Model Question Paper

First Semester B.E. Degree Examination

Renewable Energy Sources 22ETS15E/25E

Time: 03 Hours **Max. Marks: 100**

Note: 1. Answer any FIVE full questions, choosing at least ONE question from each module.

			Marks
		Module -1	
Q. 1	a	Briefly explain the principles of renewable energy, energy & sustainable development and the implications of renewable energy	10
	b	Discuss renewable energy availability in India and worldwide.	10
		OR	
Q. 2	a	Briefly describe solar, wind and biomass energy.	10
	b	Briefly describe energies from the ocean.	10
		Module-2	
Q. 3	a	Explain solar radiation and its estimation.	10
	b	Explain the pyranometer and pyrheliometer.	10
		OR	
Q. 4	a	Explain solar flat plate collector.	10
	b	Explain the principle of the solar photovoltaic cell.	10
		Module-3	
Q. 5	a	Describe wind energy availability in India and the major problems associated with it.	10
	b	Explain with a sketch the basic components of the wind energy conversion system (WECS).	10
		OR	
Q. 6	a	Explain the photosynthesis process.	05
	b	Classify biomass conversion technologies.	05
	c	Explain with a sketch downdraft gasifier.	10
		Module-4	
Q. 7	a	Explain with a sketch single basin tidal power plant.	10
	b	What are the advantages and limitations of wave energy?	10
		OR	
Q. 8	a	Explain the principle of working the OTEC power station.	10
	b	What are the problems associated with OTEC?	10
		Module-5	
Q. 9	6	Explain the fuel cell.	06
	6	Classify fuel cells.	06
		Explain zero energy concepts.	08
		OR	
Q. 10	8	Explain with a sketch the electrolysis method of hydrogen energy production.	10
	b	Describe hydrogen energy storage and applications.	10

Solution to Model Question Paper.

Module - 1

Q1.a. Principles of renewable energy:

The energy sources which can be continuously replenished within the timeframe of human society or which donot get depleted easily are called as renewable energy sources.

- Renewable energy sources include both 'direct' solar radiation and indirect solar energy such as wind, hydropower, ocean energy and biomass resources that can be managed in a suitable manner.
- Most of the renewable energy sources like wind/ solar heat / waves 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 their consumption should be maximised.
- Most of renewable energy sources are pollution free.
- Utilisation of renewable energy sources will lead to conservation of foreign exchange & generate local employment.

Energy and sustainable development.

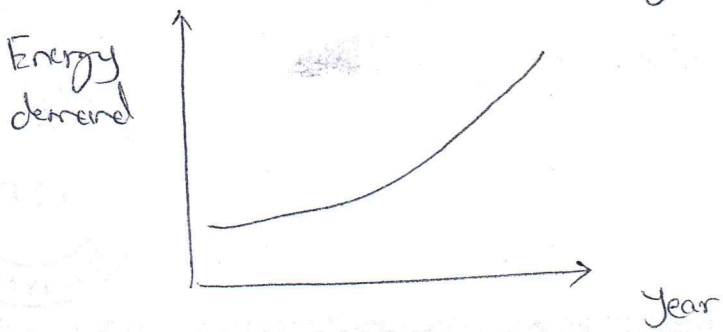
It explains how a country can maintain development/growth rate at a certain rate overcoming the obstacles. Economic growth of a country should progress at certain rate. Energy is important input in all sectors of any country's economy. Development of a country is measured in proportion to energy consumption. 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.

Social implications of renewable energy sources.

		Implications
Hydro energy	–	Non depleting source
	(+ve)	Processing does not produce pollution
		Intangible benefits like agriculture, flood relief etc.
	(–ve)	Development of project will take 6 to 10 years.
		Trees / vegetation may have to be cut.
		Problems of relocation of village, compensation for damage
Solar energy	–	Abundantly available
		Can generate local employment if systems are designed, manufactured, assembled & installed locally.
		Domestic application is feasible.
		Awareness & educating the people about the usage
		Convincing the people about investment.
		Slow process of energy conversion.
Wind energy	–	Non polluting, non depleting.
		Scope for research work.
		Large areas are needed to install wind farms (problem of compensation, cutting of vegetation)
		harmful to birds.
		Noisy in operation. ∴ have to be away from population.

Tidal/wave energy

- Scope for research work, employment generation
- Pollution free

- Marine life affected
- Can affect fishery industry.
- Can affect tourism.

Bio fuels

- Boost for agriculture and allied industries.
- Large employment generation
- Scope for research work.
- Development of villages.

- Can generate some amount of pollution.

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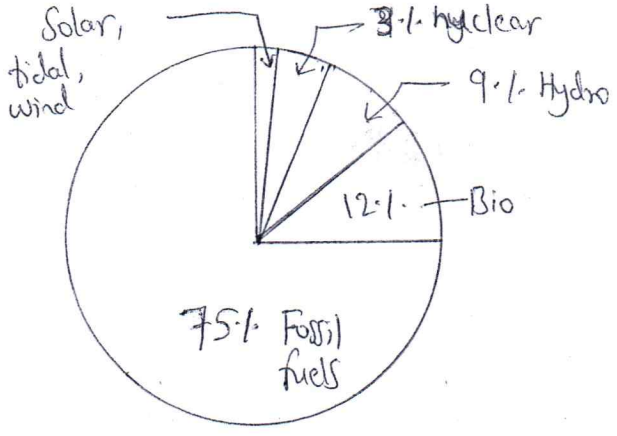
Q1.b. World wide renewable energy availability

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

Renewable energy availability in India

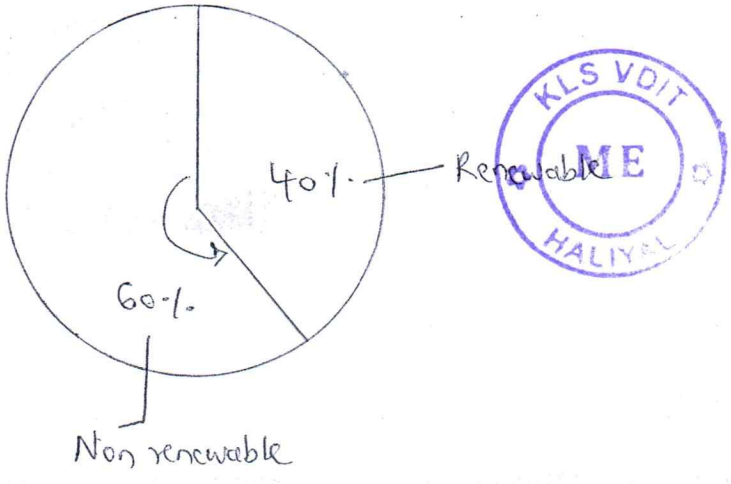
With a population of 1.3 billion, India has massive demand for energy to fuel its rapidly growing economy. From a power deficit nation at the time of Independence, the efforts to make India energy-independent have continued for over seven decades. Today we are power sufficient nation with a total installed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



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Energy generation in India is with both non renewable energy sources [about 60% share] and renewable energy sources [about 40% share]. Energy equivalent to nearly 240GW is produced by non renewable energy sources comprising of power plants run by coal, gas and diesel. Energy in excess to 160GW is produced by non renewable energy sources.

Q2.a. Solar energy: The radiant energy emitted by the sun is called solar energy. Solar radiation consists of gamma rays, X-rays, ultraviolet, visible, infrared, radiowaves etc. Solar power is the power obtained by harnessing the energy given out by sun's rays. It is used for harnessing electrical energy, thermal energy for heating applications and many other applications. 3 important solar energy conversion processes

1) Heliochemical process: Solar energy → chemical energy
   ex- photosynthesis process → biomass energy.

2) Heliothermal process: Solar energy → heat energy.
   ex: Solar heat collectors, solar pond.

3) Helio electrical process: solar energy → electrical energy
   ex: photovoltaic cell.

Wind energy: Kinetic energy associated with the movement of large masses of air over the earth's surface is called as wind energy. Wind results from air in motion, which is because of pressure gradient. Wind is caused by i) convective circulation (movement of air from equator to polar region)
ii) local winds (caused by heating of land & water, mountains etc)
This wind energy can be harnessed to satisfy several energy needs. Wind energy conversion systems like wind turbines are used to produce electricity.

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, plant and animal waste.

Solar energy ⟶ Photosynthesis ⟶ Biomass ⟶ Energy generation

Biomass resources fall in 3 categories:

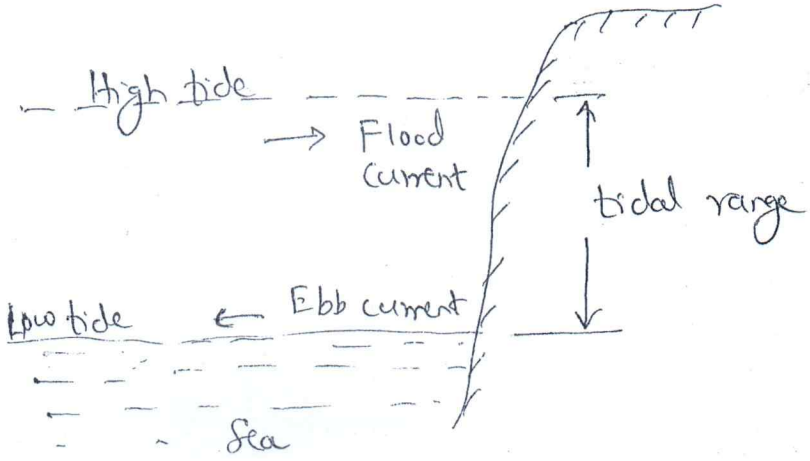
1) Biomass in solid form - wood, agricultural residue, animal waste
2) Biomass in non traditional form - converted into liquid fuels
   ex - ethanol, methanol, biodiesel
3) Biomass in gaseous form converted by digestion or fermentation process.

Q2.b. Energy from oceans:

- Tidal energy
- Wave energy
- Ocean thermal energy

Tidal energy:

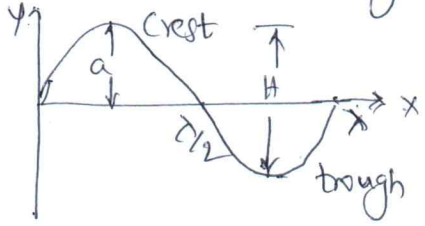
Tides are produced mainly by the gravitational attraction of the moon and the sun on the water of solid earth and the oceans. About 70% of the tide producing force is due to the moon and 30% to the sun. Thus the moon is the major factor. Surface water is pulled away from the earth on the side facing the moon, and at same time solid earth is pulled away from the water on the opposite side. Thus high tides occur in these 2 areas and low tide in intermediate areas.



High tide accompanied by flood current, Low tide with ebb current.

Wave energy:

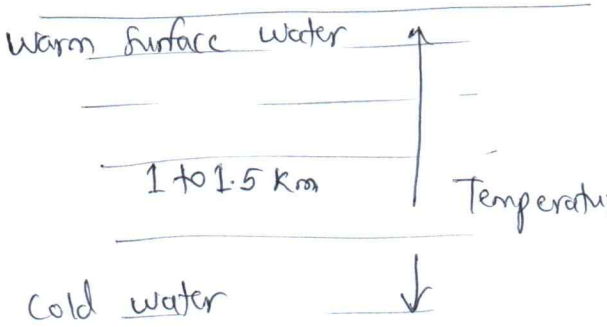
Periodic to & fro, up & down motio of water in large lakes, oceans & seas is called waves. They originate because of surface winds. Waves are generated because of local winds or planetary winds. They posess both Kinetic energy & potential energy. Wave energy can be much more concentrated than solar energy. Important characteristics of waves are: wave height & wave period.



a - wave amplitude, H = Height
λ - wavelength.

Ocean thermal energy:

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. 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.



Module - 2

Q3a. Fundamentals, Solar radiation:

The energy produced and radiated by the Sun, more specifically the Sun's energy that reaches the earth is referred to as solar energy. This energy is radiated as electromagnetic waves of which 99% have wavelengths in the range of 0.2 to 4.0 μm. Solar energy reaching the top of the earth's atmosphere consists of about 8% ultraviolet radiation (short wavelength 46% visible light (medium wavelength), 46% infrared radiation (long wavelength).

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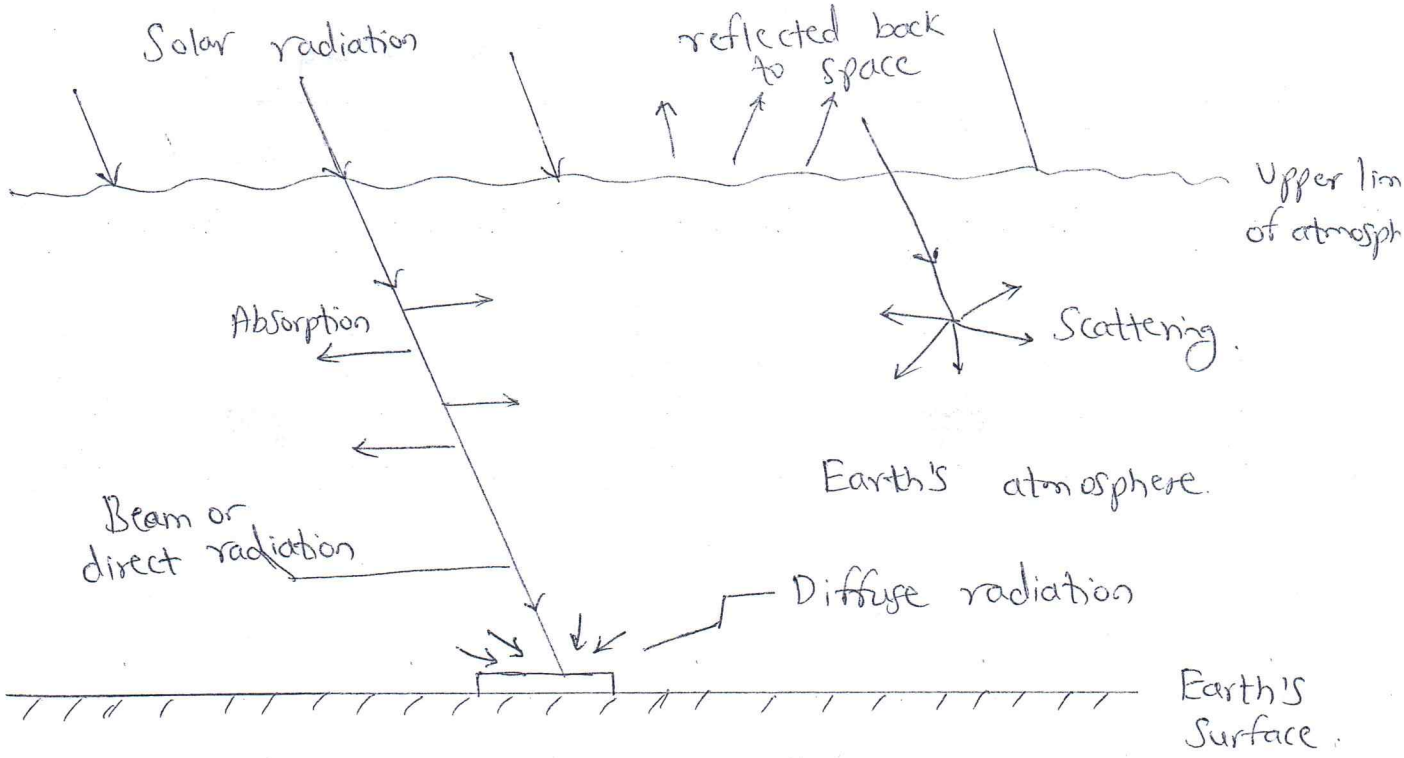


Beam radiation or direct radiation: The solar radiation received at the earth's surface without change of direction/deflection i.e, inline with the sun is called beam or direct radiation.

Diffuse radiation:
Some portion of radiation is absorbed and scattered in earth's atmosphere. Oxygen and ozone (O_3) will absorb nearly all the ultraviolet radiation. Water vapour and carbon dioxide will absorb some amount of energy in infrared range. On the other hand, scattering occurs due to all gaseous molecules and particulate matter in the atmosphere. The radiation received at the earth's surface after scattering in the atmosphere and absorption is called diffuse radiation.

Q3 a. Contd.

Estimation of solar radiation:

The measurement of solar radiation over a period of time at a place is the best approach for estimating average radiation data for that place. If this is not possible, data from near by locations having similar geography and climate can be used. If both of these approaches are not possible, one can use empirical relationships linking the values of radiation with meteorological parameters like sunshine hours, cloud cover, precipitation etc. There are many expressions to estimate the radiation. One expression suggested by Angstrom, using the amount of sunshine is as below.

$$\frac{\bar{H}_g}{\bar{H}_c} = a + b\left[\frac{\bar{S}}{\bar{S}_{max}}\right]$$

where, a & b are constants obtained by fitting data.

$\bar{H}_g$ = monthly average of daily global radiation on horizontal surface at a location (KJ/m²-day)

$\bar{H}_c$ = monthly average of the daily global radiation on a horizontal surface at the same location on clear day (KJ/m²-day)

$\bar{S}$ = monthly average of the sunshine hours per day at the location (h)

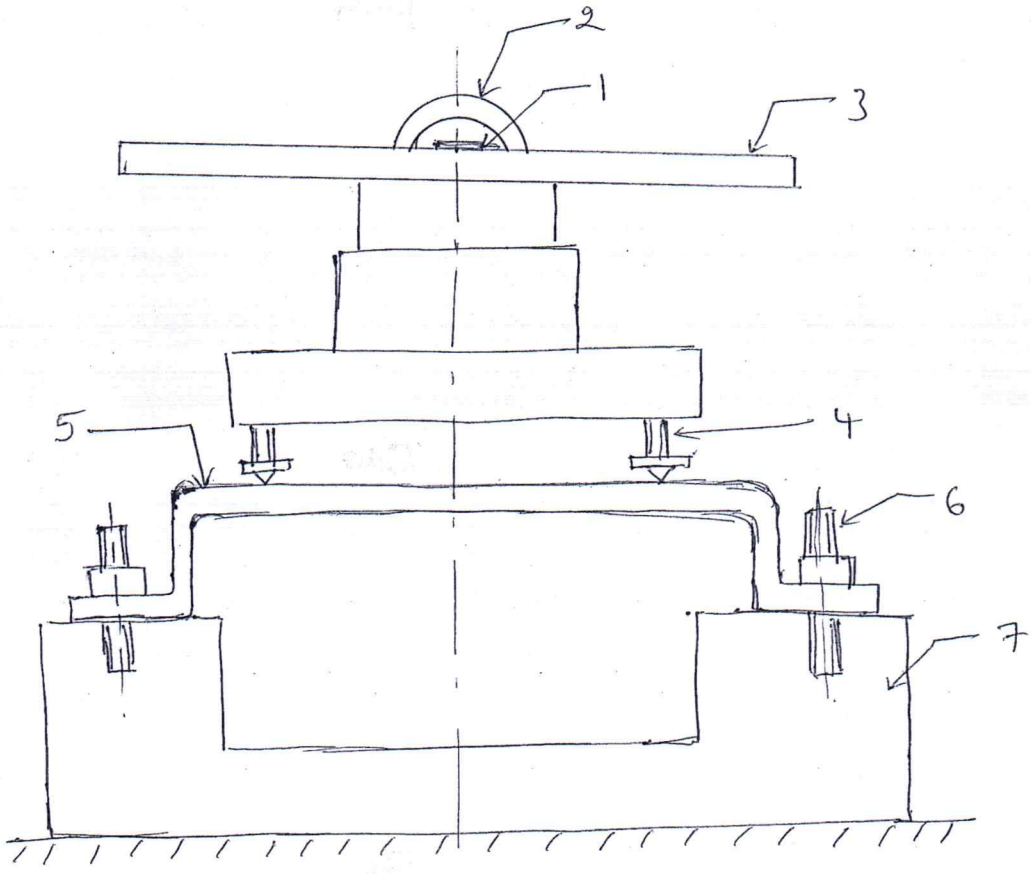
$\bar{S}_{max}$ = monthly average of maximum possible sunshine hours/day at the location (h).

Q3 b. Solar radiation measurements :

Pyranometer – Measures total radiation and it can measure diffuse radiation with special attachment.

Pyrheliometer – Measures direct radiation.

Pyranometer :



1. Black surface
2. Glass domes
3. Guard plate
4. Leveling screws
5. Mounting plate
6. bolts.
7. Platform (Base)

A pyranometer is an instrument which measures either global or diffuse radiation falling on a horizontal surface over a hemispherical field of view. Construction is as shown in the sketch. Basically the pyranometer consists of a 'black' surface which heats up when exposed to solar radiation. Its temperature increases until the rate of heat gain by solar radiation equals the rate of heat loss by convection, conduction and radiation. The hot junctions of thermopile are attached to the black surface, while the cold junctions are located under a guard plate which does not receive the radiation. An emf is generated (because of temperature difference), which is usually in the range of 0 to 10 mv. This emf reading is further calibrated as energy received in watt/meter^2.

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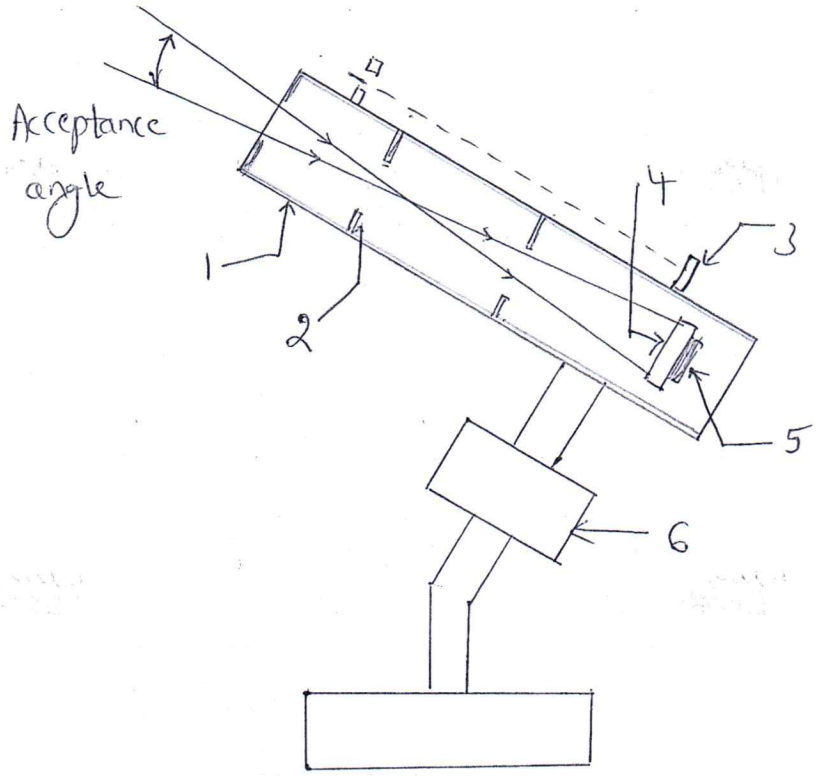
Q3b. Contd.

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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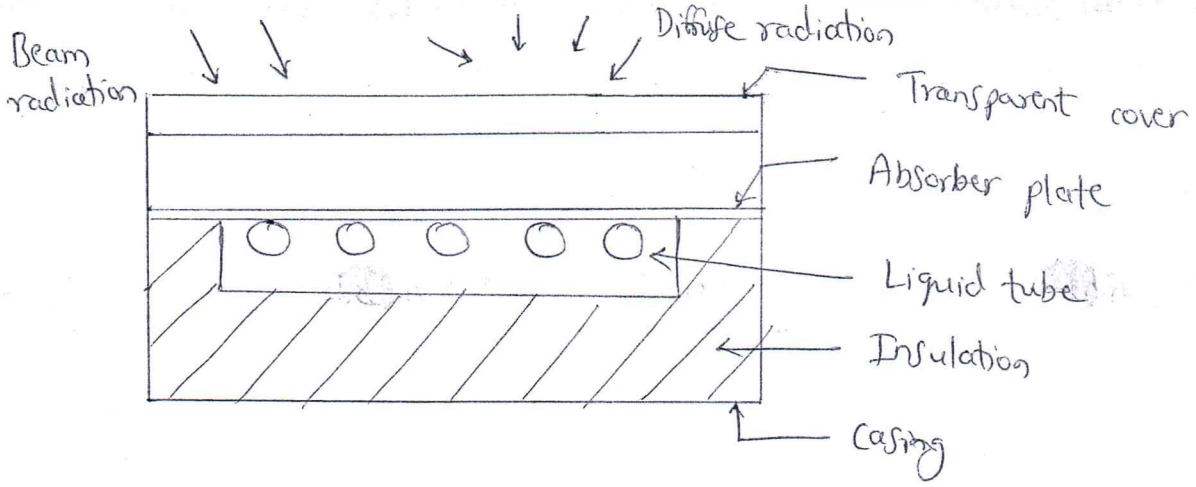
Q4a. Solar thermal systems – Flat plate collector



The principle followed is to expose a dark surface to solar radiation so that the radiation is absorbed. A part of the absorbed radiation is then transferred to a fluid like air or water. If the optical concentration is not done in the solar thermal system, then such a device is termed as flat plate collector.

The sketch of liquid flat plate collector is as shown in the figure. It consists of an absorber plate on which the solar radiation falls after coming through a transparent cover (made of glass). The absorbed radiation is partly transferred to a liquid flowing through tubes which are fixed to the absorber plate or integral with it.

The remaining part of the radiation absorbed in the absorber plate is lost by convection and re-radiation to the surroundings from the top surface and by conduction through the back and edges. The transparent cover helps in reducing the losses by convection and re-radiation, while the thermal insulation on the back and edges helps in reducing the conduction heat loss. It is fixed with supporting structure, facing south (for locating in northern hemisphere).

Five main components of flat plate collector:

i) A transparent cover made up of glass or radiation transmitting plastic sheet

ii) Tubes/fins/channels connected to absorber plate/integral with it

iii) The absorber plate (normally metallic) with black surface.

iv) Insulation provided @ back & sides to minimise heat losses.

v) The casing which enclose all the elements.

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Q4b. 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} erg/s.

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

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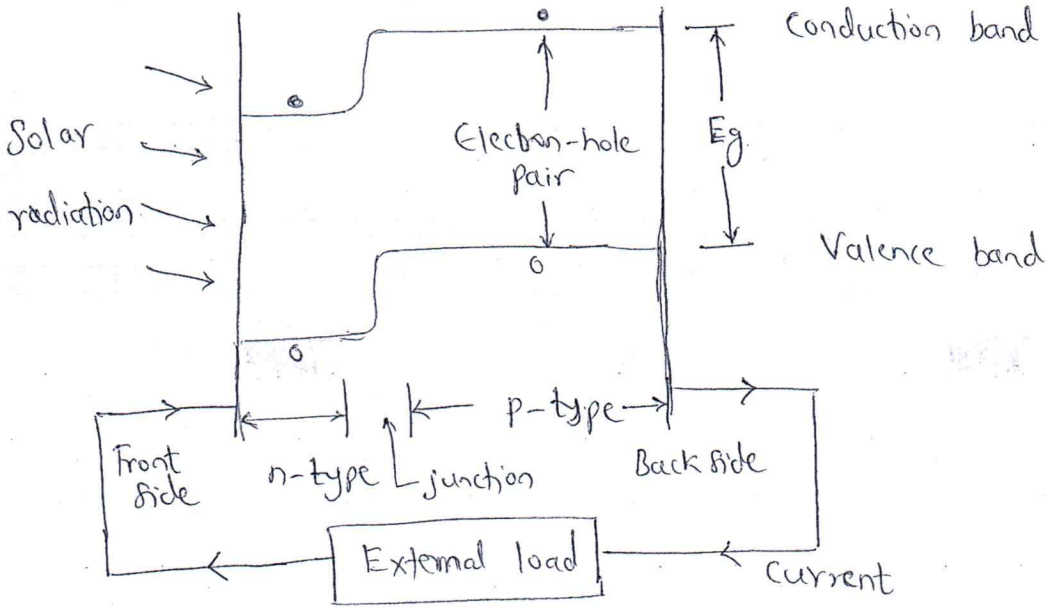
valence band and the conduction band.

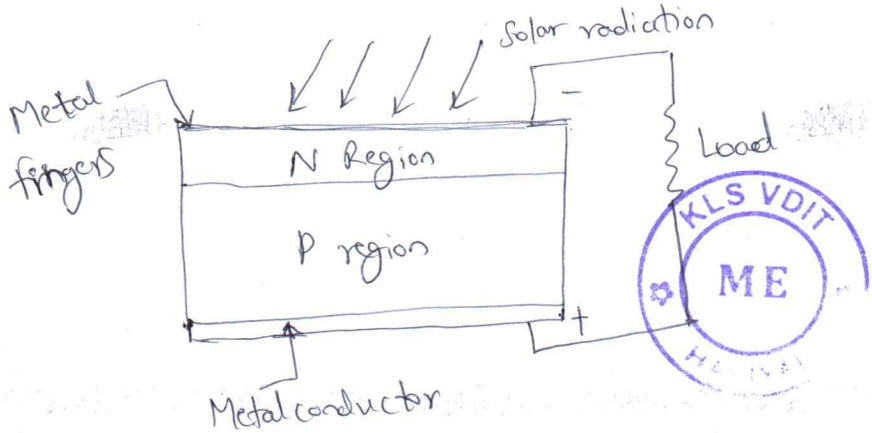
Valence band — electrons @ lower energy level — fully occupied

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 more of the electrons.





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Q5. a. Wind energy availability in India.

- As of September 2022, the total installed wind power capacity in India is 40.03 GW.
- India has 4th largest installed wind power capacity in the world.
- Wind power capacity is mainly spread across the southern, western and northwestern states.
- The Goverment of India has installed over 800 wind monitoring stations all over the country through the National Institute of Wind Energy (NIWE)
- NIWE has issued wind potential maps at 50m, 80m, 100m & 120m above ground level.
- ~~Wind power potential of India country~~
  - ~~Power height~~, &

Total wind energy over earth - 16.7×10^{12} MWh/year.

Wind energy over land area - 1.67×10^{12} MWh/year

Usable wind energy in the world - 0.001×10^{12} MWh/year

Usable wind energy in India - 175×10^{6} MWh/year.

Present installed capacity in India - 40.03 GW.
(as on Sep 2022).

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Wind power capacity installed in India by state
(as of March 2021)

Tamil Nadu	–	9608.04 MW
Gujrat	–	8561 MW
Maharashtra	–	5000 MW
Karnataka	–	4938 MW
Rajasthan	–	4326 MW
Andhra Pradesh	–	4096 MW
Madhya Pradesh	–	2519 MW
Telangana	–	128.1 MW
Kerala	–	63 MW
Others	–	4.3 MW

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Major problems associated with wind power

1) Availability of wind energy is fluctuating in nature.

2) There are issues related to installation at proper site, operation and control, maintenance, grid connection & safety.

3) For larger machines, an issue of importance is whether to use fixed speed wind machines or variable speed machines.

[fixed speed machines deliver constant power — low cost.
variable " " can " more power — more cost, because of electronic parts.]

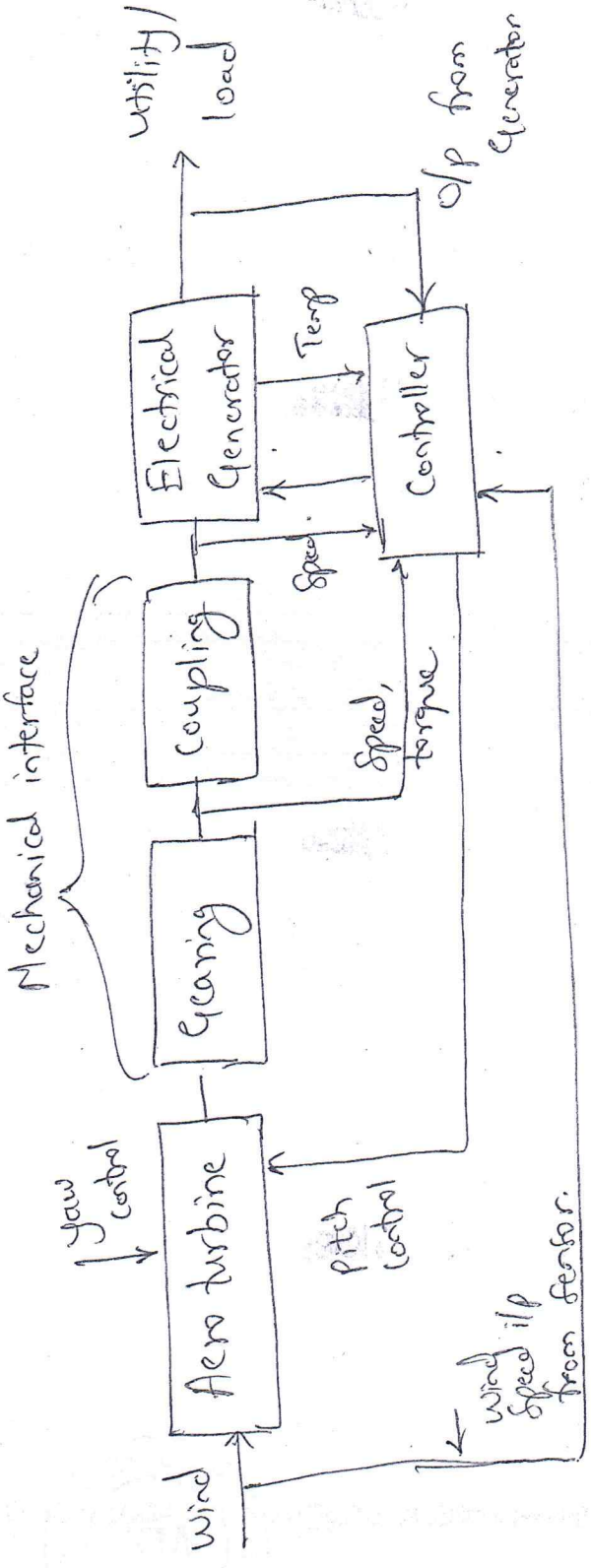
4) Wind machines are noisy in operation and hence have to be installed away from residential areas.

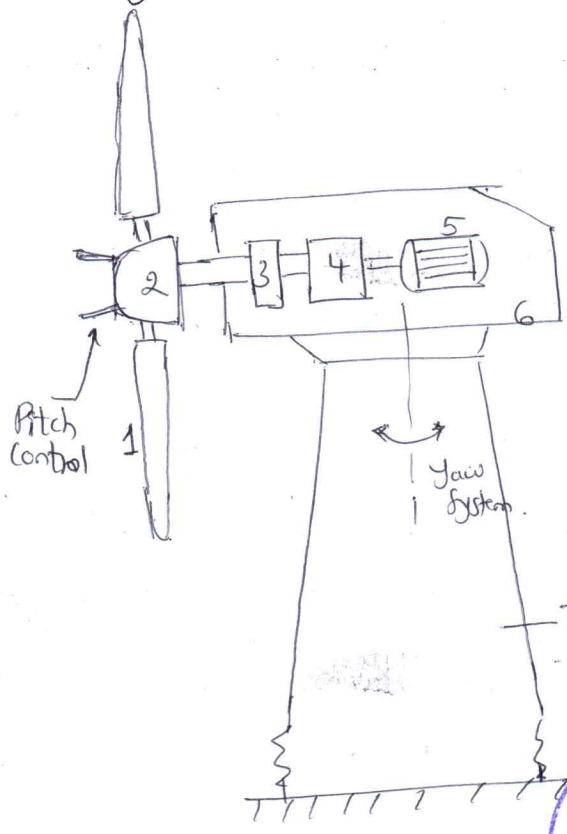
5) Many environmental issues have arisen in recent areas. Risk to birds, electromagnetic interference, land-use impact are some issues of concern.

6) Efficiency and reliability of wind machines need lot of improvement.

Q5.b. Basic components of Wind Energy conversion system.

(Block diagram)





1 - Wind turbine blade

2 - Hub , 3 - Bearing

4 - Transmission (Gears & brake)

5 - Generator & controls

6 - Nacelle

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Aeroturbines 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.

Nacelle: It is a cover housing that houses all the components of a wind turbine.

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Q6. a. 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.

$CO_2 + H_2O + \text{light} + \text{chlorophyll} \longrightarrow$

$(H_2CO)_6 + O_2 + \text{chlorophyll}$

(Sugar)

$6CO_2 + 12H_2O \longrightarrow C_6H_{20}O_6 + 6H_2O + 6O_2$

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The absorbed light is in the UV & IR range. Visible light having wavelength $< 700A^{\circ}$ 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 $< 700^{\circ}A^{\circ}$, 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

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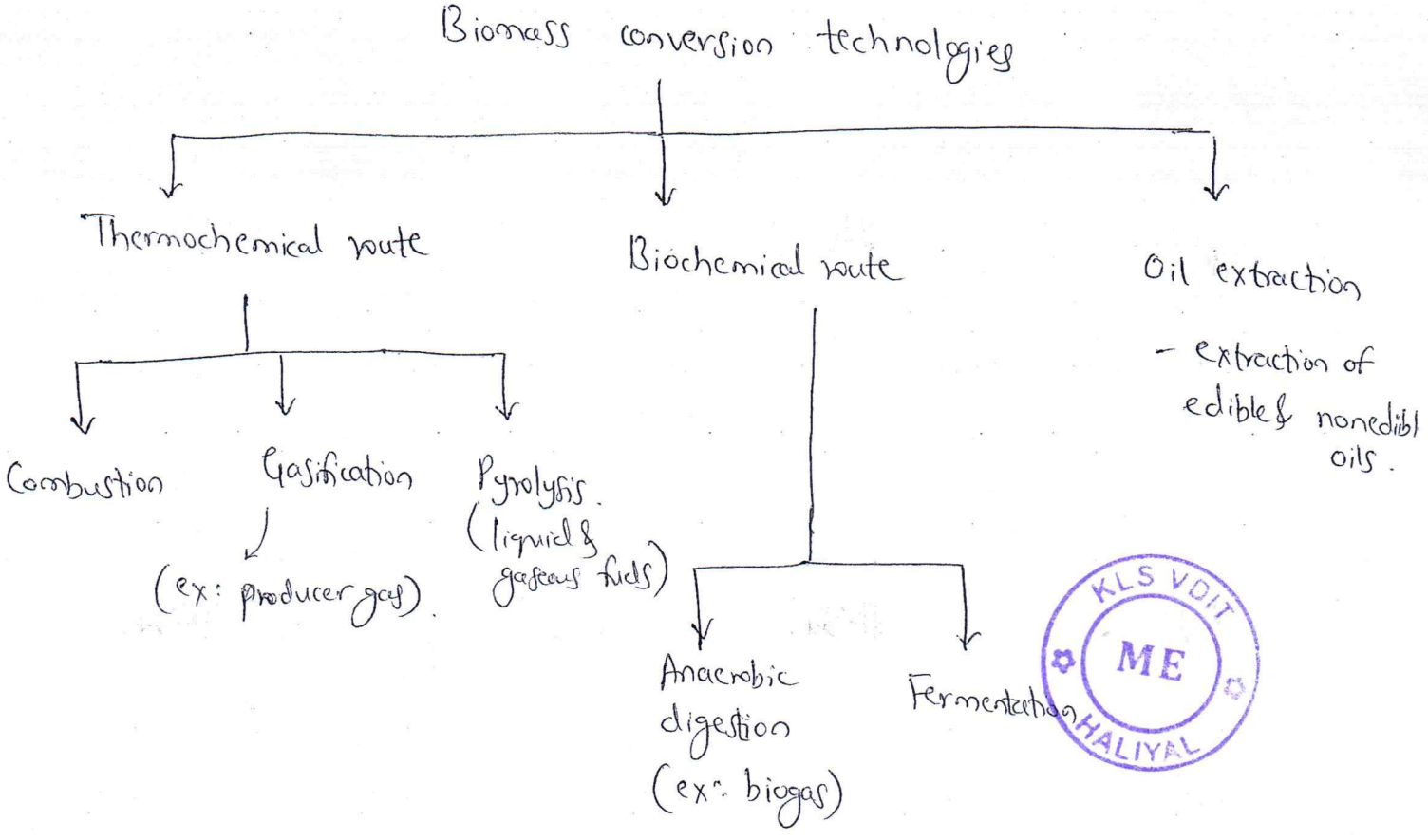
Q6.b. Biomass conversion Technologies — classification

These are the wide variety of conversion technologies which are used for manufacturing premium fuels from biomass. Especially liquid & gaseous fuels are obtained from biomass which are not only having higher calorific value but also burn clearly with little or no residue. The coice of the process is determined by a number of factors like the location of resource and its physical condition, the economics of competing process and the availability of suitable market for the product.



a) Thermochemical route – These processes use supply of heat energy.

Combustion – direct burning of wood / agricultural waste.

Gasification – Partial supply of air to produce fuel gas (ex – producer gas)

Pyrolysis – heating in absence of air to get energy rich fuels (ex: liquid & gaseous fuels)

b) Biochemical route – Usage of biological organisms through biochemical reaction.

Anaerobic digestion – Bacterial decomposition in the absence of air ex – biogas generation

Fermentation – biochemical reaction using yeasts / enzymes ex – fermentation of sugar to get ethanol.

c) Oil extraction – getting oils from crops which can be used as fuel / or for other application.

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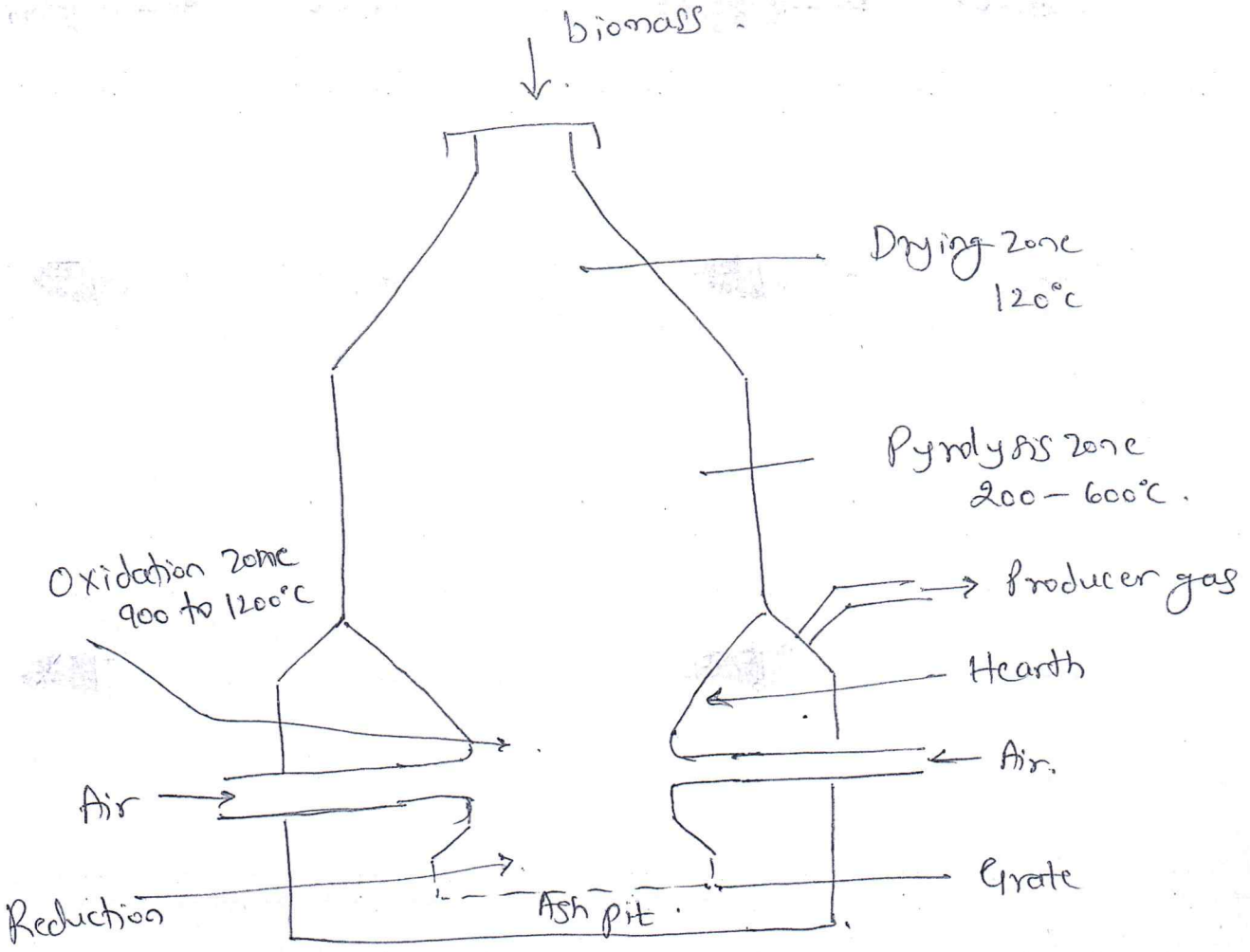
Q6. c. Biomass Gasification: (Down draft)



[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 is converted through a series of processes into 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.

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Module – 4

Q7.a. Single basin tidal power plant:

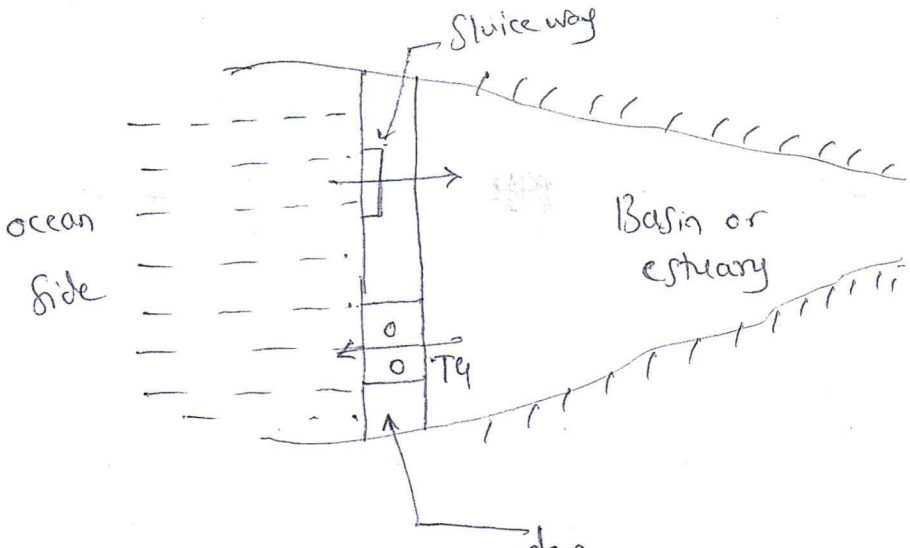

Fig - I

(Plan view)

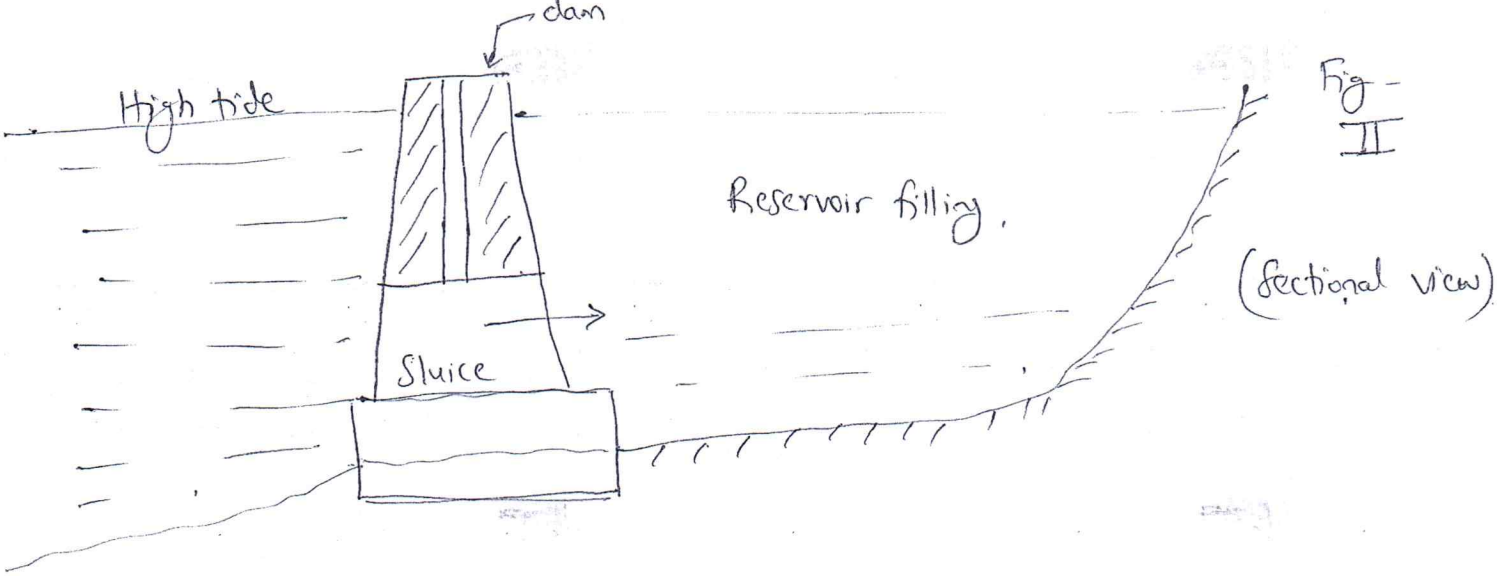

Fig - II

(Sectional view)

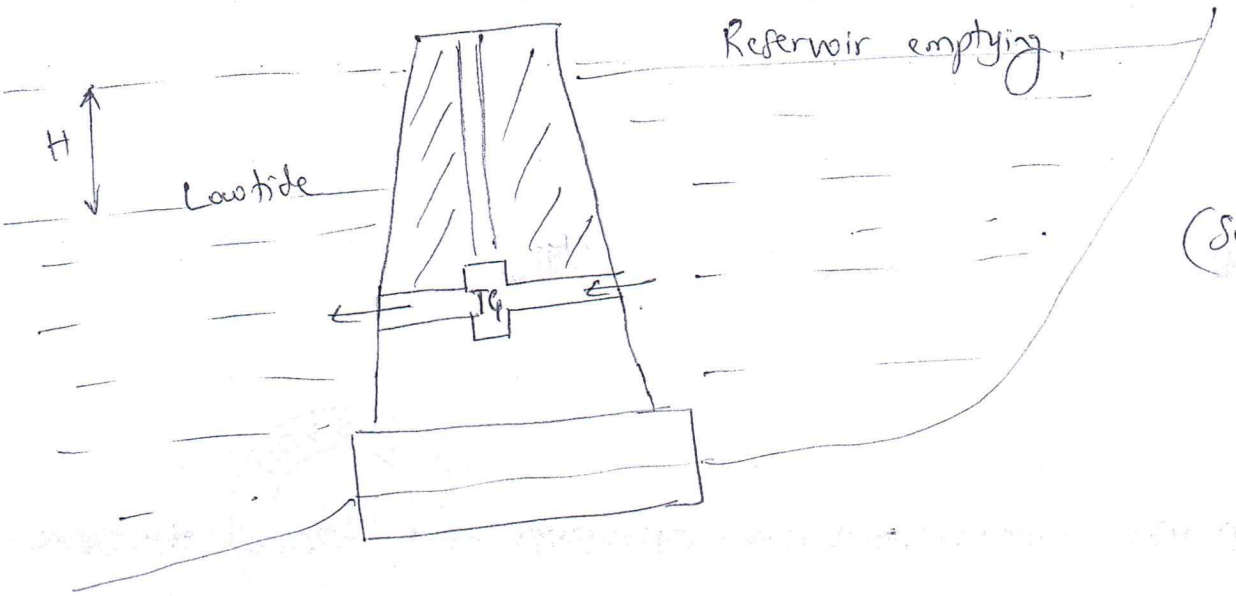

Fig - III

(Sectional view)

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 <u>single ebby cycle system</u>.

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 <u>single tide cycle system</u>.

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Q7.b. Advantages of wave energy:

1) It is renewable energy source and is pollution free.

2) It has advantage over wind/solar energy that energy is naturally concentrated by accumulation overtime & space and is transported from winds.

3) The power density of waves is high

4) Wave power devices do not use up large land masses unlike solar or wind.

5) Wave energy is available during night also.

6) Variation in the energy is not as high as tides.

7) If wave energy is harnessed, it leaves the water in a relatively placid (calm) state. (Sound disturbance is minimised & hazards on the shore are reduced)

8) Wave energy is independent of the water cycle

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Disadvantages of wave energy :

1) The energy is available on the ocean. The extraction equipment must be operated in marine environment. (construction cost, maintenance, reliability are affected).

2) Wave energy converters must be capable of withstanding very severe peak stresses in storms.

3) Efficiency of devices is less.

4) There is relatively scarcity of accessible sites of large wave activity

5) Still lot of development activity needs to be done which can throw light on capital investment, maintenance cost, repair & replacement etc.

6) Marine life may be affected

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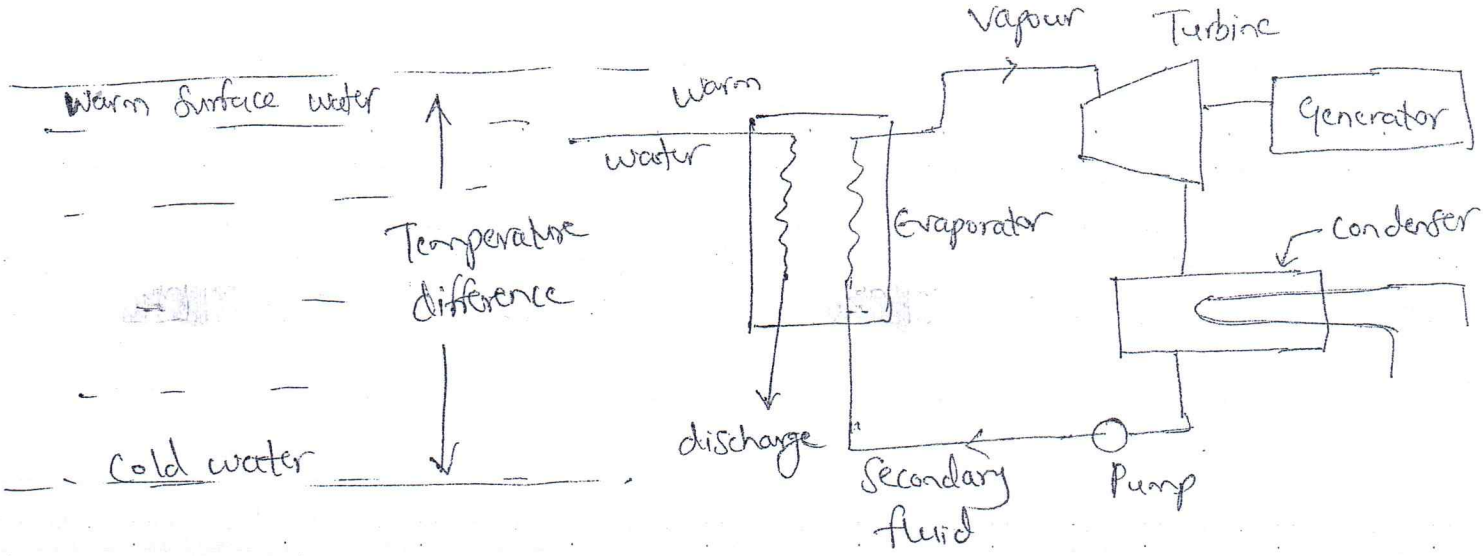
Q8.a. Ocean thermal energy conversion

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 day time.

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

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.

Q8.b. 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 ext-remely 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.

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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.

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Module - 5

Q9. a. Fuel cells.

A 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. The fuel cell is similar to other electric cells in the repect that it consists of positive and negative electrodes with an electrolyte between them.

Fuel in a suitable form is supplied to the negative electrode and oxygen, often from air, to the positive electrode. When the cell operates, the fuel is oxidised and the chemical reaction provides the energy that is converted into electricity.

Fuel cells differ from conventional electric cells in the respect that the active materials (i.e, fuel and oxygen) are not contained within the cell but are supplied from outside.

ex: Hydrogen fuel cell

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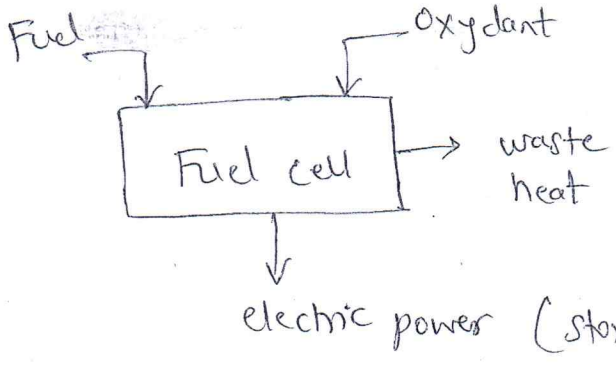
Fuel cell is basically a controlled chemical – electro energy conversion device that continuously converts chemical energy to electrical energy.



Fuel cells have gained importance because,

- direct conversion of energy & high efficiency
- least pollution
- modular configuration.

Applications:

- Used as substitutes for storage batteries & primary cells for higher KW ratings.
- Replacement for internal combustion engines in tractors, automobiles etc
- Sources of electrical power for remote installations, space ships, oceanships, mega buildings, subornines, electric vehicles etc.

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Q9.b. 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.

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A secondary fuel cell is the one 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.

There are other classifications also made based on:

- fuel and oxydant
- Basic or acidic electrolyte
- applications (automobiles, space, submarine, defence applications etc.

Types of fuel cell:

i) hydrogen ii) fossil fuel iii) hydrocarbon fuel

iv) Alcohol fuel v) hydrazine fuel.

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Zero energy concept.

The zero energy concept, also known as net zero energy, refers to the idea of designing buildings or establishments or communities that use no more energy than they generate from renewable sources. This means that a zero energy structure or community generates as much energy anually as it uses. It means that, here the energy requirement is not dependent on conventional energy sources, rather they are met by the renewable energy sources, and also by efficiency gains, i.e, utilisation of energy in an optimised way.

Achieving zero energy requires a combination of energy-efficient design, passive solar techniques and the use of renewable energy sources such as solar, wind, tidal or geothermal power. Along with these techniques, other methods which are used are advanced insulation, energy efficient windows, lighting sytems, energy efficient appliances, HVAC systems etc.

The zero energy concept is gaining popularity as a way to reduce energy costs for building owners and occupants and to improve the overall quality

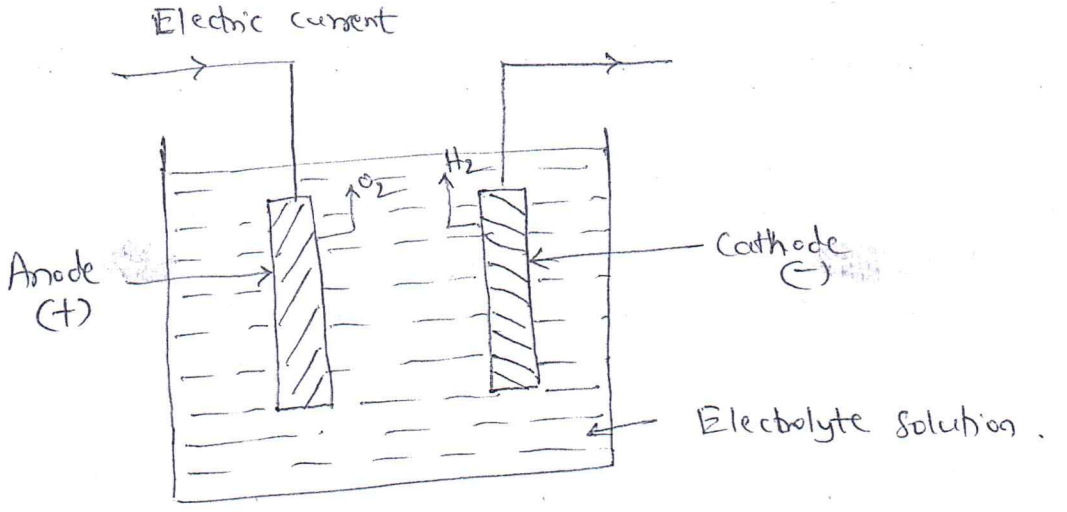
of life by creating healthier, more sustainable communities.

The zero energy concept is based on the principles of energy efficiency, renewable energy and a sustainable design. A zero net energy building typically incorporates features such as:

- High levels of insulation & air sealing to reduce energy consumption
- Energy-efficient appliances and lighting
- On-site renewable energy generation, such as solar panels or wind turbines
- Energy storage systems to store excess energy generated by renewable sources for later use.

The zero energy concept is gaining popularity as a way to reduce greenhouse gas emissions, improve energy security and save money on energy costs over the long term. The several associated terms with same concept are: "Net zero energy", "zero net", "nearly zero energy building" (nZEB) etc.

Q10.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.

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%.

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Q10.b. 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.

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 pipeline 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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5) Metal hydrides (Storage in chemically bound form):

Many metals and alloys form metal hydrides when come in contact (direct reaction) with hydrogen. When this metal hydride is heated, the hydrogen is released and the original metal is recovered for further use.

An important property of metal hydride is that the pressure of gas released by heating a particular hydride depends mainly on the temperature and not on composition. (i.e, at fixed temperature, pressure of H_2 gas released will be almost constant).

P.T.O.

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Applications of hydrogen:

i) Residential uses: Electricity for lighting & for domestic appliances (refrigerators) could be generated by means of fuel cells, with H_2 gas at one electrode and air at the other. It can be used in domestic cooking by modifying the burner. Hydrogen would be useful in radiant space heaters.

ii) Industrial uses: Hydrogen can be used as fuel instead of natural gas for many process heating applications with advantage of pollution free gas. It can also be used instead of coal or coal-derived gases to reduce oxide ores (ex iron ore to the metal iron.).

iii) Automotive & transportation: Research work on hydrogen as fuel for transportation is being done extensively and many trial vehicles are running with modified design. Hydrogen can be used as fuel for IC engines of automobiles, buses, trucks & farm machinery. This reduces dependency on conventional fuels & also addresses pollution problem. Modifications required would be — modification of carburetor for petrol engine, maintaining required fuel to air ratio in compression ignition engines, etc.

iv) Aircraft application — as fuel for jet engine. This can reduce overall weight of the fuel and storage tank.

v) Electric power generation.

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Solution to model question paper :

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