CBCS SCHEME

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BETCK105E

First Semester B.E./B.Tech. Degree Examination, Dec.2024/Jan.2025
Renewable Energy Sources

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Explain the principles of renewable energy and sustainable development.	6	L1	CO1
	b.	Discuss India and World wide renewable energy availability.	8	L1	CO1
	c.	Briefly discuss Solar Energy Source.	6	L1	CO1
		OR			
Q.2	a.	Explain with a neat sketch, construction and working of Geothermal Energy power plant.	8	L2	CO1
	b.	Write a short note on Internet of Energy [IoE].	6	L2	CO1
	c.	Discuss the Biomass Energy and soil shale.	6	L2	CO1
		Module – 2			
Q.3	a.	Define i) Diffused Radiation ii) Beam Radiation iii) Irradiance iv) Solar constant.	8	L2	CO2
	b.	With a neat diagram, discuss the construction and working of Pyrhelio meters.	6	L2	CO2
	c.	With simple sketch, explain the solar distillation process.	6	L2	CO2
		OR			
Q.4	a.	With a neat diagram, explain solar pond electric power plant.	8	L3	CO2
	b.	Explain the working principles of Photovoltaic cell.	6	L2	CO2
	c.	Write the advantages , disadvantages and application of solar energy.	6	L2	CO2
		Module – 3			
Q.5	a.	Explain the various factors in wind energy site selection.	6	L1	CO3
	b.	With a neat block diagram, explain the working of Wind Energy Convention System (WECS).	8	L2	CO3
	c.	With a neat diagram, explain the working of Horizontal axis wind turbine.	6	L2	CO3
		OR			

Q.6	**a.**	Define Biomass Energy. Explain the Photosynthesis process.	**6**	**L2**	**CO3**
	b.	Explain with a neat sketch, fixed come biodigester.	**8**	**L1**	**CO3**
	c.	With a line diagram, discuss the working of down draft gassifier.	**6**	**L3**	**CO3**
		Module – 4			
Q.7	**a.**	Discuss the problem faced in exploring tidal energy.	**6**	**L2**	**CO4**
	b.	With neat diagram, explain single basin tidal power plant.	**6**	**L2**	**CO4**
	c.	Explain wave energy and list out the advantages and limitations of wave energy.	**8**	**L1**	**CO4**
		OR			
Q.8	**a.**	Explain with a neat sketch, working of OTEC power plant.	**8**	**L2**	**CO4**
	b.	Discuss in detail about the problem associated in OTEC.	**6**	**L1**	**CO4**
	c.	Write a OTEC power station in the World.	**6**	**L1**	**CO4**
		Module – 5			
Q.9	**a.**	Explain the principle and working of Hydrogen fuel cell.	**8**	**L2**	**CO5**
	b.	Classify fuel cells in detail.	**6**	**L2**	**CO5**
	c.	Explain zero energy concepts.	**6**	**L1**	**CO5**
		OR			
Q.10	**a.**	Explain with a neat sketch, electrolysis method for hydrogen production.	**8**	**L2**	**CO5**
	b.	Discuss different method of hydrogen storage (any two).	**6**	**L2**	**CO5**
	c.	Write the advantages and disadvantages of hydrogen fuel.	**6**	**L1**	**CO5**

* * * * *

Q1a. Principles of renewable energy:

Principles:

The energy sources which can be continuously replenished within the time frame of human society or which do not get depleted easily are called as renewable energy sources.

- Renewable energy sources include both 'direct' solar radiation and indirect solar energy such as wind, hydro power, ocean energy and biomass resources that can be managed in a suitable manner.
- It also includes geothermal fields, chemical energy stored in food, ronfuel plant products etc.
- Most of the renewable energy sources like wind/solar heat/waves etc cannot be stored in original natural form. It is continuously converted to electrical form, transmitted, distributed and utilised without longterm intermediate storage.
- Renewables are available free of cost. Hence consumption of renewables should be maximised.
- Cost effective approaches to energy efficiency ranging from no or low cost measures to systems requiring moderate capital investment such as should be implemented.

Energy and sustainable development.

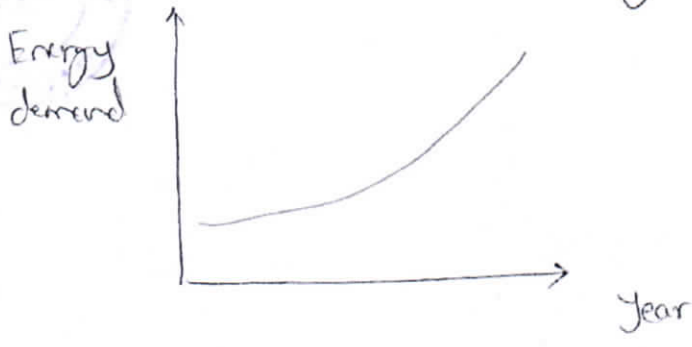
It explains how a country can maintain development / growth rate at a certain rate overcoming the obstacles. Economic growth of a country should progress at certain rate. Energy is important input in all fectors of any country's economy. Development of a country is measured in proportion to energy consumption. The Standard of living of a country can be directly related to per capita energy consumption.

Currently the energy crisis can be attributed to:

1) Population of the world has increased rapidly
2) Standard of living of people has increased.

Inturn per capita energy consumption is a measure of per capita income of the country.

Energy demand is increasing year by year.



The development that meets present needs with continuous focus on futuristic requirements is called sustainable development.

Q1b. Renewable energy availability in India

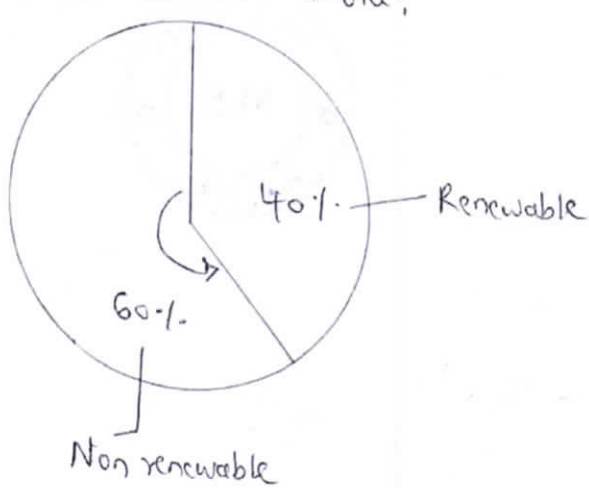
With a population of 1.3 billion, India has massive demand for energy to fuel its rapidly growing economy. From a power deficit nation at the time of Independence, the efforts to make India energy-independent have continued for over seven decades. Today we are power sufficient nation with a total installed electricity capacity of over four lakh MW.

Installed capacity of renewable sources of energy in India

Solar	48.55 GW
Wind	40.03 GW
Large Hydro	46.51 GW
Small Hydro	4.83 GW
Bio power	10.62 GW
Nuclear	6.78 GW

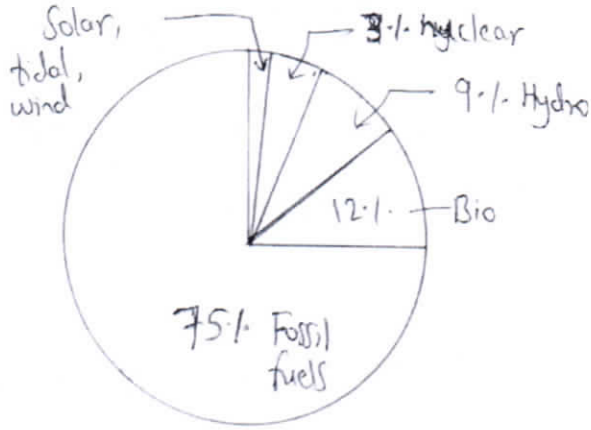
Source: Press Information Bureau
Govt. of India
Ministry of new and renewable energy.
as on 9 Sep 2022.

Current scenario in India:



World wide renewable energy availability

Current world energy scenario:



Energy usage in the world varies from county to county and by geographical location. The world is still relying on conventional fuels for meeting majority of energy needs. Paradigm shift is required from concentrated usage of energy (from conventional fuels) to distributed usage of energy (in terms of renewable energy sources).

Renewable energy generation in the world (2021)

Solar energy – 1033 TWh

Wind energy – 1862 TWh

Hydropower – 4274 TWh

Other renewables – 763 TWh

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Q1-C

Solar energy:

The radiant energy (particularly electromagnetic energy) emitted by the sun. Solar radiation consists of gamma rays, X rays, ultraviolet, visible, infrared, radio waves etc.

Solar power is the power obtained by harnessing the energy given out by sun's rays. It is used for harnessing electrical energy, water heating, cooking & in power plants.

Solar energy conversion:

1) Heliochemical process : Conversion of solar energy into chemical energy. Ex: Photosynthesis — plants using solar energy synthesise to produce starch & cellulose. consuming CO_2 & water.

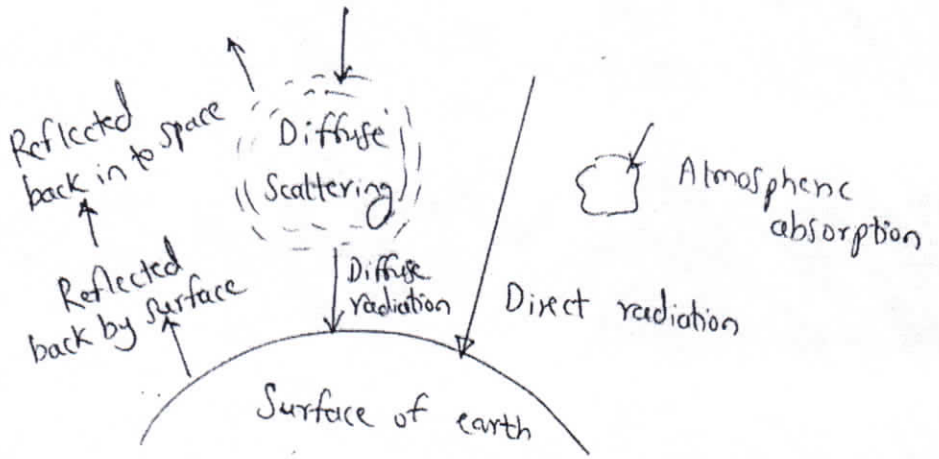
2) Helio electrical process: Solar energy is directly converted into electrical energy using the principle of photovoltaic effect. ex: Solar cells.

3) Heliothermal process: The radiant solar energy falling on the surface of the object is converted directly into thermal energy.
ex: Solar water heater, Solar pond.

1.C.

Solar energy

Solar radiation:

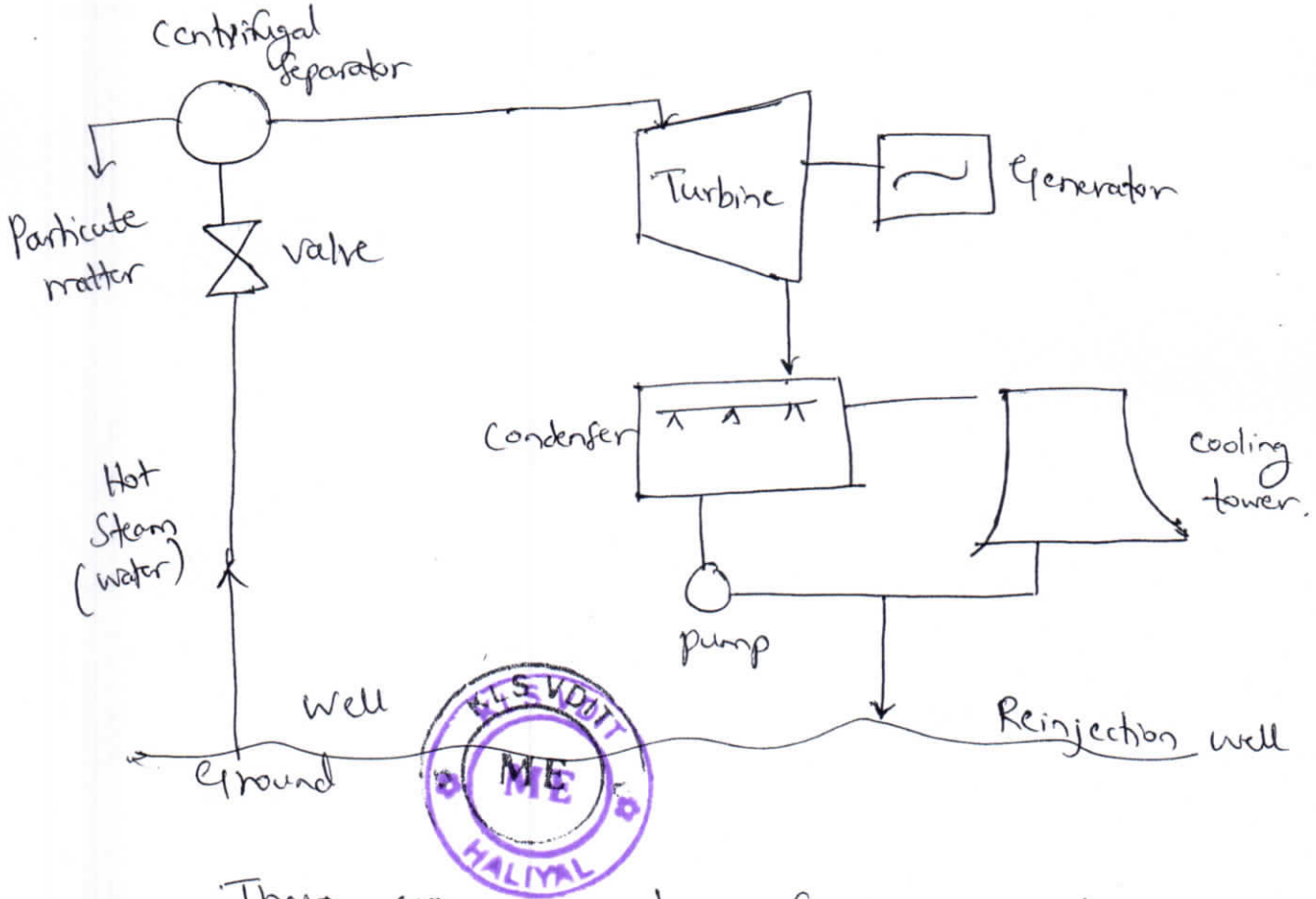


The solar radiation that penetrates the earth's atmosphere and reaches the surface differs in both amount and character from the one at the top of the atmosphere. Part of the radiation is reflected back into space (by clouds). Some portion is absorbed by atmosphere. Oxygen and ozone will absorb all the ultraviolet radiation, and water vapour & Co_2 will absorb the infrared radiation. Some part of the radiation is scattered by dust particles & droplets in the cloud. The remaining radiation that has not been absorbed or scattered and reaches the ground directly from the sun is called direct radiation or beam radiation.

The other radiation received from the sun after its direction has been changed by reflection/scattering is called diffuse radiation.

Q2 b. Geothermal power plant.

The thermal energy present in the earth's crust is termed as geothermal energy. This is because of increase in temperature of earth with increase in depth below the surface. The temperature here can be upto 200°C. It is present in the form of hot steam/ hot water reservoir. Geothermal power plant is used to harness this heat energy and convert it into useful electrical energy.



There are many types of systems used to harness geothermal energy. One of the type is shown in the figure. This is used in vapour dominated grs.

Systems, i.e, where vapour/steam is present in abundant quantity. A hole is drilled upto hot steam reservoir. Steam is sent to centrifugal separator, to remove impurities. Filtered steam is sent to turbine, which is coupled to generator. (Conversion of mechanical energy into electrical energy). The steam coming out of the turbine is condensed in condenser and the water is discharged into reinjection well. A cooling tower is used to cool the condenser water.

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Q2b. Internet of Energy (IoE)

Internet of energy refers to the automation and upgrading of energy infrastructure (the power grid) from grid operators to energy producers and distribution utilities.

The IoE allows for the exchange of the energy information through Big data. Big data analytics provide grid operators, energy producers and distribution utilities with real time energy consumption trends, allowing them to forecast where and when energy demand or energy consumption will peak. Grid operators who manage & track energy production & delivery, can direct adjustments in the energy supply as needed with that data.

The IoE includes energy infrastructure in energy production and delivery by using artificial intelligence (AI) at power plants and power delivery systems.

It also means upgrading and automating our appliances and metering at the point of delivery (homes etc). Smart meters and intelligent appliances or devices help optimise our energy supply, energy management and energy use.

Within IoE, smart grid technology enables power producers and distributors monitor and deliver power on a more efficient basis.

ex: Connected appliances - Smart home's ability to turn on lights or trigger the security system.

In case of natural calamities, like storm or floods, when there is disrupted power generation & distribution networks, IoE helps grid operators rearrange the grid in real time to diagnose which lines need to be deenergized and reroute power along different power lines.

IoE also allows local utilities to pinpoint trouble spots within their microgrids, such as blown transformers and identify and communicate with affected customers. This will help to send repair crews to the spot.

Q2. C. Biomass energy

The organic matter produced by plants - both terrestrial and aquatic and their derivatives is termed as biomass. It includes agricultural/forest crops, crops grown for energy content and animal waste.

Solar energy → Photosynthesis → Biomass → Energy generation

Biomass resources fall in 3 categories:

1) Biomass in its traditional solid mass
   (wood and agricultural residue)

2) Biomass in non traditional form - converted into liquid fuels
   ex- ethanol, methanol

3) Biomass in gaseous form converted by digestion/fermentation
   ex- biogas.

Biomass includes:

* Sugar crops - sugar cane, sorghum, corn
* herbaceous crops - non woody plants which are easily converted into liquid and gaseous fuels
* forestry plants - eucalyptus, poplar, alder, other fuel wood trees
* Aquatic crops - sea weeds, marine algae etc

Oil Shale

Oil Shale is a sedimentary rock containing relatively large amounts of organic matter (kerogen) from which significant amount of oil and combustible gas can be extracted by destructive distillation.

Oil Shales are organic matter rich sediments which have never been buried to greater depth. They contain little extractable bitumen but generate oil when heated to temperatures of about 500°C.

The organic carbon content in most of the oil shales exceeds 20% and hydrogen/carbon atomic ratio is very high, more than 1.5.

The organic matter consists of freshwater/marine algae and bacterial biomass. The shale oil produced by heating contains considerable amounts of sulphur and nitrogen bearing compounds in addition to pyrolytically formed unsaturated hydrocarbons (olefins) which are normally not present in crude oils.

Processing from oil Shale: From the oil Shale, crude oil can be recovered by thermochemical processes like pyrolysis. The processing of shale oil is essentially done by retorting, which consists of heating crushed shale in a closed vessel upto a temperature (500°C) at which the matter releases Crude oil, gases, char & Stream. The fraction of extractable oil is 10 to 20% by volume.

Q3.a. i) Diffused radiation: The radiation received on the earth's surface after scattering in the atmosphere and absorption is called diffused radiation.

ii) Beam radiation: The solar radiation received on the earth's surface without change of direction / deflection i.e, which is inline with the sun is called beam radiation. It is also called as direct radiation.

iii) Irradiance: Irradiance is the measure of radiant power (Solar radiation) incident on a surface per unit area. Radiant energy can be any form of electromagnetic radiation.

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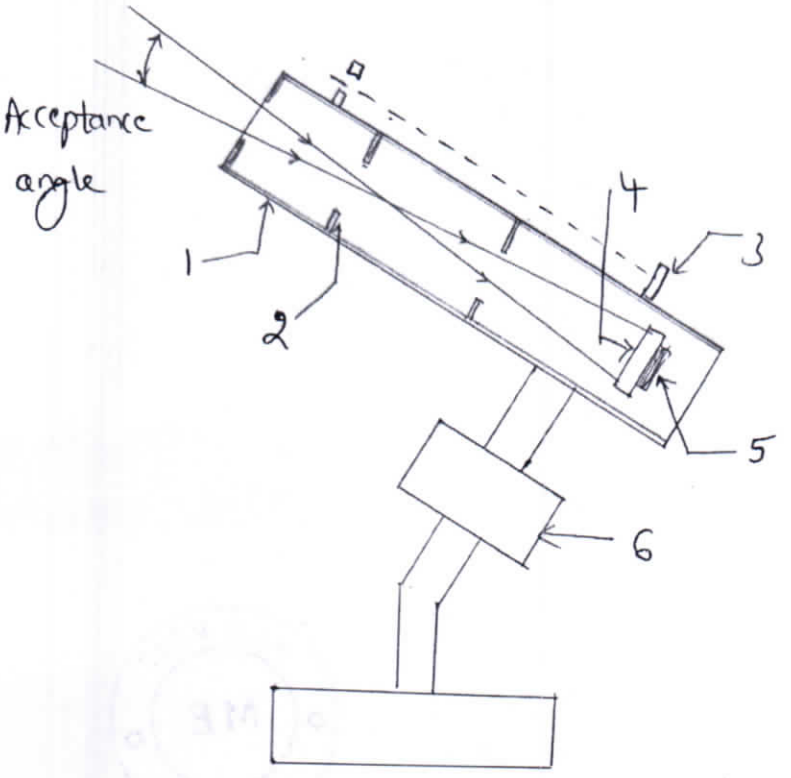
iv) Solar constant: Solar constant (I_{sc}) is the rate at which energy is received from the Sun on a unit area perpendicular to the rays of the Sun, at the mean distance of earth from the Sun. Based on experimental investigations its value is found out to be 1367 W/m^2.

Q3 b.

Pyrheliometers :



1. Tube blackened on inside surface
2. Baffle
3. Alignment indicator
4. Black absorber plate
5. Thermopile junction
6. 2-axis tracking mechanism.

A pyrheliometer is an instrument which measures beam radiation falling on a surface normal to sun's rays.

The black absorber plate (with hot junctions of thermopile attached to it) is located at the base of a collimating tube. The tube is aligned with the direction of Sun's rays with the help of 2-axis tracking mechanism and an alignment indicator. Inside black coating of the tube and the baffles will absorb/deflect the diffuse radiation and the black surface receives only beam radiation (and small amount of diffuse radiation falling within the 'acceptance angle' of the instrument.

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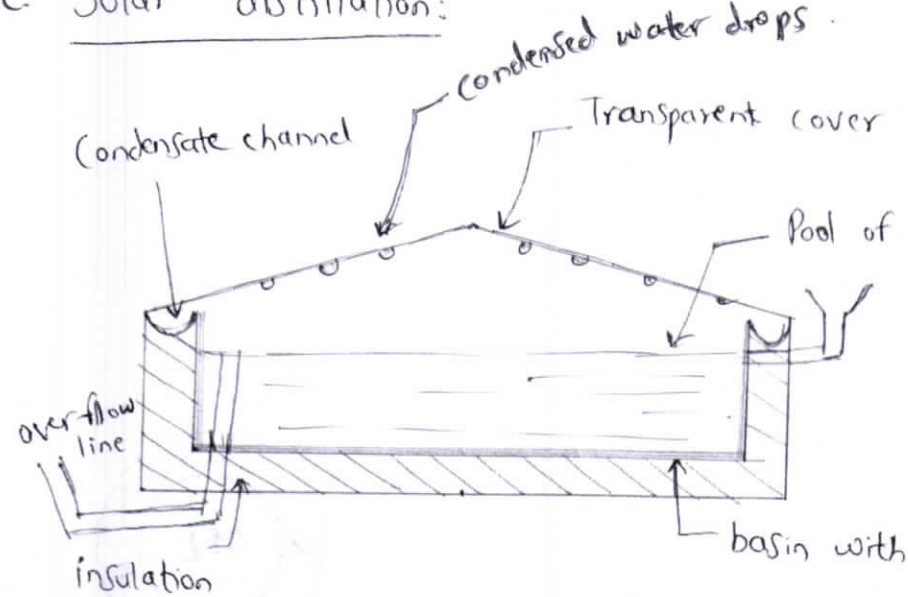
Q3c. Solar distillation:



In many small communities, natural supply of fresh water is inadequate in comparison to the availability of brackish or saline water. In such places, Solar distillation becomes an effective way of supplying drinking water to such communities.

Solar distillation process makes use of Solar still. This consists of a shallow airtight basin lined with a black, impervious material which contains the saline water. A sloping transparent cover is provided at the top. Solar radiation is transmitted through the cover and is absorbed in the black lining. It thus heats up the water by about 10° to 20°C, and causes it to evaporate. The resulting vapour rises, condenses

Grill

as pure water on the underside of the cover and flows into condensate collection channels on the sides. An output of about 3 litres/m^2 with an associated efficiency of 30 to 35% can be obtained in a well designed still on a bright day.

Operating efficiency : 35 to 50%.

Efficiency of solar distillation is estimated as:

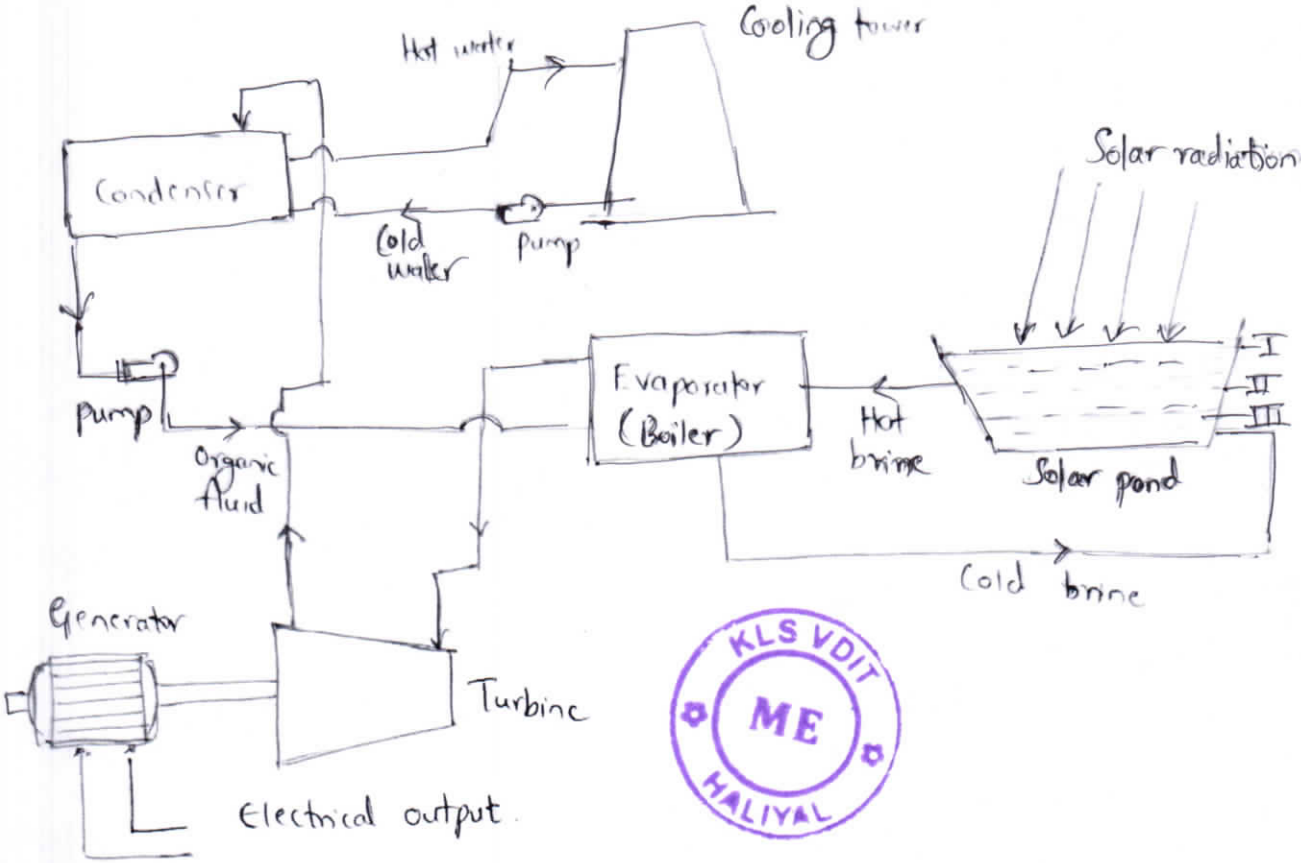
$$\eta = \frac{w \Delta h}{H}$$

w = weight of distillate /m^2/ day.

Δh = enthalpy change from cold water to vapour

H = Solar radiation intensity/m^2/ day.

Q4a. Solar pond electric power plant



The solar pond has 3 zones with different salinity

i) Surface convective zone (upper convective zone) : Salinity < 5%
(0.3 to 0.5m)

ii) Non convective zone 1 to 1.5m, Salinity increases with depth

iii) Storage zone or lower convective zone : 1.5 to 2m,
Salinity ≈ 20%

The lower convective zone serves as main heat collection as well as thermal storage medium. Convection in the zone is due to the process of heat extraction, accomplished by hot brine withdrawal and cool brine return. Hot water can be extracted from the solar pond without disturbing the concentration gradient.

Thermal energy from the solar pond is used to drive Rankine cycle heat engine. Hot water from the bottom level of pond is pumped to the evaporator, where the organic fluid is vaporized. The vapour flows under high pressure to the turbine and thereby expanding through the turbine wheel and electric generator linked to it. The vapour then travels to the condenser where cold water from the cooling tower condenses the vapour back it to a liquid. The liquid is pumped back to the evaporator and the cycle is repeated.

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Q4. b. # Photovoltaics

Principle of Solar cell:

2 important steps are involved in the principle of working of a solar cell.

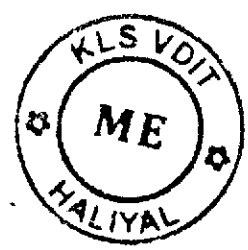
1. creation of pairs of +ve & -ve charges (called electron- hole pairs) in the solar cell by absorbed solar radiation.
2. Separation of the positive & negative charges by a potential gradient within the cell.

The cell must be made of a material which can absorb the energy associated with the photons of sunlight. The energy (E) is given by the equation:

$$E = hc/\lambda$$

where, h = Planck's constant = 6.62×10^{-27} ergs.

c = velocity of light = 3×10^{8} m/s.



Substituting these values, we get

$$E = 1.24/\lambda$$

E is in electron volts (ev) & λ in μm.

Materials suitable for absorbing the energy of photons of sunlight are semiconductors like silicon, cadmium telluride, gallium arsenide. In the semiconductor the electrons occupy one of 2 energy brands, the

Grey

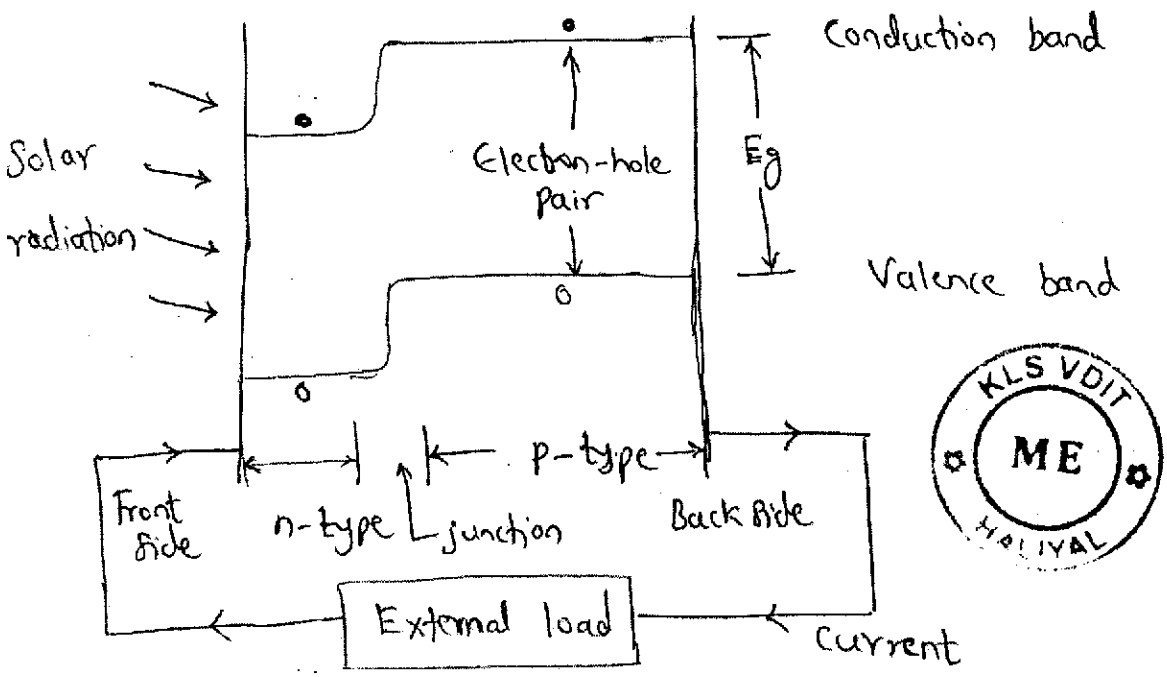
valence band and the conduction band.

Valence band — electrons @ lower energy level — fully occupied

Conduction " — electrons @ higher " " — not fully "

The difference b/w the 2 energy levels (valence & conduction bands) is called the band gap energy E_g.

Photons of sunlight having energy E > band gap energy(E_g) are absorbed in the cell material and excite some of the electrons.



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Q4.c. Advantages of Solar energy:

1) Solar energy is inexhaustible source of energy

2) It is a primary source of energy and is not dependent on other energy sources.

3) It is clean & green energy. Harnessing of solar energy involves least impact on environment.

4) It is abundantly available. In most of the places in tropical zone, solar energy can be harnesse around the year (except rainy season).

5) Safer than other energy sources

6) Utilisation of solar energy will lead to technology development, giob opportunities & entrepreneural opportunities.

7) It promotes distributed energy generation [Small scale & domestic energy generation]

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Disadvantages of solar energy:

1) Storage of solar energy is difficult & expensive
2) Overall efficiency of solar equipment is very low. Energy harnessed is very less in areas beyond tropical zones.
3) High initial investment
4) Space constraints
5) Some instruments need tracking / orienting systems.

Applications of solar energy:

1) Solar heat collectors can be used for heating water, air, buildings for domestic / commercial applications.
2) Solar energy can be used for industrial applications like water desalination, food processing, chemical processing etc
3) Solar energy can be used to generate electricity — used for domestic / large scale. It can even be used for transportation (EV)
4) Solar energy can be used for drying of agricultural crops fruits, sea food etc.
5) Miscellaneous — cooking, solar pumping, solar distillation etc

Eg:-

Q5a. Various factors in wind energy site selection.

1) High annual average windspeed. : Adequate supply of wind is essential for WECS. Power in the wind is given by. $P_w = K V^3$ K= constant, V= velocity of wind. Small increase in 'V' will exponentially increase power (P_w)

2) Availability of anemometry data: Wind speed measured at a particular place over a period of time. Here anemometer height above ground, accuracy, linearity, location of support tower, shadowing influence the readings.

3) Availability of wind (V_t) curve at the proposed site. This curve determines the maximum energy in the wind & hence is an important (initial controlling factor. It decides electrical output & hence revenue return of the WECS.

4) Wind structure at the proposed site.: Wind near the ground is turbulent & gusty, and changes rapidly in direction & velocity. This departure in homogeneous flow is referred to as "the structure of the wind".

5) altitude of the proposed site: It affects the air density and thus the power in the wind & hence useful power output.

6) Terrain and its aerodynamic : In some sites it is possible to obtain 'speed up' of the wind velocity/power.

7) Local ecology : If the surface is base rock, it may mean lower hub heights & hence lower structure cost. If vegetation is present, which will tend to reduce the wind velocity, then heigher hub heights are required.

8) Distance to roads & railways — for transport of heavy machinery, structures, materials, blades etc.

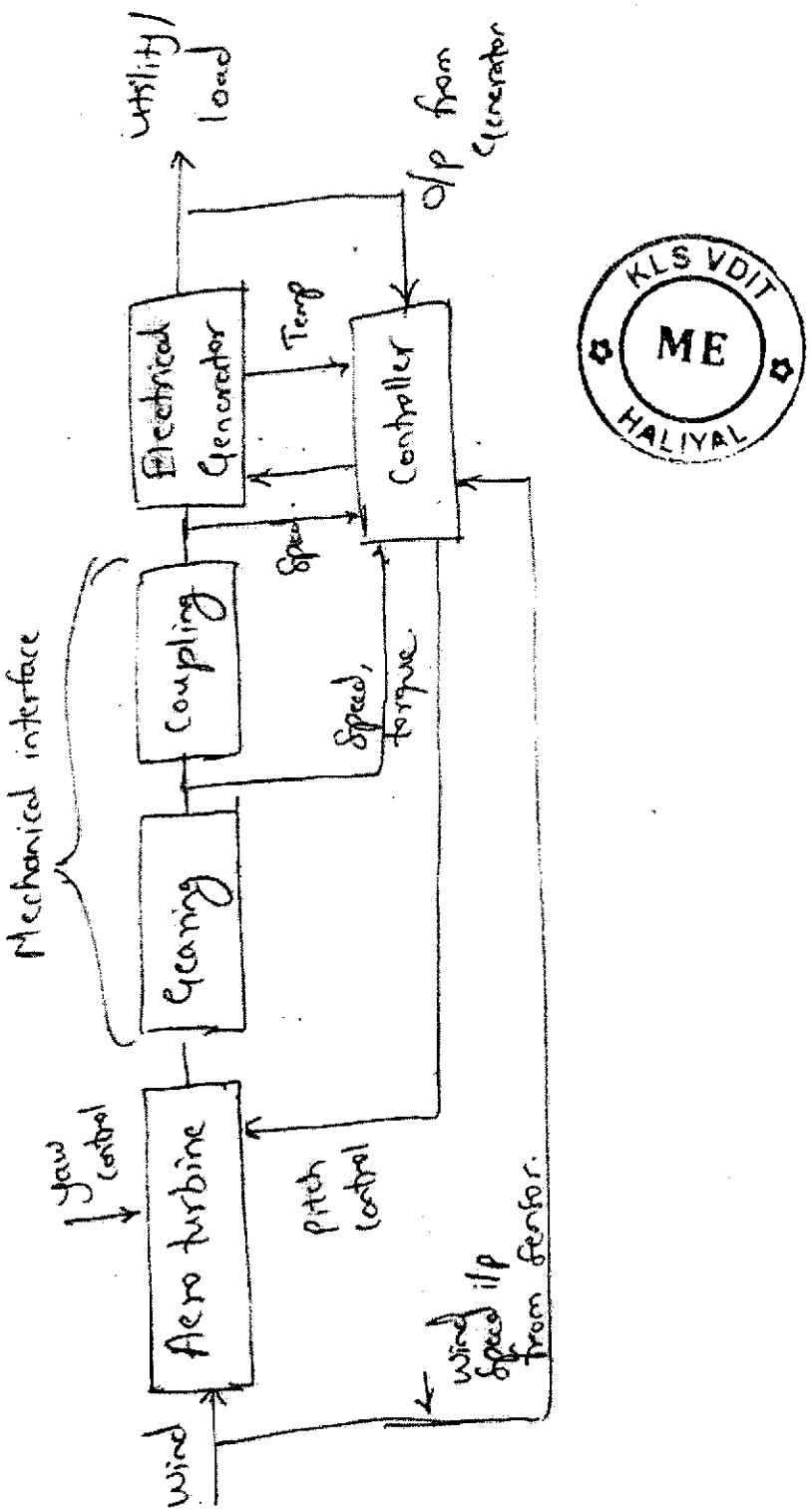
9) Nearness of site to local centre/users.

10) Nature of ground [foundation should be secured and stable]

11) Favourable land cost

12) other conditions like icing problem, salt spray, blowing dust should not be present.

Q5-b.) Basic components of Wind Energy conversion system.
(Block diagram).



Aero turbines convert the energy in moving air to rotary or mechanical energy. They need pitch control and yaw control for horizontal axis machines. Yaw control refers to rotation of turbine slowly in accordance with direction of wind (about vertical axis) Pitch control refers to control the orientation of blade about the hub to maximise the output.

Gears (transmission) are used to increase the speed of shaft. The shaft connected to wind turbine blades (rotor) rotates at very slow (50 rpm) speed. This speed will not be sufficient to generate the power. Speed required would be around (1500 – 2000 rpm). ∴ Setup involves gears, belts & chains along with hydraulic systems are used.

Generator: Either constant speed or variable speed generators are used.

Control system: It consists of:

i) Sensor – mechanical / pneumatic / electrical

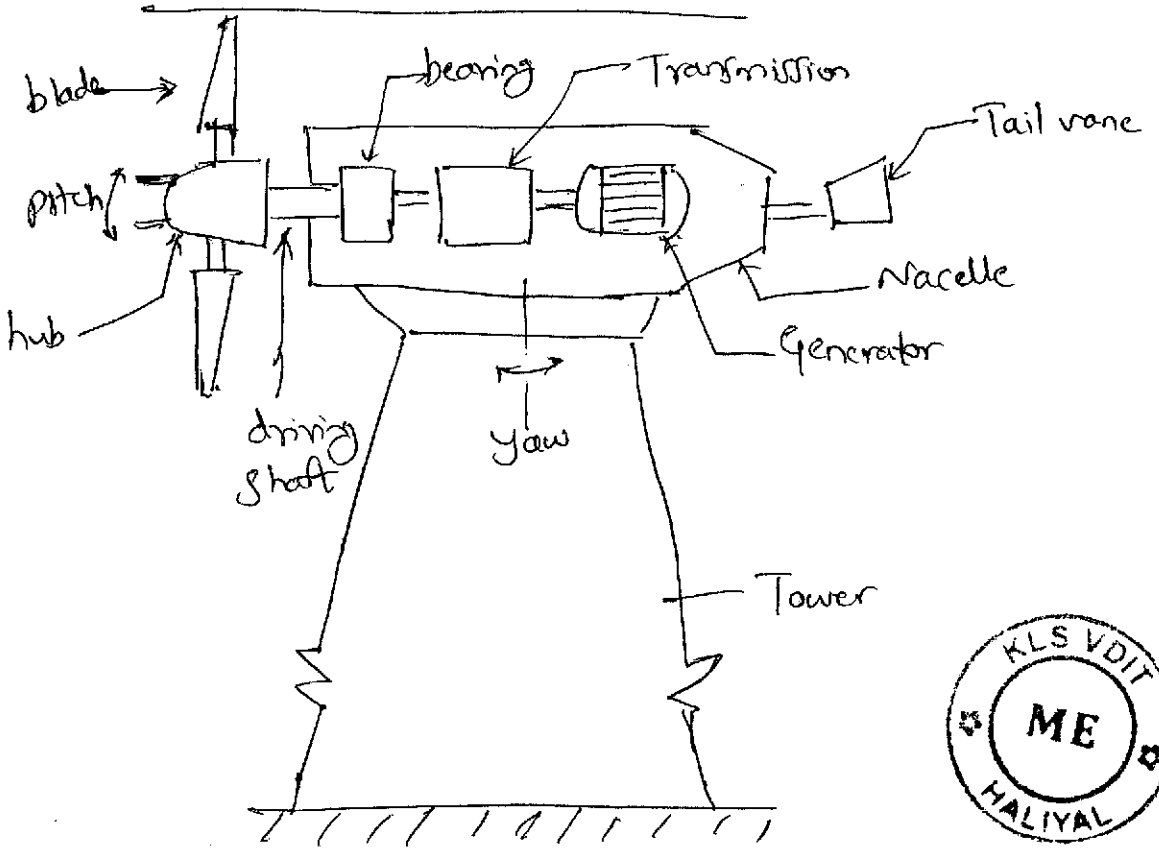
ii) decision elements – relays, logic modules, analog circuits, microprocessor

iii) Actuators – hydraulic, electric, pneumatic

Functions of controller: Orientation of the rotor in the direction of wind, generator output monitoring, protection of generator, maintenance, shutdown owing to malfunction etc.

Gears.

Q5.C. Horizontal axis wind mill.



Axis of rotation is horizontal. System consists of hub (attached with number of blades), driving shaft, bearing transmission [gears & brake], generator. Nacelle holds all the elements on top of tower. System consists of pitch control and yaw control to orient the device in the direction of wind.

Energy conversion:

K.E of wind → rotational mechanical energy of turbine → Electrical energy (generator) → output

Wind is swept by the blades of hub. The driving shaft rotates. The speed obtained is very less. This is further enhanced by gears & the output shaft is connected to generator.

Q6a. Biomass energy is the energy derived from the organic matter (terrestrial, aquatic & their derrivatives)

Photosynthesis process:

Radiant energy of sun is absorbed by the green pigment chlorophyll in the plant and is stored within the plant in the form of chemical bond energy. It is the biological conversion of solar energy into sugars and starches which are energy rich compounds. Photosynthesis is a type of energy plantation.

In this reaction, water & CO_2 molecules are broken down and a carbohydrate is formed with the release of pure oxygen.

$CO_2 + H_2O + \text{light} + \text{chlorophyll} \longrightarrow (H_2O)_6 + O_2 + \text{chlorophyll}$

(Sugar)

$6CO_2 + 12H_2O \longrightarrow C_6H_{12}O_6 + 6H_2O + 6O_2$

Good

The absorbed light is in the UV & IR range. Visible light having wavelength < 700A° is absorbed by the green chlorophyll which becomes activated and passes its energy on to the water molecules.

Steps:

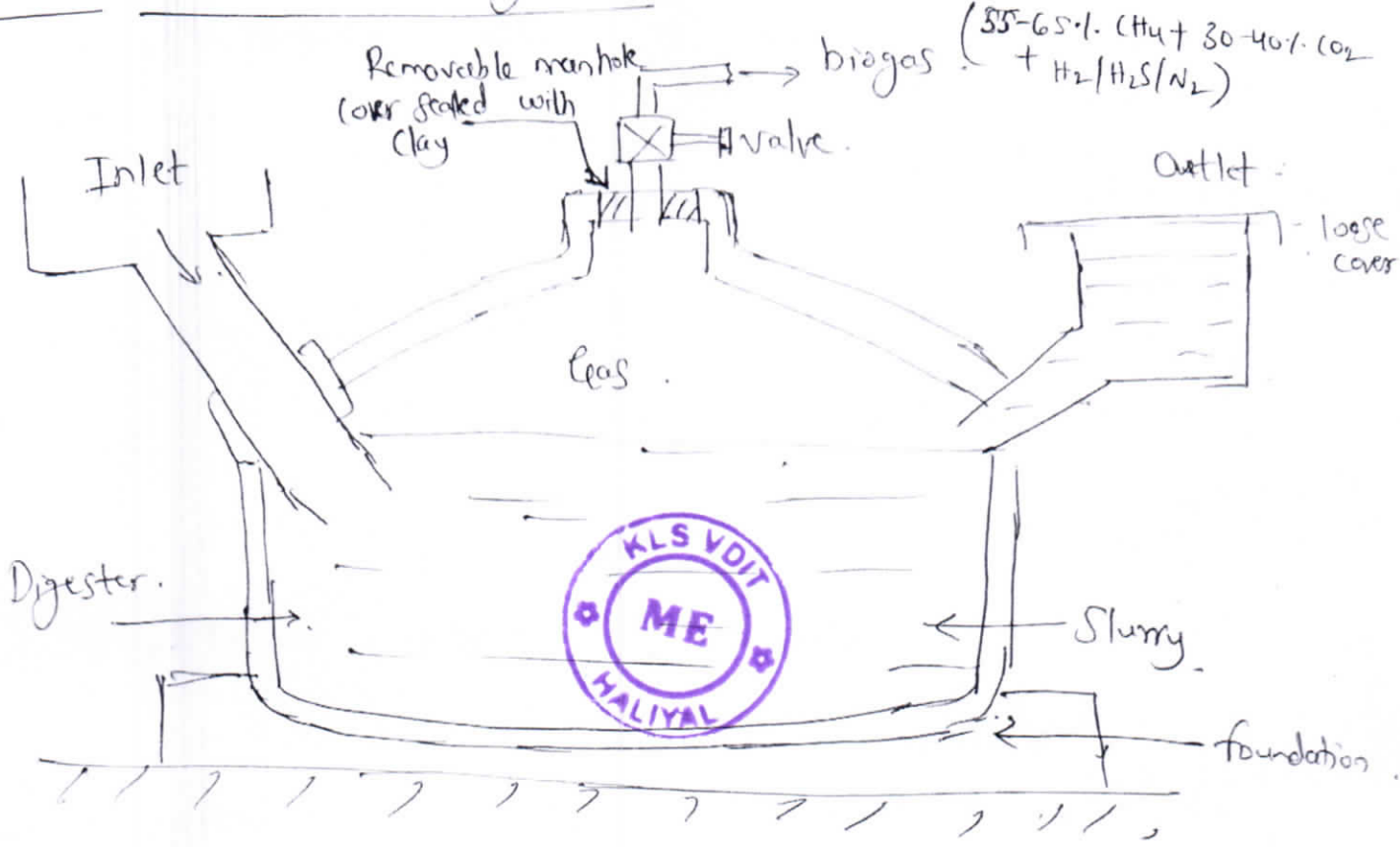
1) Splitting of water molecules into H_2 & O_2 under the influence of sunlight and chlorophyll (which is a ligh reaction)
2) The hydrogen released is transferred to unknown compound and oxygen is released to atmosphere.

2) In the 2nd phase, hydrogen is transferred from this unknown compound to CO_2 to form starch or sugar. This is a dark reaction.

Conditions necessary for photosynthesis:

1) Light of wavelength < 700°A°, which is 45 to 50% sunlight. This is called as Photosynthetically Active radiation (PAR)
2) CO_2 concentration (0.03 to 0.04 %)
3) Temperature of 0 to 60°C

Q6b. Fixed dome digester.:



In the fixed dome digester, the gas holder and digester are combined. In India, the biogas plants are classified into two types.

1) KVIC - Khadi Village Industries commission - model
2) Janata model The KVIC plant is of steel drum type (or floating gas holder) design in which the digestion takes place in a masonry wall and the drum floats as the gas collects and is taken out from the top.

In the Janata model or fixed dome digester, it is a drumless type similar in construction to the KVIC model except that steel drum is replaced by a fixed dome roof of masonry construction. The dome roof in the Janata model requires specialised design and skilled masonry construction. The digester is fixed in the ground with strong foundation. Fixed dom is suited for batch process, especially when dail feeding is done in small quantities. It is suited for cooler regions. After the digestion biogas formation takes place which is collected on the top and the pressure of the gas pushes the spent slurry to outlet, which can be used as organic manure.

Advantages: 1) Low cost compared to floating type, it uses only cement (no steel)

2) No problem of corrosion

3) Heat insulation is better

4) Cattle manure and fibrous stalks can be fed.

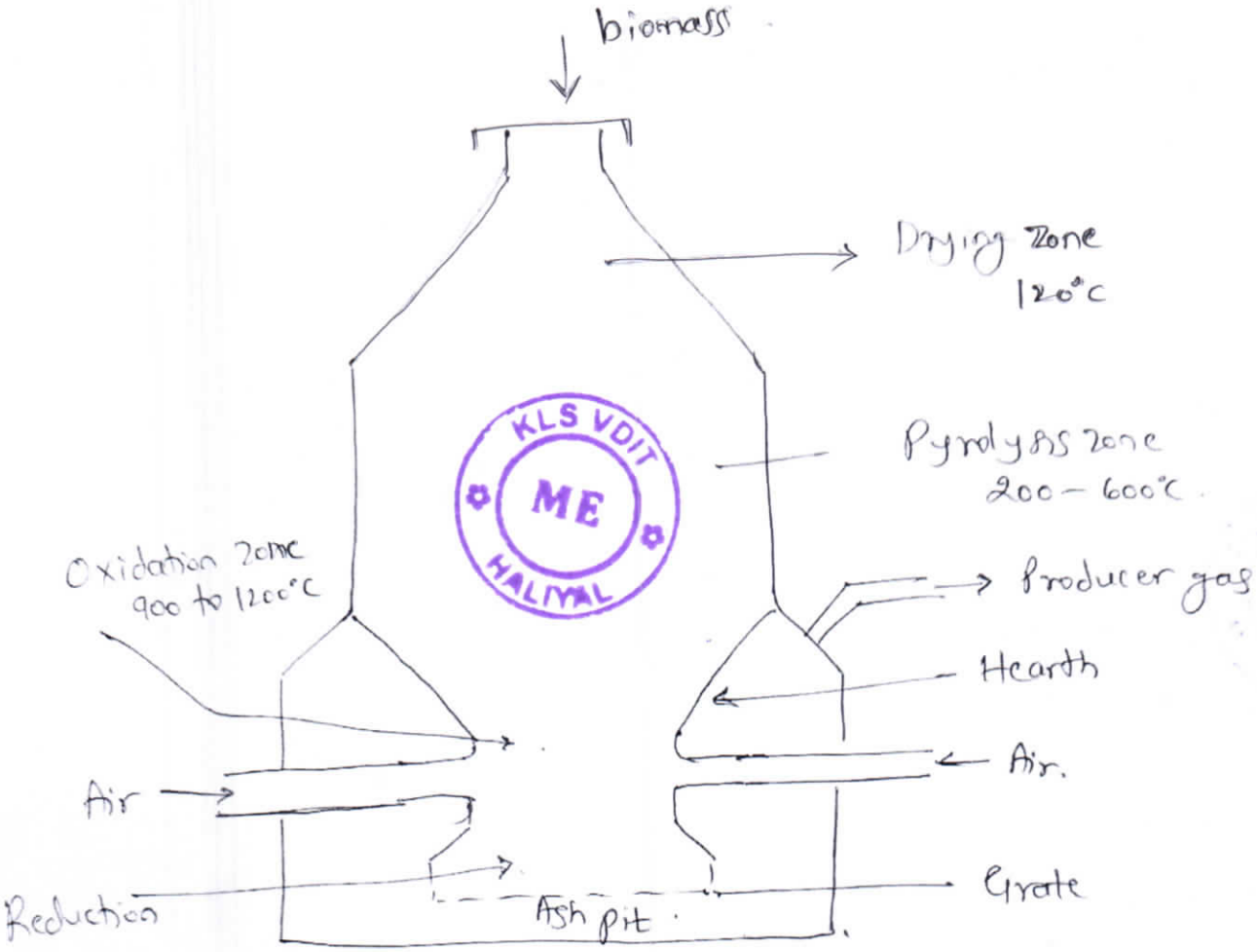
5) less maintenance.

Disadvantages: 1) Skilled workers required for construction

2) Gas production per unit volume is less

3) It has variable gas pressure.

Q6. C. Biomass Gasification: (Downdraft)



[Producer gas contains: CO, H_2, N_2, traces of CH_4, CO_2, water vapour]

Biomass gasification is a process of partial combustion in which solid biomass usually in the form of pieces of wood or agricultural residue is converted into a combustible gas mixture. Partial combustion occurs because the air supply is intentionally kept less than the amount required for the full combustion of biomass. As a result

a gaseous mixture of carbon monoxide, carbon dioxide, hydrogen and nitrogen called producer gas is obtained. The figure shows down draft type gasifier. It is a vertical cylindrical vessel of varying cross section. The biomass is fed in at the top at regular intervals of time and converted through a series of processes to producer gas and ash as it moves down slowly through various zones of gasifier. Volatiles and tars produced from the decending fixed bed have to pass through the reaction zone where they are racked & gasified. Also the throat ensures that, gases pass through hottest zone & they contain less tar & more ash. They are suitable for wood & agricultural waste. In gasifier, the air enters through radial tuyers and the partial combustion takes place in the zone (infront of tuyere openings). The heat will pyrolyze the fuel & hot gases proceed downward. It is mostly used for engine applications because of ability to produce clean gas.

Q7.a. Problems in tidal power exploration.

1) The main drawback of tidal power is variability in output caused by the variations in the tidal range.

2) Interruption in the power output in case of Single basin power stations.

3) Efficiency of the plant is affected because of variation in the tidal range.

4) Sea water is corrosive & proper anticorrosion techniques are required, which will increase the cost.

5) Stainless steel with high chromium content, added with molybdenum are found to be useful.

6) Although the duration of power cycle is constant, but its time of occurance keeps on changing, & this puts challenges in load sharing with grid.

6) Tidal power plant may hamper other natural uses of estuaries like; fishing, navigation & tourism.

7) Cost is not favourable.

Q7.b. Single basin tidal power plant :-

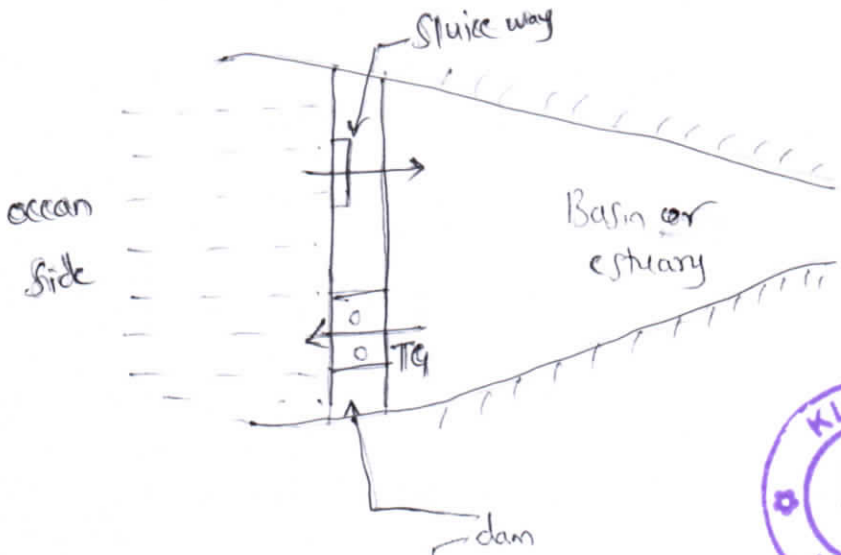
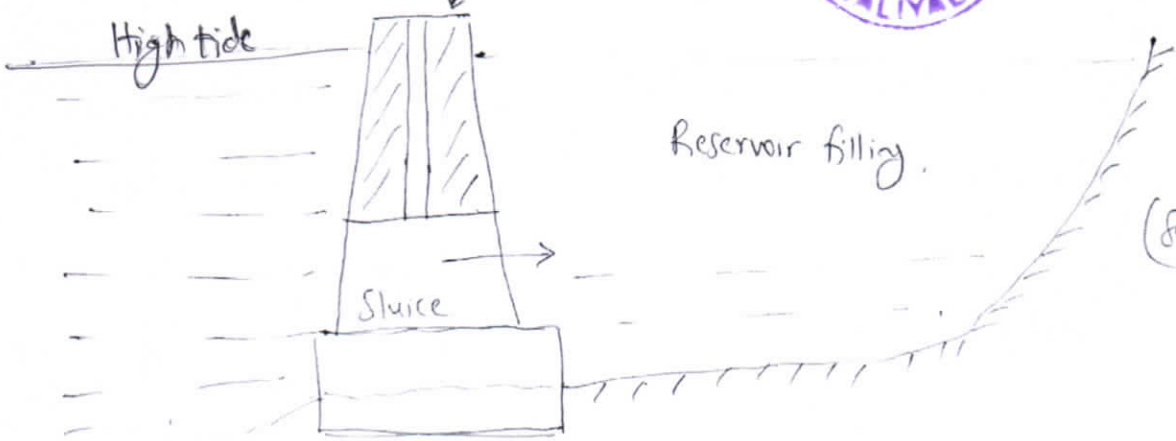


Fig - I

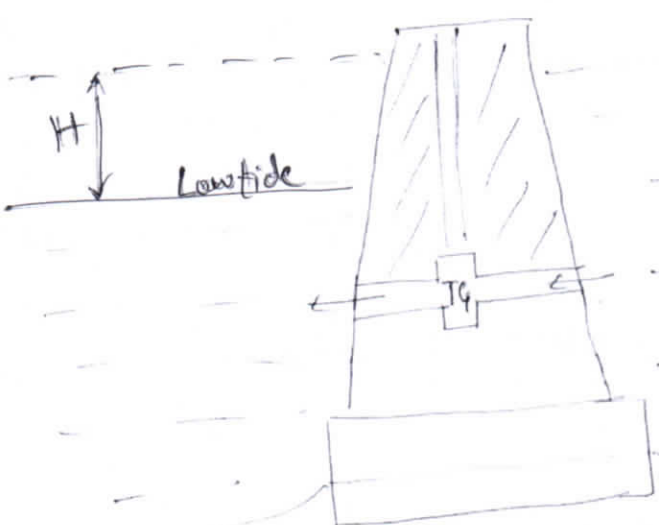
(plan view)



Reservoir filling.

Fig - II

(sectional view)



Reservoir emptying.

Fig - III

(Sectional view)

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Single basin tidal power plant will have, dam constructed across a estuary to form a basin, where water can be collected. Figure I shows plan view (top view). Fig II shows sectional view with sluice way. Fig III shows sectional view with turbine-generator setup. Left side is ocean (sea) side. During high tide, water level on ocean side will be higher than reservoir side and water is allowed to enter the reservoir through sluice ways. Then the way is closed with the help of gates. During low tide, water on the reservoir side will be higher than ocean side & it is allowed to go back to ocean through turbine path — during this time power is generated. The cycle repeats.

If the operation is in the above sequence, then it is called as single ebby cycle system.

If the water is allowed to enter the reservoir through turbine side (power generated in the 1st half) & during emptying water will come out of sluice ways, then it is called as single tide cycle system.

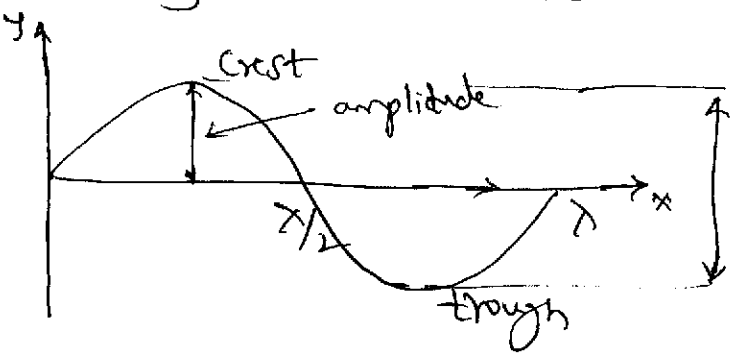
Grid

Q7c. Wave energy:

Periodic to & fro, up & down motion of water in large lakes, oceans & seas is called waves. Waves originate because of surface winds (planetary/local). Winds inturn derive energy from solar energy. ∴ Waves are also derrivatives of solar energy. Waves posses both potential energy and kinetic energy.

Important characteristics of waves are:
- Wave height.
- Wave period.

These are dependent upon — wind velocity, depth of ocean & contour of shore.



λ = wavelength

Wave energy can be much more concentrated than solar energy. ∴ These devices produce much high power densities than solar devices.

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Advantages of wave energy:

1) Energy is naturally concentrated by accumulation overtime & space and transported from the point at which it was originally present in winds
2). Free & renewable energy source.
3) wave power devices do not use up large land masses unlike solar or wind
4) pollution free & leave the seawater in relatively placid stat
5) available in night time also.

Limitations of wave energy:

1) Energy is available in ocean/sea. Equipment should operate in marine environment. [corrosion]
2). Devices must withstand severe peak stresses in storms
3) Scarcity of accessible sites
4) Devices are complicated.
5) Challenging factors - capital cost, maintenance cost, problems of biological growth of marine organisms.

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Q8a. Ocean thermal energy Conversion Power Plant

Ocean thermal energy refers to conversion of solar energy stored as heat in the ocean into electrical energy by making use of temperature difference between the warm surface water and colder deep water. The facilities proposed for achieving this conversion are referred to as OTEC - Ocean thermal energy conversion plants or sometimes as Solar sea power plants (SSPP)

Since ocean waters are heated by the Sun, they constitute inexhaustible source of energy. Unlike direct Solar energy, the ocean energy is available continuously rather than only in the daytime.

Principle: The working of OTEC is based on thermo-dynamic principle. If a heat source, is available at a higher temperature and a heat sink (where heat is dissipated) at a lower temperature, it is possible to utilize the temperature difference in a machine or prime mover (turbine) that can convert the heat into useful work. Thus heat contained in

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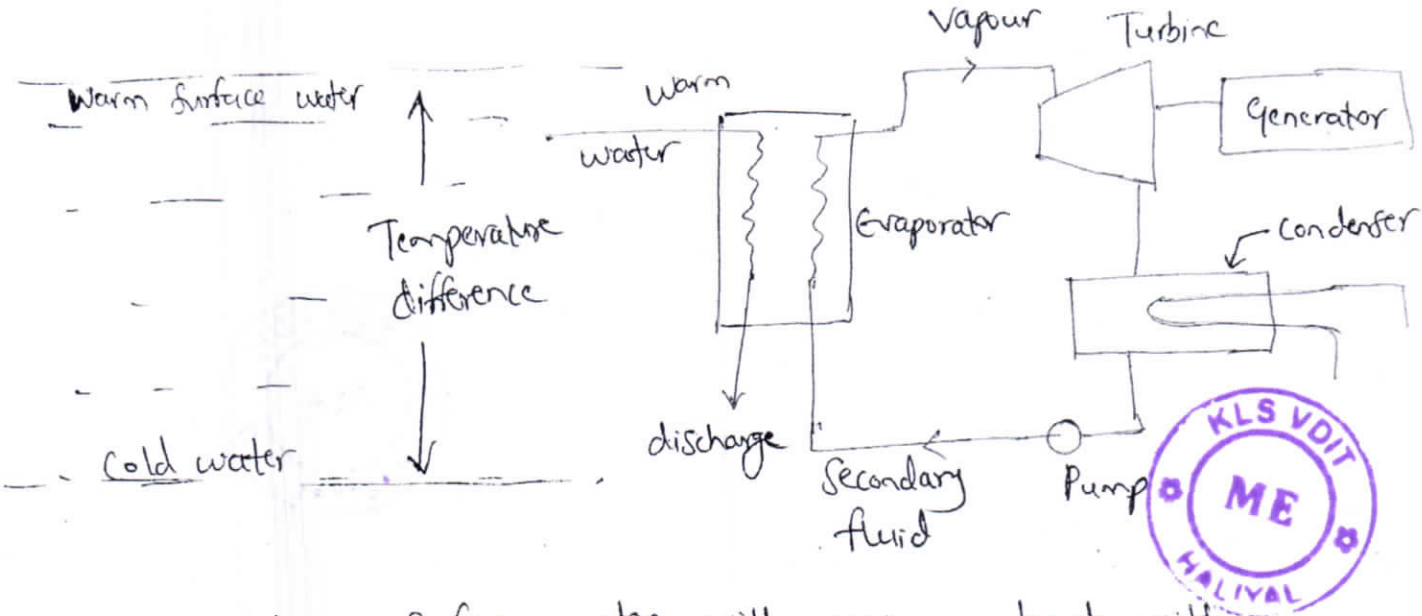
the oceans, which is originally solar energy could be converted into electricity by utilizing the fact that the temperature difference between the warm surface water of the tropical oceans and the colder water in the depth is about 20 to 25°K.



Warm surface water will exchange heat with secondary fluid (low boiling point) & the secondary vapour will run the turbine, which is coupled to generator. Then the vapour is condensed in a condenser and the fluid will again flow into evaporator and the cycle repeats.

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Q8b. Problems associated with OTEC

1) Very large flow of ocean water in terms of mass and volume are required. This requires large size pumps for the process.

2) Since the temperature difference to work with is less & the steam formation takes place at lesser pressure, the turbine has to operate at low pressure. Hence the output is reduced.

3) Turbine is physically large.

4) Open cycle OTEC plants operate at high cost. Therefore they are not economically viable.

5) OTEC plants are subjected to ocean storms, high waves etc. The plant is subjected to extremely severe stresses.

6) Corrosion of metal parts due to saline water. Erosion of metal parts due to particles in flowing water. Materials like stainless steel with high chromium & molybdenum with superior coating techniques have to be used.

7) Algae and kelps (marine plants) grow in pipes and obstruct the water flow. Periodic maintenance is required.

8) OTEC power generation gives less efficiency.

9) Problem of conveying large volumes of cooling water from the lower depths is of considerable importance. Materials like fibreglass reinforced plastic, prestressed concrete and aluminium have been used.

10) Construction of floating power plants is difficult.

11) Power transfer from offshore OTEC plant to land based load centre is difficult and costly.

12) Plant size is limited to lesser power generation due to large size of components.

Q8C. OTEC Power plants in the world

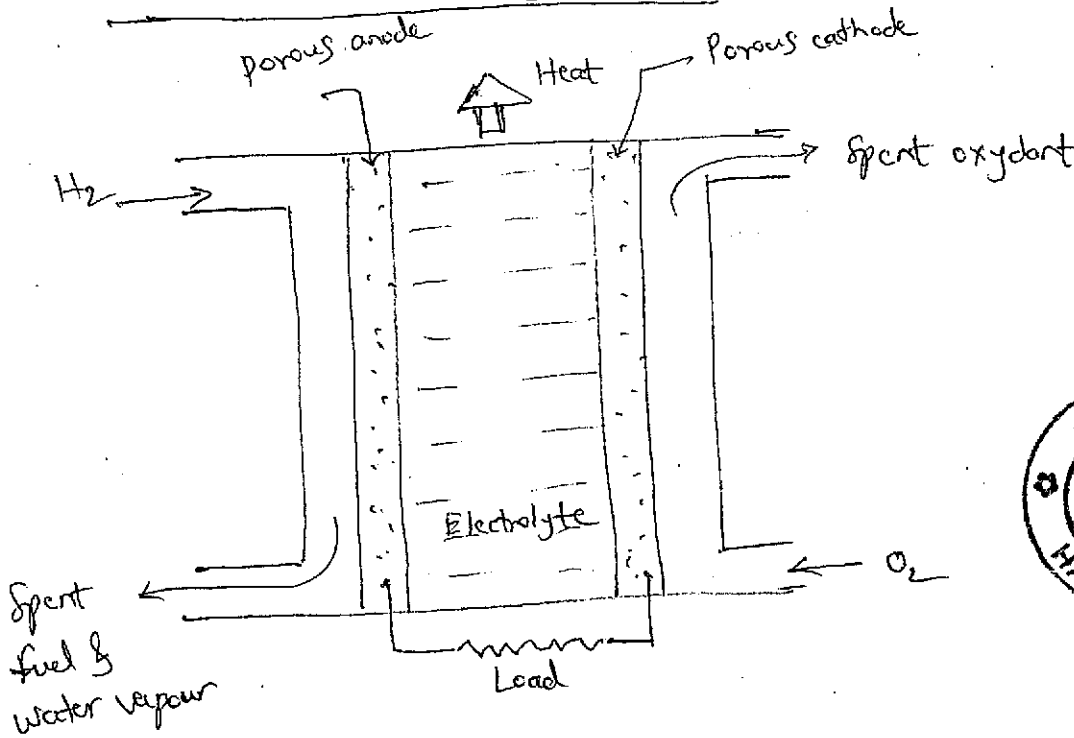
OTEC power plants are of lesser capacity and the efficiency of the plants is also less (less than 10%.) Still, many plants are being built considering the importance of OTEC as a renewable energy source and its no-fuel consumption. Some of the OTEC plants are as below:

- OTEC plant built by Claude in Cuba in 1929 (1st demonstration plant)
- OTEC plant at Ivory coast, Africa built by Frech company Energy Electrique.
- OTEC plant in Kulasekharapatnam, Tamil nadu, India
- " " in Kavaratti, Lakshadweep, India
- " " in Japan by Okinawa company & Saga University
- " " " Hawaii by Makai Company

Q9.a. Operating principle of fuel cell. (H_2-O_2 fuel cell)

A fuel cell has an anode (fuel electrode), a cathode (oxygen electrode), electrolyte, other components for containers, sealing, separators, fuel supply oxydant supply etc

$H_2 - O_2$ fuel cell (Acidic):



- 2 porous electrodes are immersed in electrolyte of good conductivity.

- The porous anode is immersed in hydrogen at certain pressure. The H_2 as a fuel bubbles across the anode.

- The porous cathode is immersed in oxygen at certain pressure. The oxygen as oxydant

bubbles across the porous cathode.

- The chemical reactions in the electrolyte produce: electrical energy, water, spent fuel and spent oxidants.

- The porous electrodes provide space for electro chemical reactions b/w the fuel & oxydant. Electrodes provide conducting path to electrons flowing through the external circuit. Electrolyte provides path for migration of hydroxyl ions from cathode to anode.

Anode reaction: $H_2 \longrightarrow 2H^+ + 2e^-$

Cathode reaction: $\frac{1}{2}O_2 + 2H^+ + 2e^- \longrightarrow H_2O$

Overall reaction: $H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$.

(In acidic electrolyte — major migration is by hydrogen ions).

Q9b. Classification of fuel cells

1) Fuel cells are classified according to the temperature range in which they operate:

Low temperature		25 – 100°C
Medium	"	100 – 500°C
High	"	500 – 1000°C
Very high	"	above 1000°C

2) According to physical state of the fuel.

Gas – hydrogen, lower hydrocarbon

Liquid – alcohols, hydrazine, higher hydrocarbons

Solid – metals etc.

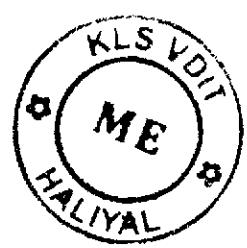
3) According to type of electrolyte:

Aqueous electrolyte

Non-aqueous "

molten "

Solid "



4) Primary & secondary fuel cell:

A primary fuel cell is the one in which the reactants are passed through the cell only once, the products of the reaction being discarded.

ex – $H_2 - O_2$ fuel cell.

Direct type fuel cells - fuel is directly introduced in to the fuel cell without conversion at input stage.

ex: direct hydrogen supply

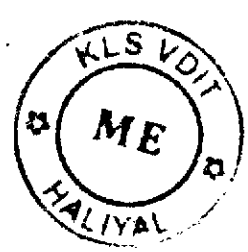
Indirect type fuel cell - Input fuel is first converted to intermediate form and the intermediate form is supplied to fuel cell

ex: reformed methanol fuel cell

Primary fuel cell: The fuel cell in which the reactants are passed through the cell only once & products of reaction are discarded. ex: H_2-O_2 fuel cell

Secondary fuel cell: The fuel cell in which the reactants are passed through the cell many times because they are regenerated from the products by thermal / electrical / photochemical methods.

ex: Nitric oxide - chlorine fuel cells.



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Q.9. Zero energy concepts:

Zero energy concept refers to reducing the energy needs through efficiency gains such that the balance of energy for vehicles, thermal and electrical energy within the defined scope is met by renewable energy. It means energy requirement of the community (within the defined scope) are not dependent on conventional energy sources, rather they are met by the renewable energy sources and also by efficiency gains. i-e, utilisation of the energy in an optimised way. ex: Zero energy building (ZEB). It is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies. Different ways of defining zero energy building are:

- Net zero site energy
- Net zero source energy
- Net zero energy costs
- Net zero energy emissions.

A zero energy building produces enough renewable energy to meet its own annual energy consumption

Gurunath Hewundi

requirements, thereby reducing the use of non renewable energy in the building sector. This also applies to campuses, portfolios and communities.

Hence in a building / campus / community with zero energy consumption, the total amount of energy used by the building on an annual basis is equal to the amount of renewable energy created on the site or in other definitions by renewable energy sources offsite, using technology such as heat pumps, high efficiency windows & insulation, solar panels etc. The goal is that these buildings contribu less overall greenhouse gases to the atmosphere.

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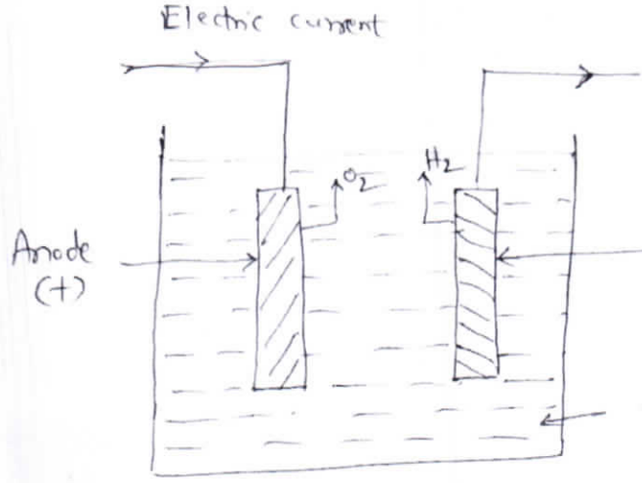
Q 10. a. Electrolysis method of Hydrogen energy production.



The process of splitting water into hydrogen and oxygen by means of direct electric current is known as electrolysis. Electrolysis cell consists of 2 electrodes, commonly flat metal or carbon plates, immersed in aqueous conducting solution called the electrolyte. A direct current voltage is connected to the electrodes and current is established from anode to cathode.

As a result the water in the electrolyte solution is decomposed into Hydrogen gas (H_2) which is released at the cathode and oxygen gas (O_2) released at the anode.

Gurunath Mavundi

Although only water is split, an electrolyte [alkali - ex KOH solution or acid - H_2SO_4] is required because water itself is a poor conductor of electricity. Temperature of cell is maintained at around 70°C.

$$2H_2O\ (liquid) \longrightarrow \underset{\text{at cathode}}{2H_2\ (gas)} + \underset{\text{at anode}}{O_2\ (gas)} + heat$$

Decomposition voltage required : 2V.

Electrical energy requirement: 4 to 4.6 KW-hr/m^3 of hydrogen.

Efficiency : 60 to 70%.

Improvements in the process:

1) Increasing electrolysis efficiency by decreasing decomposition voltage for a given current density. — Using catalyst.
   Catalyst : Platinum, nickel plated steel (cost effective)

2) Diaphragms between electrodes. It prevents electronic contact between electrodes and passage of dissolved gases.
   Diaphragm material : asbestos.

Q 10b. Hydrogen energy storage

Hydrogen is storable. This advantage is with reference to electricity storage in that, storage of H_2 is seems relatively easy. But when compared to other fuels like gasoline or oil, storing of hydrogen is challenging.

Five principle methods are considered for hydrogen storage (any 5 methods)

1) Compressed gas storage
2) Liquid storage
3) Line pack system
4) Underground storage
5) Storage as metal hydrides.

1) Compressed gas storage: Hydrogen can be conveniently stored in high pressure cylinders. This method is expensive and very bulky, because it requires large quantity of steel. For storing of H_2 as a fuel, very large size containers are required. (Suitable for small scale application).

2) Liquid Storage: This method employs cryogenic storage in vacuum insulated or super insulated

Storage tank Here the temperature has to be very low, because hydrogen liquid boils at -253°C Therefore temperature should be lower than this. Caution to be taken is flammability danger. Also considerable amount of energy is required to convert H_2 gas into liquid. About 25 to 30% of heating value of hydrogen is required to liquefy hydrogen

3) Line packing: This method uses pipline for storage & supply of hydrogen gas (similar to natural gas) The difference between the mass of hydrogen gas in 2 consecutive periods is considered as stored gas The capacity would be reduced compared to natural gas because of reduced 'heating value' of hydrogen

4) Underground Storage: This is one of the cheapest way to store large amounts of hydrogen just Similar to natural gas. These facilities would include depleted oil & gas reservoirs. Other alternatives would be caverns produced by conventional mining.

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Q10.C. Benefits of hydrogen energy

Hydrogen has some unique advantages, which make it as better fuel than the fossil and synthetic fuels. The advantages of hydrogen are as below:

1) Hydrogen is a 'clean fuel'. Combustion product is water which doesnot produce pollution. Water can be converted to hydrogen and oxygen.

2) Hydrogen can be produced by several alternate methods.

3) Hydrogen can be produced from water, fossil fuels, biomass etc., Supply of hydrogen will be abundant. Hydrogen is a renewable energy form.

4) Hydrogen has high energy density (heating value) as compared to natural gas.

5) Hydrogen can be transported by high pressure pipeline system. Presently this method is not economically competitive to electrical energy transport or natural gas pipeline transport.

Problems associated with the hydrogen energy

- Since hydrogen is a highly flammable gas, it must be handled with care in special equipment designed for safety. The extensive use of hydrogen on the grounds is dangerous. The danger of fire or explosion can be minimised by taking proper precautions with hydrogen.

- Another problem associated with hydrogen is leakage. It will leak about 3 times as fast as natural gas. Sufficient measures to be taken to avoid leakage of hydrogen.

- Chief danger of hydrogen gas is its very low ignition energy, which is less than $1/10^{th}$ of natural gas. Hence a very weak spark can also ignite air-hydrogen mixture. In handling H_2, special care has to be taken to avoid flames & sparks.

- Liquid hydrogen has one more problem. The low temperature of the liquid may cause air in the vicinity to liquefy. Since oxygen is more readily liquefied than nitrogen, an oxygen rich liquid may form. This will increase flammability danger.

- Liquid oxygen could also be formed from the air present in an empty tank or pipe when it is filled with liquid hydrogen. ∴ Air must be removed

by purging with hydrogen or helium.

- A problem could arise with evaporation of hydrogen gas from the storage tank of the vehicle, especially when it is parked in an enclosed space such as garage. Suitable precautions have to be taken.

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