated analysis shows that

$$\left(\frac{dc}{dx}\right) > -\left(\frac{\nu + \alpha}{\nu + D}\right)\left[\frac{\left(\frac{\partial \rho}{\partial T}\right)_c \left(\frac{dT}{dx}\right)}{\left(\frac{\partial \rho}{\partial C}\right)_T}\right]$$

ν = kinematic viscosity
α = thermal diffusivity
D = diffusivity of salt in water

For salt solution under conditions encountered in solar ponds, the term $\left(\frac{\nu+\alpha}{\nu+D}\right)$ is about 1.15.

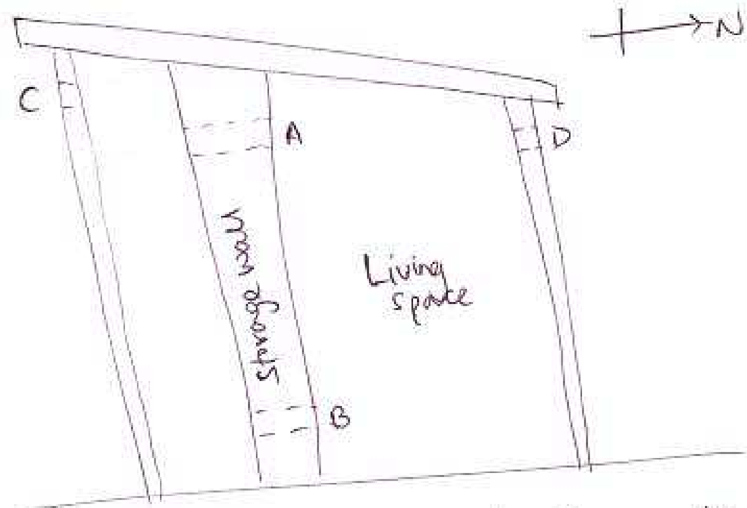


I → surface convection zone
II → concentration gradient zone
III → Lower convective zone

A schematic of a solar pond is shown above. Typically, it is about 1 to 2 metres deep with a thick plastic ~~linear~~ liner at the bottom. Salts like $MgCl_2$, $NaCl$ are dissolved in water, the concentration varying from 20 to 30% at bottom and almost zero at the top.

A solar pond combines the function of heat collection and long term storage and can provide sufficient heat for the entire year. In order to extract energy, hot water is continously removed from the bottom, passed through a heat exchanger and returned to the bottom.

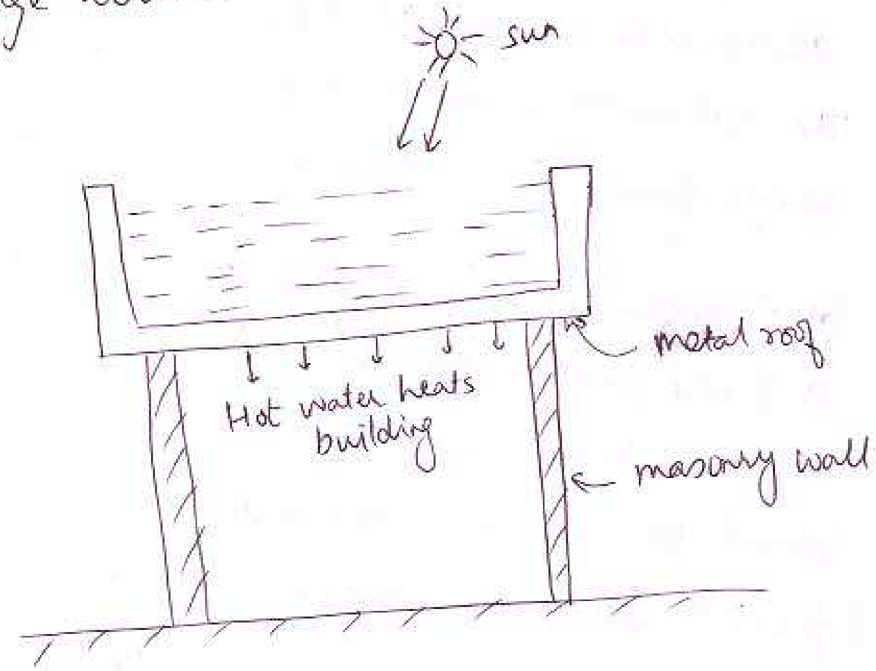
3(b) Thermal storage wall



A diagram of passive ~~system~~ solar heating system is shown above. The south-facing wall of the house is double glazed. Behind it is a thick black concrete wall which absorbs the sun's radiation and serves as a thermal storage. During the day time, the vents A and B are kept open. The air between the inner glazing and the wall gets heated and flows into the living room through the top vent. Simultaneously the cold air from the room is pulled out of the living space through the bottom vent. Some energy transfer to the living space also takes place by radiation from the inner surface of the storage wall.

Roof Pond system

A roof pond passive solar system, sometimes called solar roof, uses water stored on the roof to temper hot and cold internal temperatures, usually in desert environments. It is typically constructed of containers holding 150 to 300mm of water on a flat roof. Solar radiation heats the water which acts as a thermal storage medium. At night or during cloudy weather, the indoor space below the roof pond can be heated by thermal energy emitted by the roof pond storage above.



4a Effect of various parameters on performance

(a) Selective surface: Absorber plate surfaces with high value of absorptivity for incoming solar radiation and low value of emissivity for out going re-radiation are called selective surfaces. Such surfaces are desirable because they maximize the net energy collection. Some examples of selective surface layers are copper oxide, nickel black and black chrome.

(b) Number of covers: With increase in number of covers, the flux absorbed by the absorber plate decreases. The value of heat loss from the absorber plate also decreases. Maximum efficiency is obtained with one or two covers.

(c) Spacing- Heat loss also varies with spacing between two covers and that between the absorber plate and first cover. The spacing at which minimum loss occurs varies with temperature and also with ~~tilt~~ tilt. Since collectors are designed to operate at different locations with varying tilts, an optimum value is difficult to specify. Spacing in the range from 4 to 8 cm is normally suggested.

(d) Collector tilt – Flat plate collectors are normally used in a fixed position and do not track the sun. Hence, the tilt angle at which it is positioned is very important. The usual practice is to recommend a value of $(\phi + 10)^\circ$ or $(\phi + 15)^\circ$ for winter applications and $(\phi - 10)^\circ$ to $(\phi - 15)^\circ$ for summer applications (ϕ = latitude)

(e) Dust on top of cover: Dust accumulated over the collector reduces the transmitted flux. Hence, the covers are cleaned once in a few days. ~~In the~~ The incident flux is multiplied by a correction factor to account for the reduction in intensity. Typically, this factor varies from 0.92 to 0.99.

5(a) Wind turbine converts the kinetic energy of wind into mechanical energy The output from wind turbine depends on

(i) windspeed

(ii) Cross-section of wind swept by rotor

(iii) efficiency of rotor, transmission system and generator.

The mass of air passing in unit time through an area A with velocity V is given as

$$\dot{m} = \rho A V$$

The Kinetic energy (KE) of this air is

$$KE = \frac{1}{2} \dot{m} V^2$$

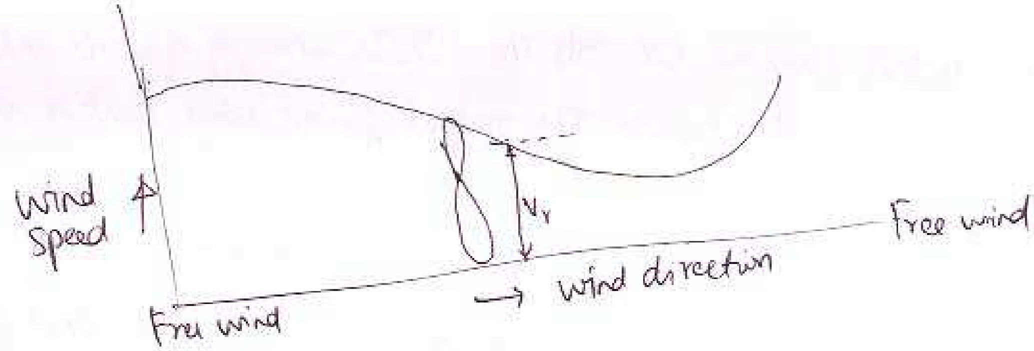
$$= \frac{1}{2} \rho A V^3$$

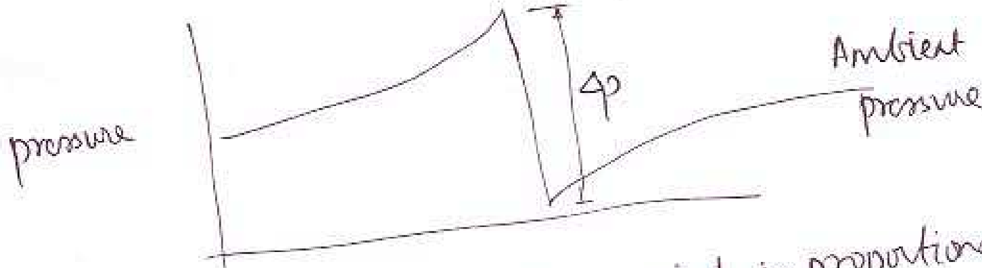
This expression indicates that wind speed has a significant effect on the power of wind. The wind power is also proportional to the density of air and to the area intercepted by air. Hence, larger wind turbines with larger swept areas has higher power output.

For a horizontal axis wind mill,

$$\text{Available power} = P = \frac{1}{2} \rho \frac{\pi D^2}{4} V^3 \quad \left(A = \frac{\pi D^2}{4}\right)$$

$$P = \frac{1}{8} \pi \rho D^2 V^3$$





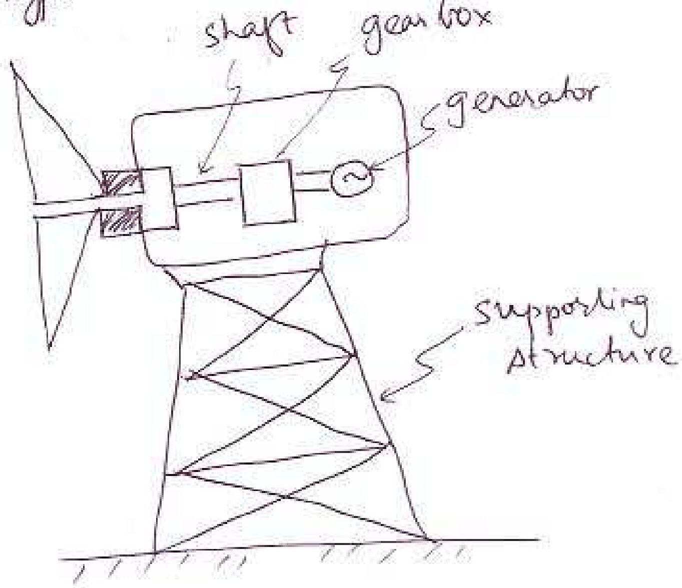
The power extracted from wind is proportional to the product of the wind speed and the pressure drop Δp.

The fraction of free power that can be extracted by a rotor is called power coefficient.

$$\text{power coefficient} = \frac{\text{power of wind rotor}}{\text{power available in wind}}$$

The max. theoritical power coefficient is equal to 16/27 or 0.593.

windmills are classified on the basis of their axis of rotation as horizontal axis type and vertical axis type.



In a two-blade horizontal axis design, the rotor drives the generator through a gear box. The blade rotor is usually designed to be oriented down wind of the rotor.

Because of high cost of the blade, rotors with more than two blades are not recommended. The rotor with more than two blades will have higher power coefficient. The most effective way to get more torque is by increasing the length of the blades.

5(b) Site selection considerations

(a) High annual average wind speed:

A fundamental requirement is an adequate supply of wind. The power in the wind through a given cross-sectional area for a uniform wind velocity V is

$P_w = KV^3$, where K is a constant. Hence, a site with high wind velocity is more suitable.

(b) Availability of wind data: Anemometry data should be available over some time period at the precise spot where the wind turbine is to be installed. This data also determines the reliability of power generation by wind mill, for if the data indicates zero wind ~~water~~ velocity, the power generated during this time will be zero. The ideal case for a site would be such that the wind velocity is constant.

(c) Altitude of proposed site: It affects the air density and thus the power output of the turbine. The winds tends to have higher velocities at higher altitudes.

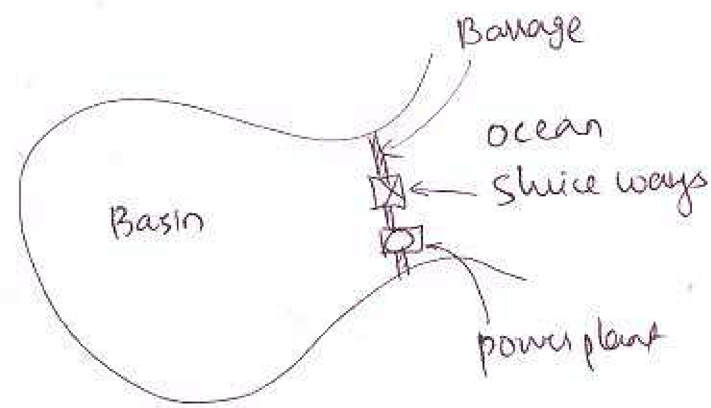
(d) Terrain and its aerodynamics.

The details of the terrain at the proposed site should be known. It may be possible to make use of hills or mountains which channel the prevailing winds into a pass region, thereby obtaining higher wind speed.

e) Nearness of site to users: This minimizes the transmission line length and hence losses and cost.

(f) Nature of ground – ground condition should be such that foundation for the heavy windmills are secured. Erosion problem should not be there, as it could possibly later wash out the foundation, destroying the whole system.

6(a) Single Basin Tidal power plant



A single basin powerplant consists of a basin interacting with the sea. The two are separated by a dam or a barrage and the flow between them is through sluice gates located along the dam. Potential head is provided by rise and fall of tidal water levels. This is usually accompanied by blocking the mouth of a long

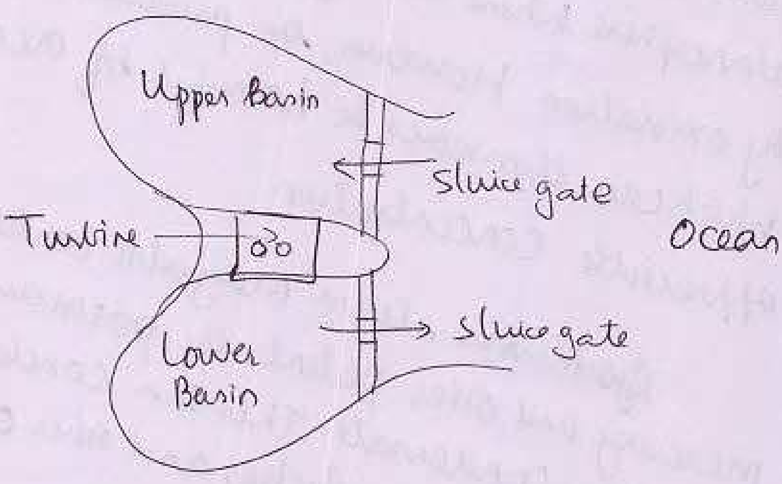
... can be achieved by

(1) Single ebb-cycle system

(2) Single tide-cycle system

(3) Double cycle system

Double basin arrangement



It consists of two separate but adjacent basins. One is called the upper basin, the water level is maintained above that in the other, lower basin. Because there is always a head between upper and lower basins, electricity can be generated continously, although at a variable rate.

The turbine is located between the two adjacent basins, while the sluice gates are as usual embodied in the dam across the mouths of the two estuaries. At the begining of flood cycle, the turbines are shut down, gates of upper basin are opened and those of lower basin are closed. As soon as the rising water level provides sufficient difference in head between the two basins, the turbines are started.

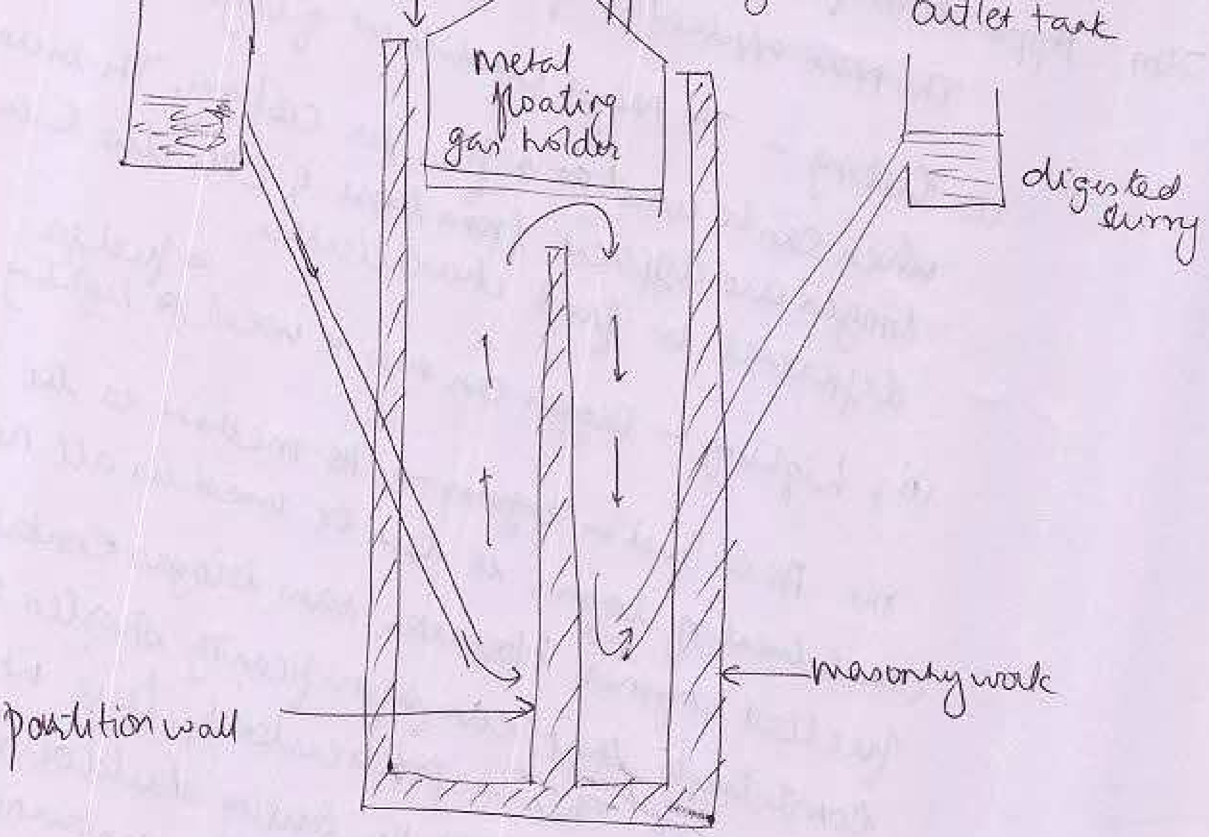
When the ebb tide level gets lower that the water level in lower basin, its sluice gates are opened and the water level starts falling. This continues until the head and water level in upper basin is sufficient to run the turbines. With the next flood cycle tide, the cycle repeats itself.

6(b) Hydrothermal resources contain some non-condensable gases mainly CO_2 and small amounts of H_2S, NH_3, CH_4 etc. In the past, the non condensable gases have been released to atmosphere where the hydrogen sulphide is gradually destroyed by oxidation. However, the products are oxides of sulpher which can themselves be harmful if accumulate at appreciable concentration.

Geothermal steam may also contain boron, arsenic, mercury and other potentially poisonous elements, which are found in condensate. This can contaminate the ground water and poison fishes and other aquatic life, if not disposed off safely.

In wet steam fields, the mineral and salt content of the hot water can be as high as 20-30% dissolved solids. This poses liquid waste disposal problems. Also, withdrawing a large amount of steam (or water) from hydrothermal resource may result in surface subsidence. These problems can also be dealt by reinjection of used water deep into the ground.

Some fears have been expressed that prolonged geothermal exploitation could trigger off earthquakes especially if reinjection is practiced in zones of high shear stress where fairly large temperature difference occurs.



A cross-section of the indian biogas plant (KVIC plant) is shown in figure above. It has an inverted mild steel drum to work as gas holder. This is the most expensive component in the plant. The digestor is an underground masonry construction with partition wall. The bifurcation of the digestion chamber through a partitioning wall provides optimum condition for growth of acid formers and methane formers. In the initial acid-forming stage of the digestion process, pH values may be around 6 or less. However, during the methane formation stage, a pH of 6.5 to 7.5 is to be maintained as the methane forming bacteria are very sensitive to acidity. Hence, due to the presence of this partion wall, the yield from this plant is very good. The main disadvantage of this plant is the cost involved in maintaining the gas holder.

7(b) Applications of Biogas

The main application of biogas are

(i) Cooking – The major constituent of biogas is methane which can be used as a fuel for cooking. The burners for biogas are different from those of LPG due to the difference in fluid characteristics.

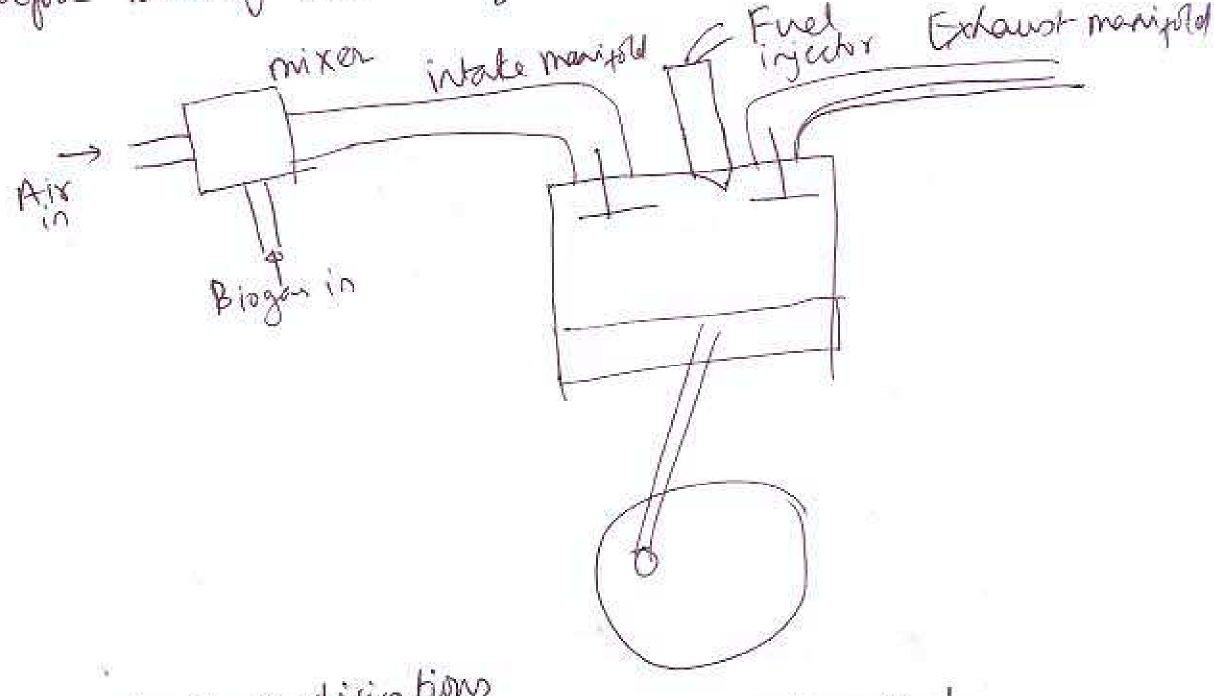
(ii) Lighting → Biogas can also be used a fuel for lighting.

(iii) As a fuel in engines → As methane is the major constituent of biogas, it can be used in all natural gas fuelled engines. However, raw biogas contains corrosive constituents that can significantly shorten the useful life of the engine. This is particularly true when the engine is operated intermittently. During shutdown, the last few strokes of the engine, piston intake unburned biogas. The various acidic components (for eg. H_2S) present corrode the surfaces of the cylinder walls, piston ring, valve seats and spark plug. Thus, a gas scrubbing system needs to be installed to remove H_2S from biogas before using it in IC engines.

Modification in CI engine

CI engine can operate on duel fuel and the necessary engine modifications include provision for the entry of bioges with air, advancing the injection timing and provision of a system to reduce diesel supply.

The entry of biogas and mixing of gas with intake air can be achieved by providing a mixing chamber below the air cleaner which facilitates through mixing of biogas with air before entering into the cylinder.



~~Moa~~ Major modifications

(1) The injection timing needs to be advanced

(2) Due to the reduced amount of fuel through the injectors, the injectors may get heated up very fast. To avoid this, extra diesel is circulated around the injector to keep its temperature below a safe limit.

8(a) Methods of hydrogen storage

(a) Compressed gas storage – H_2 is conveniently stored for many applications in high pressure cylinders. It is typically stored at pressures of 350–700 atms. This method of storage is rather expensive and very bulky because very large quantities of steel are needed to contain quite small amount of H_2.

(b) Liquid storage – Liquid hydrogen boils at −253°C and therefore must be maintained at or below this temperature in storage unless pressure build up can be tolerated.

(c) Underground storage - The cheapest way is to store H_2 in underground facilities similar to those used for natural gas. These facilities would include depleted oil wells, gas reservoirs and aquifers. Since H_2 tends to ~~espace~~ escape readily through porous material, some geological formations suitable for natural gas may not be suitable for H_2.

(d) Metal Hydrides - A number of metals and alloys form solid compounds called metal hydrides by direct reaction with H_2. When the hydride is heated, H_2 is released as the original metal (or alloy) is recovered for further use.

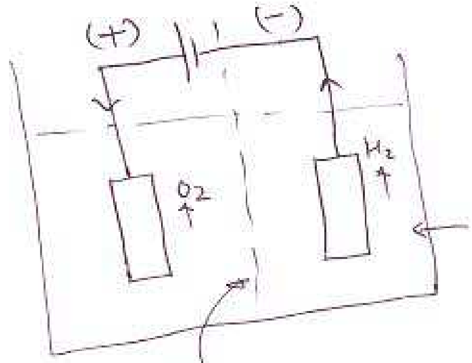
8(b) Production of H_2

Although hydrogen is third most abundant element on earth, it does not exist in free state. It is therefore produced by two routes

(1) Fossil fuels such as natural gas, coal, methanol, gasoline etc and biomass are decomposed by thermo-chemical methods to obtain H_2. The CO produced in the process is eliminated by water-shift reaction

(2) H_2 can also be produced by splitting water into hydrogen and oxygen by using electric or thermal means (ie electrolysis and thermolysis)

Electrolysis of water



An electrolysis cell consists of two electrodes, immersed in an aqueous solution called electrolyte. A direct current decomposes water into hydrogen and oxygen which are released at cathode (-ve electrode) and anode (+ve electrode) respectively. As water is a poor conductor of electricity, an electrolyte, commonly aqueous KOH is used.

A decomposition voltage of 1.23V per cell should be sufficient at normal temperature and pressure, However due to various reasons, a voltage of about 2V per cell is applied in practice. The energy required is 3.9 - 4.6 kWh per m^3 of H_2 produced. The efficiency of this process is about 60 to 70% which can be improved to 80% by using catalyst.