CBCS SCHEME

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18EE653

Sixth Semester B.E. Degree Examination, July/August 2022
Renewable Energy Resources

Time: 3 hrs. Max. Marks: 100

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

Module-1

1 a. Discuss causes of energy scarcity and solution to energy scarcity. **(06 Marks)**

b. Briefly explain energy resources and its classification. **(08 Marks)**

c. Explain worldwide renewable energy availability. **(06 Marks)**

OR

2 a. With necessary diagram, explain layers of the sun. **(08 Marks)**

b. Define the following terms:
i) Zenith angle
ii) Declination angle
iii) Altitude angle
iv) Incident angle. **(08 Marks)**

c. With a neat diagram, explain Rankine cycle of electricity production. **(04 Marks)**

Module-2

3 a. With a neat sketch, explain important parts of flat plate air collectors and concentrating collectors. **(08 Marks)**

b. With the help of diagram, explain solar cooker and write advantages and disadvantages of it. **(08 Marks)**

c. Discuss the various material aspects of solar collector. **(04 Marks)**

OR

4 a. Explain any six applications of solar cells. **(06 Marks)**

b. Draw and explain I-V characteristics of solar cell and the factors limiting the efficiency of the cell. **(08 Marks)**

c. Explain solar cell material. **(06 Marks)**

Module-3

5 a. State and explain methods of hydrogen production technologies. **(08 Marks)**

b. Discuss the applications, advantages and disadvantages of hydrogen energy. **(06 Marks)**

c. Describe the main consideration in selecting a site for wind generators. **(06 Marks)**

OR

6 a. With a neat sketch, explain dry steam based geothermal power plant. **(06 Marks)**

b. With necessary diagram, explain waste recovery management scheme. **(08 Marks)**

c. Write the advantages and disadvantages of waste recycling. **(06 Marks)**

Module-4

7 a. With the help of diagram, explain gasifier and their classifications. **(06 Marks)**

b. Explain chemistry of reaction process in gasification. **(08 Marks)**

c. Explain biological and chemical stages of anaerobic digestion. **(06 Marks)**

OR

8 a. With a neat sketch, explain fixed dome type biogas plant. **(08 Marks)**
b. With the help of diagram, explain two basin system in tidal power harnessing. **(06 Marks)**
c. Discuss problems faced in exploiting tidal energy. **(06 Marks)**

Module-5

9 a. Discuss motion in the sea waves. **(04 Marks)**
b. Explain various devices for harnessing wave energy. **(08 Marks)**
c. Distinguish between land-based OTEC power plants and floating OTEC power plant. **(08 Marks)**

OR

10 a. Write the advantages and disadvantages of wave power. **(06 Marks)**
b. With a neat sketch, explain closed cycle and hybrid cycle in OTEC cycle. **(08 Marks)**
c. Discuss application of OTEC in addition to produce electricity. **(06 Marks)**

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VTU Question paper solution

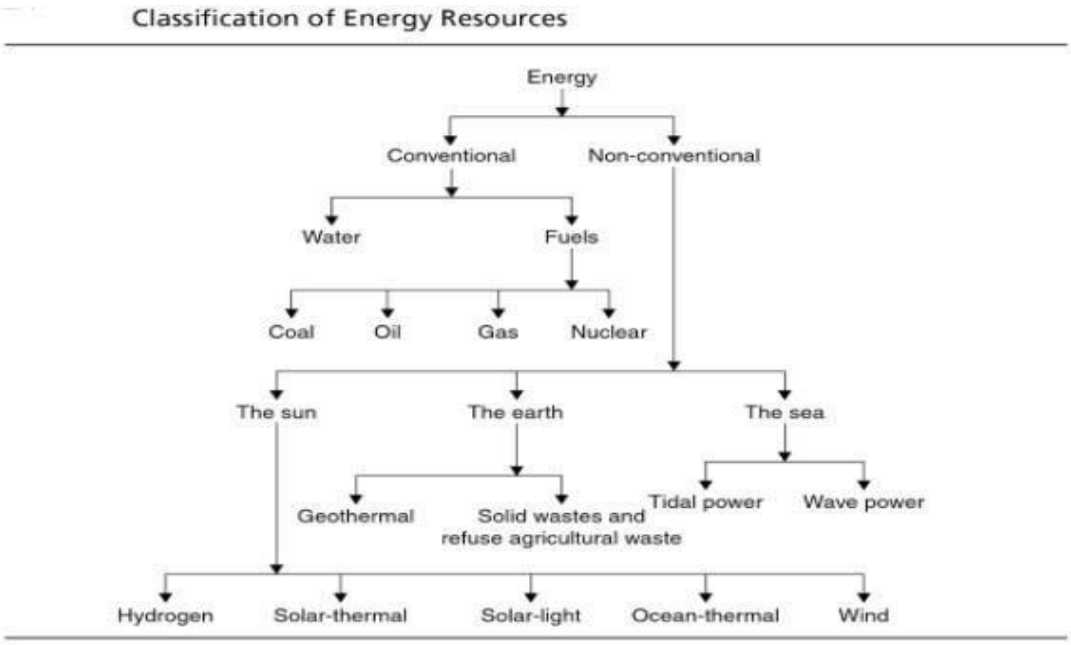
Renewable Energy, Resources-18EE653

Q. 1.a

- The energy crisis is the concern that the world's demands on the limited natural resources that are used to power industrial society are diminishing as the demand rises.
- These natural resources are in limited supply.
- While they do occur naturally, it can take hundreds of thousands of years to restore.
- Governments and concerned individuals are working to make the use of renewable resources a priority, and to lesson the irresponsible use of natural supplies through increased conservation.

1. Increasing Population
2. Increase Energy Usage or Consumption
3. Uneven Distribution of Energy Resources
4. Lacks of Technical Knowhow
5. Poor Infrastructure at power generating stations
6. Unexplored Renewable Energy Options
7. Delay in Commissioning of Power Plants
8. Wastage of Energy
9. Poor Distribution System
10. Major Accidents and Natural Calamities
11. Wars and Attacks
12. Miscellaneous Factors-strikes, military coup, political events, severe hot summers or cold winters.

Q.1.b



- Based on Usability of energy

Primary resources

Secondary resources

- Based on traditional use

Conventional energy

Non-Conventional energy

- Based on availability

Non-renewable Energy Sources

Renewable Energy Sources

- Based on commercial applications

Commercial energy source

Non-commercial energy source

- Based on origin

Fossil fuel energy, Nuclear energy, Hydro energy, Solar energy, Wind energy, etc.

1. Primary Energy Resources
- Derived directly from natural reserve
- Chemical fuels, solar, wind, geothermal, nuclear and hydro power etc.
- Use either raw energy form or by converting them to usable form

2. Secondary Energy Resources
- Energy generated from primary energy sources Electrical Energy, Steam power, hydrogen energy etc.
- Secondary energy storage is, Cost effective
- Highly efficient with improved performance Environmentally acceptable and system acceptability index approaching to unity is achievable during conversion, transportation, distribution and end use

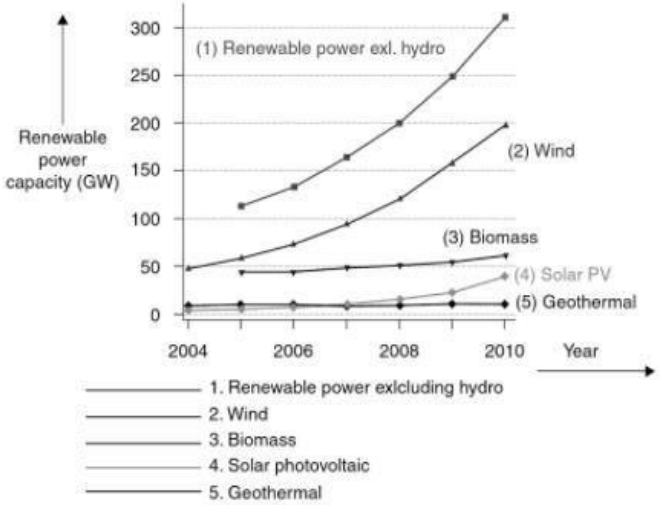
1 Conventional energy resources

- The energy stored stored within the earth and the sea. Includes fossil fuels (coal, oil, and gas) and nuclear energy (Uranium and Thorium)
- Formed over hundreds of millions of years ago.
- Continuous usage leads to fossil fuels will be no more for future generations.
- Finite energy sources

2 Non-Conventional energy resources

- Infinite energy resources Limited technical knowledge
- Required full exploitation and improved technical knowledge Cost factor and overall performance

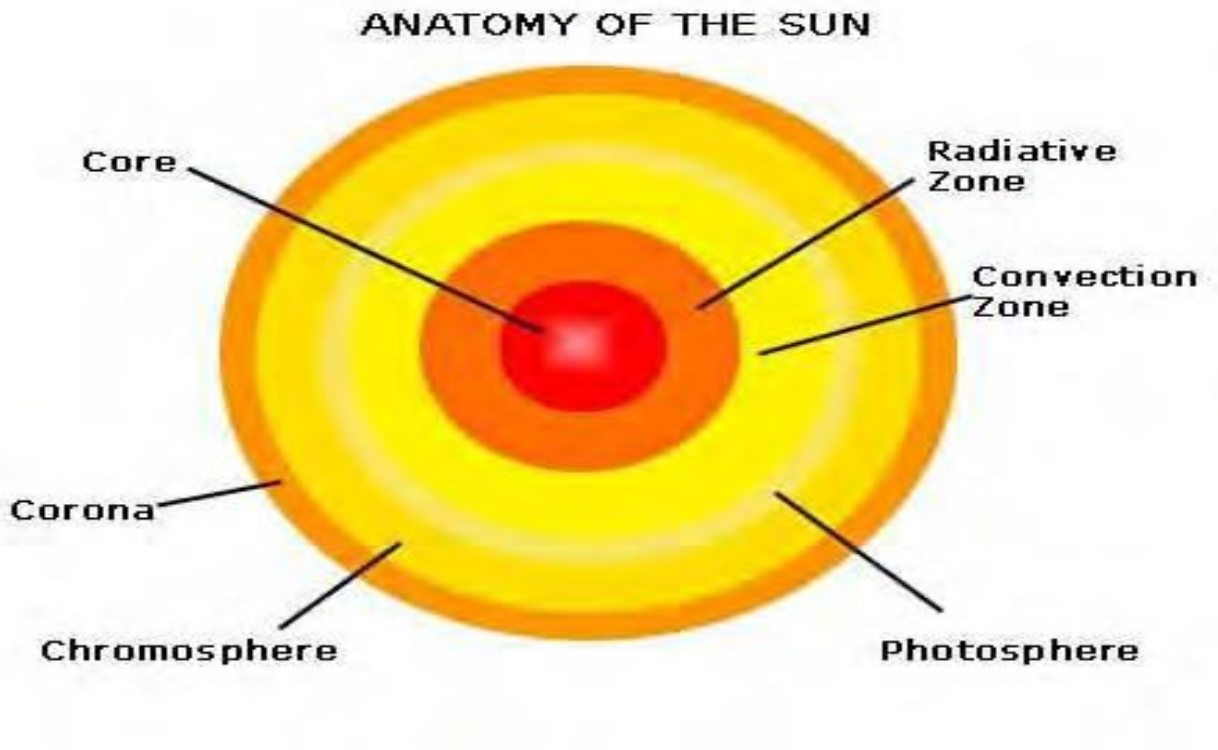
Q. 1.c <u>Worldwide Renewable Energy Availability</u>



Worldwide renewable power capacity excluding hydro

Energy Resource	Energy Amount
Solar Energy	1600 EJ
Wind Power	600 EJ
Geothermal	500 EJ
Biomass	250 EJ
Mini hydropower	50 E J
Ocean Power	1 EJ

Q.2.a Layers of the Sun



Core

- Innermost layer

- Highly dense 160g/cm^3
- 40% suns mass in 10% volume
- Gaseous state
- 1,50,00000 degree celcius
- Fusion reactions produce gamma rays and neutrinos
- Each high energy gamma ray that leaves the solar envelope will become thousand low energy photons
- Neutrinos are non reactive

Solar envelope

- Radiative envelope surrounded by convective envelope
- Temp is 4 million Kelvin
- Less dense than core
- 60% mass in 90% volume
- Puts pressure on core and maintains core temperature
- Cooler and More Opaque than core
- Energy movement in huge cells in convection zone only

Photosphere

- Zone from which sunlight is seen and emitted
- Thin layer of low pressure gases
- 6000 degree celcius

Chromosphere

- A red circle can sometimes be seen outside the sun during eclipse which is called chromosphere
- Hydrogen abundant so red in colour
- 7000 K, hotter than photosphere

Corona or Crown

- The outermost layer of the sun

- Thin and faint so difficult to observe from the earth
- Visible during total solar eclipse
- Outer layer is very dim
- It is the hottest 10^6Klayer though Spreads over several million kilometers into space, lots of room for molecules to move

Causes Solar winds

Q.2.b

Hour angle is the angular distance between the meridian of the observer and the meridian whose plane contains sun

- Hour angle is zero at solar noon
- Increases by 15 degrees every hour

Declination angle: Angle between the rays of the sun and the plane of earth's equator .

Zenith Angle(θ_z) : Complement of solar altitude angle

- $\theta_z = 90 - \alpha$

Angle of Incidence (θ) : Angle between sun's ray and the normal to the tilted surface(collector)

Solar Altitude Angle(α) :Angle between the central ray of the sun and a horizontal plane containing the observer

Q.2.c

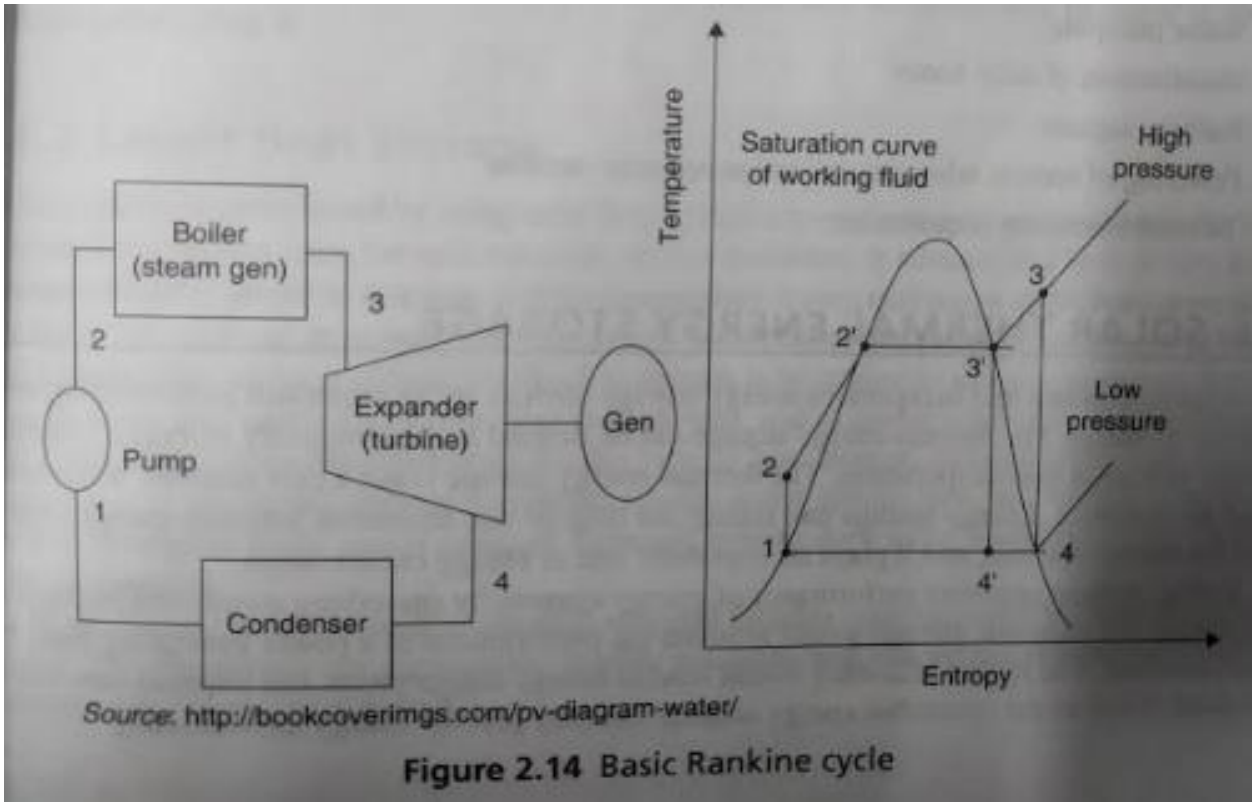
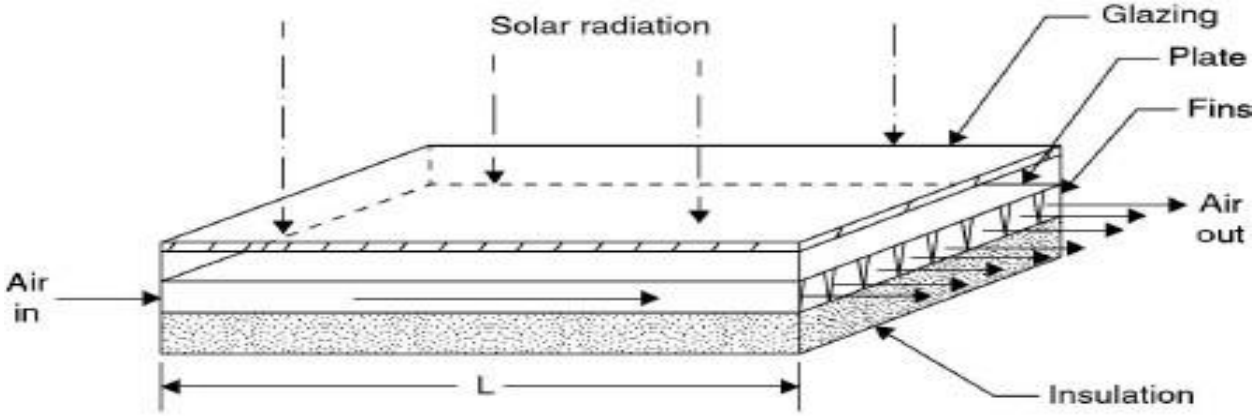


Figure 2.14 Basic Rankine cycle

Q.3.a

Flat Plate Air Collector

- Air is the transport medium
- Air flows past the absorber by natural convection or by blowers
- Less efficient than liquid type as air does not conduct heat as easily as liquid



Concentrating collectors

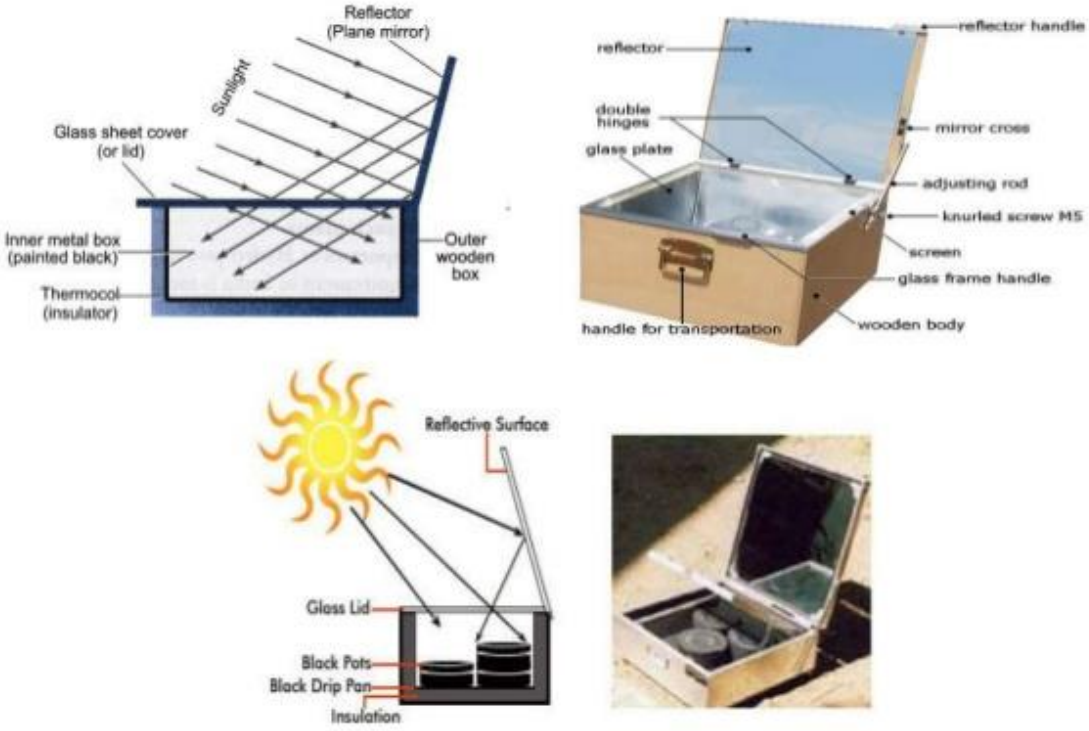
- Uses reflectors to concentrate sunlight
- Reduces the size of absorber
- Reduce heat losses
- Increases efficiency at high temperature
- Used for high temperature applications such as steam production for electricity
- Best suited for climates that have abundance of clear sky days

Q.3 b Solar Cookers

- Basic principles are

1. Concentrating Sunlight
2. Converting light to heat
3. Trapping the heat
4. Green House effect

Box Type Solar Cooker



A box-type solar cooker consists of the following components:

- **Black Box** – The box is an insulated metal or wooden box which is painted black from the inside to absorb more heat.
- **Glass Cover** – A cover made two sheets of toughened glass held together in an aluminium frame is used as a cove for box B.
- **Plane Mirror reflector** – The plane mirror reflector is fixed to the box B with the help of hinges. The mirror reflector can be positioned at any desired angle to the box. The mirror is positioned so as to allow the reflected sunlight to fall on the glass cover of the box.
- **Cooking Containers** – A set of aluminium containers blackened from the outside are kept in box B.
- The solar cooker placed in sunlight and a plane mirror reflector is adjusted in a way such that the strong beam of sunlight enters the box through the glass sheet. The blackened metal surfaces in the wooden box absorb infra-red radiations from the beam of sunlight and heat produced raises the temperature of a blackened metal surface to about 100°C.

Q.3.c Material Aspects of Solar Collectors

The following are the types of solar flat plate absorbers that are most frequently used.

1. all copper plates are with integrated water passage (roll bond type). These plates can also be made of aluminium.
2. all copper (copper tube on copper sheet).
3. copper tube or aluminium fin
4. iron or steel
5. plastic (polymers)

Absorptive Coatings

Many varieties of absorptive coating are being used, ranging from flat black paint to baked enamel. Flat black absorber coatings have high absorptivity.

Specification requirement of an absorber coating for a flat plate collector is as follows:

1. It must not degrade under ultraviolet exposure.
2. It must withstand temperature up to 200° C.
3. It must withstand many temperature cycles over ±40° C.
4. It must withstand many cycles of low to high relative humidity.
5. It must not chalk, fade, or chip.
6. It must not be so thick that heat conduction through the paint to the metal absorber is impeded.

Glazing

One or more sheets of glass or other diathermanous (radiation transmitting) material is used as transparent covers. Following are its important functions:

1. It must reduce convective losses from the absorber plate.
2. It must suppress radiative heat losses from the absorber plate.
3. It must protect the absorber from the elements and from excessive UV exposures. A glazing material must be resistant to UV radiation.

The following are the specification requirement of glazing materials:

1. They must be reasonably impact resistant.
2. Thin or no tempered glass panes are questionable because of the risk of damage from hail, birds, and vandalism.
3. Plastic materials of low tensile strength (i.e., Teflon) are not advisable.
4. They must be resistant to significant temperature shock.
5. Sudden rain will cause rapid overall limb changes. A leaf on a stagnant collector can cause high localized thermal stresses.

Q.4.a

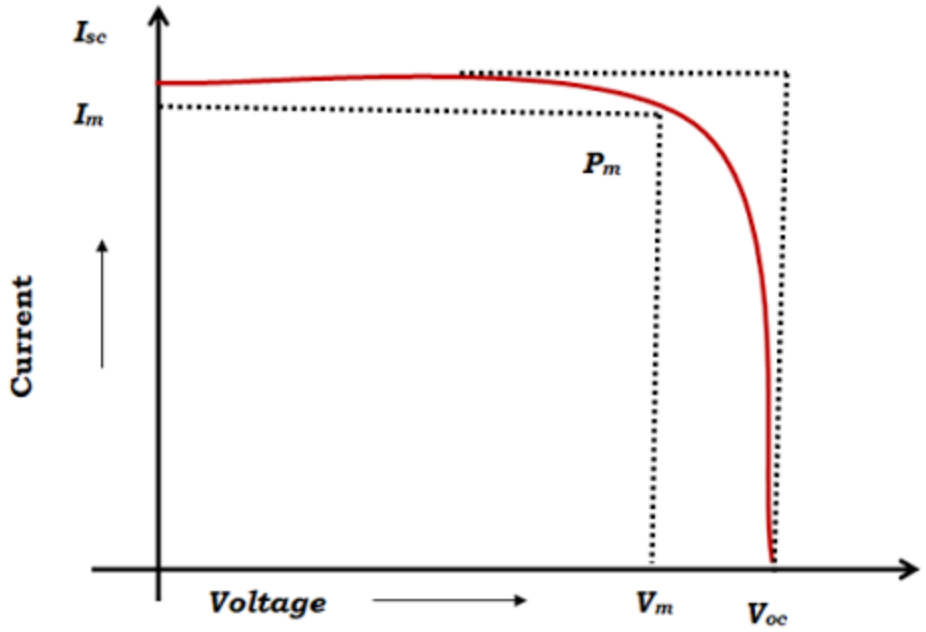
Applications of solar cells

- Solar Farms. Many acres of PV panels can provide utility-scale power—from tens of megawatts to more than a gigawatt of electricity. ...
- Remote Locations. ...
- Stand-Alone Power. ...
- Power in Space. ...
- Building-Related Needs. ...
- Military Uses. ...
- Transportation.

Q.4.b

Solar Cell I-V Characteristic

- **Solar Cell I-V Characteristic Curves** show the current and voltage (I-V) characteristics of a particular photovoltaic (PV) cell, module or array giving a detailed description of its solar energy conversion ability and efficiency.
- Knowing the electrical I-V characteristics (more importantly P_{max}) of a solar cell, or panel is critical in determining the device's output performance and solar efficiency.



Q.4.c

Solar Cell Materials

- Silicon
- Mono crystalline or single crystal Silicon
- Multi crystalline Silicon
- Poly crystalline Silicon
- Amorphous Silicon
- Thin Film
- A few micro meters thickness

Q.5.a

Hydrogen production technologies

- **Thermochemical** production technologies
- **Electrolytic** production technologies
- **Photolytic** production technologies

Q.5.b

Applications of Hydrogen gas

- Home appliances
- Work places: Noiseless efficient & environmental friendly
- Transport and Industrial Sectors

Advantages of Hydrogen energy

- Storage is easy compared to storing of electricity
- Easily available

- ▶ Decentralized production, remote areas
- ▶ Efficient when used in fuel cell
- ▶ Safe energy(only for few applications)
- ▶ Environmental friendly

Disadvantages

- ▶ Overall efficiency of electricity production is less compared to fossil fuels
- ▶ High pressure and very low temperature requirement for storage
- ▶ Safety problems (Hindenburg syndrome & Apollo challenger space)
- ▶ No existing infrastructures for transportation distribution & storage
- ▶ High cost

Q.5.c Considerations & guidelines

Factors to be considered

1. Hill effect – wind pressure increases as it reaches the hill top and increases speed

2. Roughness or amount of friction that earth's surface exerts on wind – Oceans have very little roughness, but city or forest has a great deal of roughness, which slows the wind.

3. Tunnel effect – high wind pressure and speed

4. Turbulence – It causes fluctuations in the wind speed and wear and tear on the turbine

5. **Variations in wind speed**- During day sun heats the air so the wind blow faster compared to night. Wind speed varies on Season as well.

6. Wake: the air coming out of the blade sweep has less energy because it has been slowed. The abrupt change in the speed makes the wind turbulent, a phenomenon called wake. Wind turbines in the wind forms are placed 3 rotor diameter away

7. **Wind obstacles –** Trees, Buildings and rock formation

8. **Wind shear**: It is the difference in wind speeds at different heights of turbine blades. Top pointing blade can experience wind speed of 14km per hour but bottom blade experiences 11km per hour. This causes stress on the blades results in wind shear and causes the turbine to fail.

Guidelines

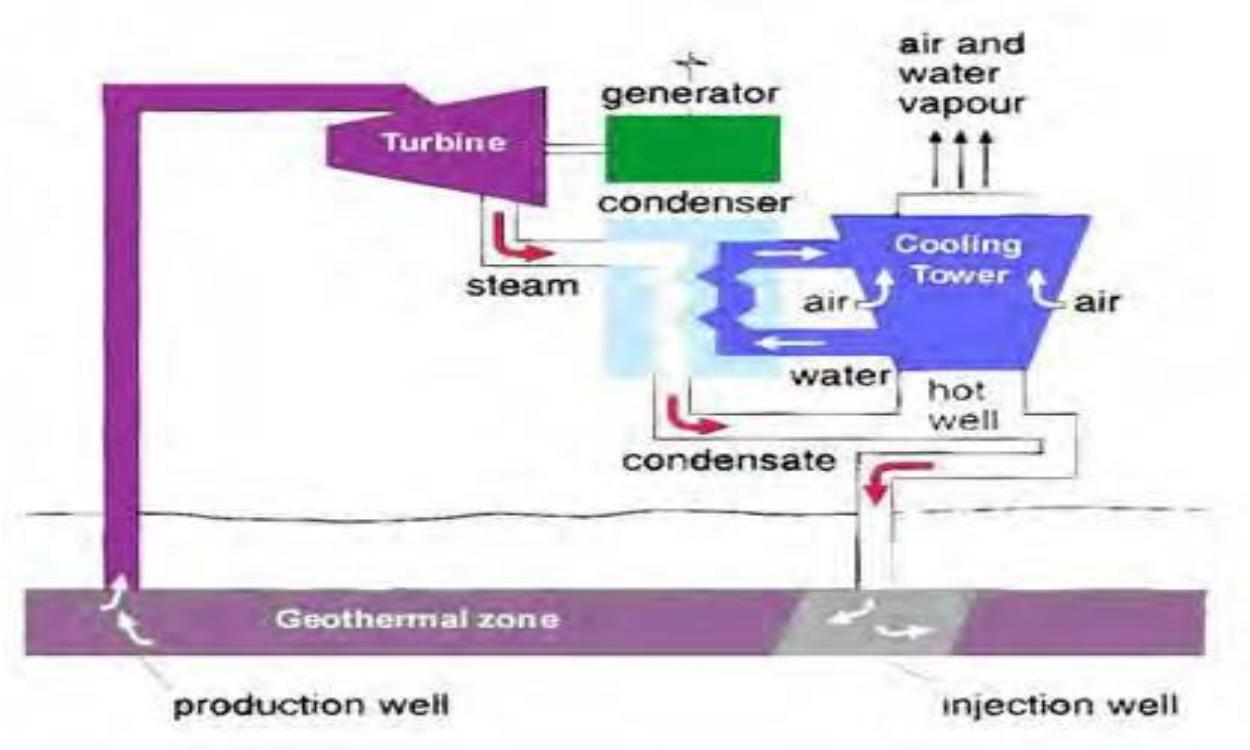
1. Turbines work good on high and exposed sites. costal sites are good.
2. Town and highly populated area
3. roof mounted turbines
4. Distance of caballing, more power loss in cables
5. Turbine height is twice obstacle distance
6. Speed of wind must be 4.5 m/s to produce electricity
7. Remote location sites are expensive as it is required to connect it with grid

Q.6.a

Dry Steam Power Plant:

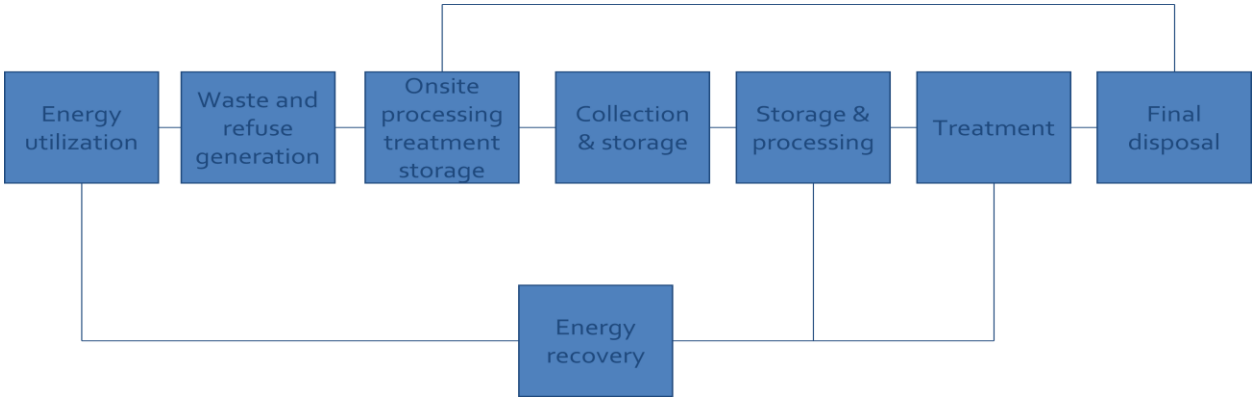
- ☐ Operating over 100 years

- Steam produced directly from the reservoir runs the turbines that power the generator
- Dry steam systems are simple
- Requires steam condensate injection piping and minimal steam cleaning devices
- Requires Rock catcher to remove large solids and Centrifugal separator to remove condensate and small solid particulates



Q.6.b

Waste recovery management scheme



1. Separation of metals, paper, and glass from the remaining waste through the process such as size reduction, screening, vibrating sorting, and electronic scanning; however, a truly homogeneous, inexpensive separation system will provide competitive input to waste energy utilization.
2. Conversion of the remaining waste product to usable form of energy and energy conversion may include the following:

   (a) Generation of methane gas (biogas conversion) or other fuels (biological conversion)
   (b) Generation of electricity either from (a) or through thermo-mechanical process
   (c) Composting of fertilizers

Q.6.c

Waste Recycling

Advantages

- Reduced damage to environment
- Reduced energy consumption
- Reduction in pollution
- Mitigate global warming
- Promotes sustainable utilization of resources

Disadvantages

- High cost of recycling
- Durability and small life span of recycled items
- Unsafe and unhygienic process

Q.7.a

Gasification processes involved with biomass are:

1. Drying of fuels: Process of drying biomass before it is fed into gasifier
2. Pyrolysis: Breaking down of biomass into charcoal by applying heat in the absence of oxygen
3. Combustion: All the heat required for gasification process are available from combustion
4. Cracking: Breaking down of large complex molecules when heated
5. Reduction: Oxygen atoms are removed in this process from combustion products and returning them to combustible form again

Q.7.b

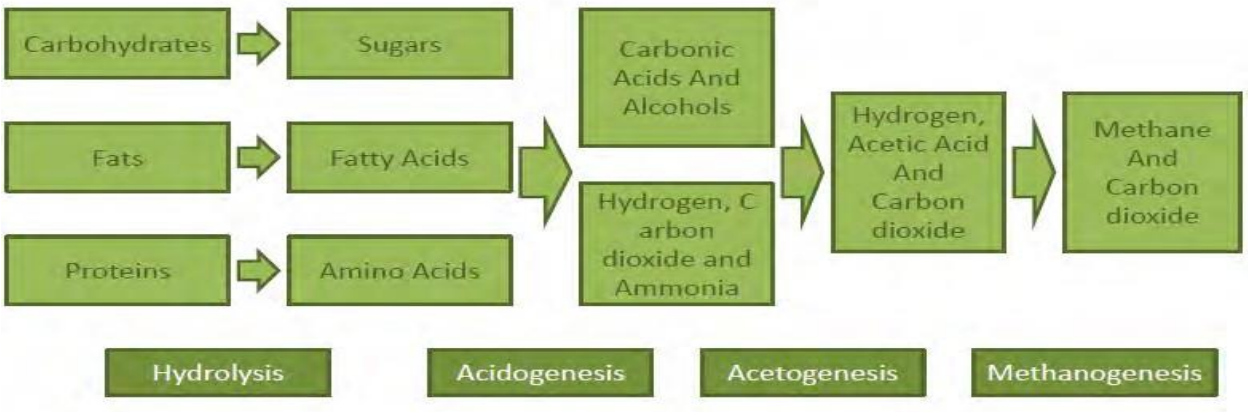
Chemistry of Reaction Processes in Gasification

- Four distinct processes are taking place in a gasifier
- 1.Drying Zone of fuel:

- In this zone moisture content of biomass is removed to obtain the dry biomass.
- Some organic acids also comes out during the drying process. These acids give rise to corrosion of gasifiers
- 2.Pyrolysis zone:
- In this zone tar and other volatiles are driven off.
- (a) Upto 200 degree Celcius, only water is driven off
- (b)Between 200 -280 degree Celcius,CO_2 ,acetic acid and water are driven off
- (c) Between 280 and 500, large quantity of tar and gases containing carbon dioxide is produced. Besides, methyl alcohol is also formed
- (d)Between 500-700,the gas production is small and contains hydrogen
- Combustion (Oxidation) zone:
- $C+O_2 \rightarrow CO_2+Heat$
- Reduction Zone:
- The hot gas passes through the reduction zone after the combustion zone
- No free oxygen in this zone.
- The carbon dioxide gas reacts with carbon in the fuel forming carbon monoxide gas
- $1.C+CO_2+heat \rightarrow 2CO$(endothermic)
- Water gas shift reaction:
- $2.C+H_2O+Heat \rightarrow CO+H_2$ (endothermic)
- Surplus water vapour reacts with CO to liberate CO_2 and hydrogen
- $3.CO+H_2O-Heat \rightarrow CO_2+H_2$ (exothermic)

Q.7.c

Process Stages of anaerobic digestion



1.Hydrolysis

› The process of breaking down large biomass organic chains into smaller constituent parts such as sugars ,fatty acids and amino acids and dissolving the smaller molecules into solution Assists the bacteria in the anaerobic digester to access the energy potential of the material

› **2.Acidogenesis**

› The products of the hydrolysis process are broken down by fermentative (acidogenetic) bacteria The products are ammonia, carbon dioxide, hydrogen and other by products

› **3.Acetogenesis**

› The products of acidogenesis are further digested to produce acetic acid, carbon dioxide and hydrogen

› **4.Methanogenesis**

› Here the methanogens use the products of preceding stages and convert them into biogas rich in methane and carbon dioxide

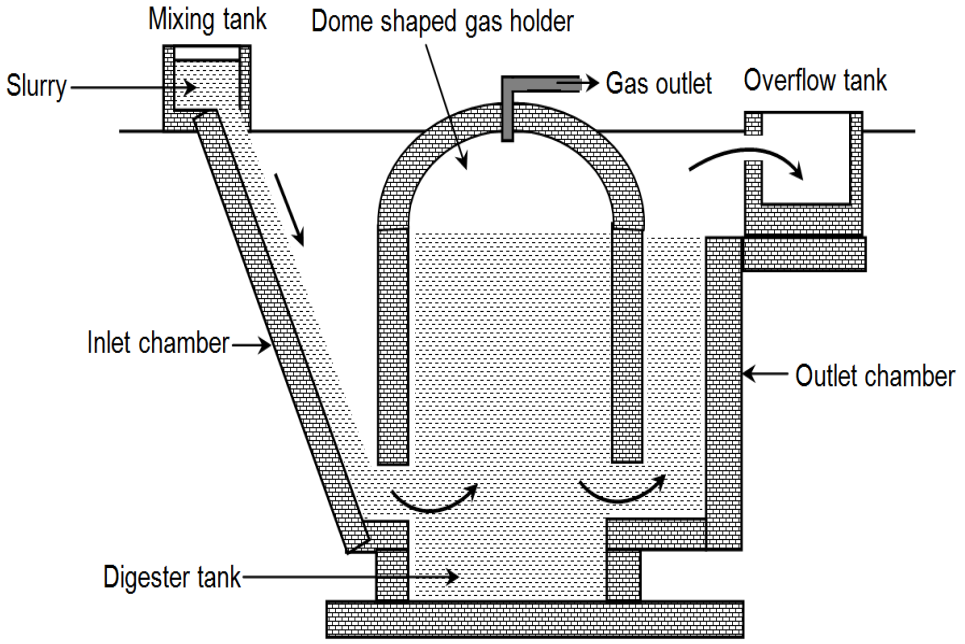
Q.8.a

Fixed Dome type

The parts of the fixed dome biogas plants are

1.Mixing tank 2.Digester 3.Inlet chamber 4.Outlet chamber 5.Fixed Dome 6.Overflow tank

7.Gas pipe & Gas control valve



Working of Fixed Dome type Biogas Plant

- The various forms of biomass are mixed with an equal quantity of water in the mixing tank. This forms the **slurry**.
- The slurry is fed into the digester through the inlet chamber.
- When the digester is partially filled with the slurry, the introduction of slurry is stopped and the plant is left unused for about two months.
- During these two months, anaerobic bacteria present in the slurry decomposes or ferments the biomass in the presence of water.
- As a result of anaerobic fermentation, biogas is formed, which starts collecting in the dome of the digester.

- As more and more biogas starts collecting, the pressure exerted by the biogas forces the spent slurry into the outlet chamber.
- From the outlet chamber, the spent slurry overflows into the overflow tank.
- The spent slurry is manually removed from the overflow tank and used as manure for plants.
- The gas valve connected to a system of pipelines is opened when a supply of biogas is required.
- To obtain a continuous supply of biogas, a functioning plant can be fed continuously with the prepared slurry.

Q.8.b

Two-basin Systems

- An improvement over the single-basin system is the two-basin system.
- In this system, a constant and continuous output is maintained by suitable adjustment of the turbine valves to suit the head under which these turbines are operating.
- A two-basin system regulates power output of an individual tide, but it cannot take care of the great difference in outputs between spring and neap tides.
- Therefore, this system provides a partial solution to the problem of getting a steady output of power from a tidal scheme.
- This disadvantage can be overcome by the joint operation of tidal power and pumped storage plant. During the period, when the tidal power plant is producing more energy than required, the pumped storage plant utilizes the surplus power for pumping water to the upper reservoir.

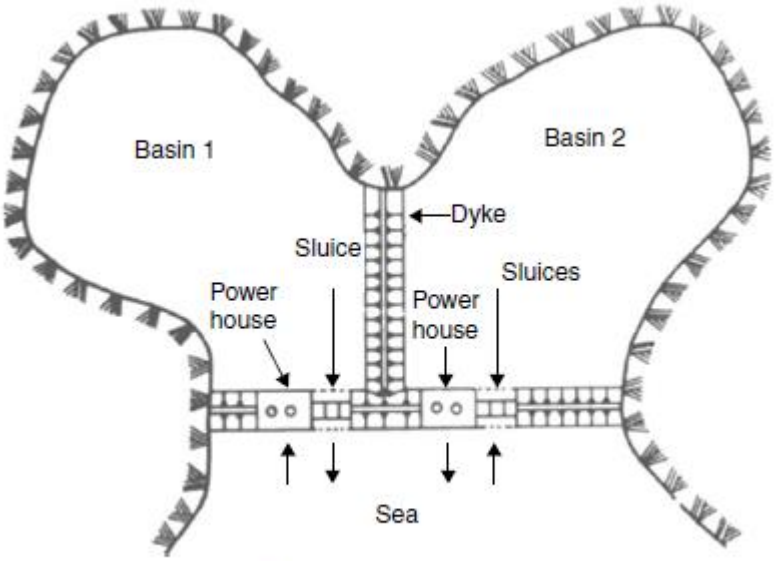


Figure Two-basin system

Two-basin Systems

- When the output of the tidal power plant is low, the pumped storage plant generates electric power and feeds it to the system.
- This arrangement, even though technically feasible, is much more expensive, as it calls for high installed capacity for meeting a particular load.
- This basic principle of joint operation of tidal power with steam plant is also possible when it is connected to a grid. In this case, whenever tidal power is available, the output of the steam plant will be reduced by that extent that leads to saving in fuel and reduced wear and tear of steam plant.
- This operation requires the capacity of steam power plant to be equal to that of tidal power plant and makes the overall cost of power obtained from such a combined scheme very high.
- In the system shown in Figure, the two basins close to each other operate alternatively.
- One basin generates power when the tide is rising (basin getting filled up) and the other basin generates power while the tide is falling (basin getting emptied).
- The two basins may have a common power house or may have separate power house for each basin. In both the cases, the power can be generated continuously.
- The system could be thought of as a combination of two single-basin systems, in which one is generating power during tiding cycle, and the other is generating power during emptying.

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Q.8.c

PROBLEMS FACED IN EXPLOITING TIDAL ENERGY

1.Usually the places where tidal energy is produced are far away from the places where it is consumed. This transmission is expensive and difficult.

2. *Intermittent supply: Cost and environmental problems, particularly barrage systems are less* attractive than some other forms of renewable energy.

3. *Cost: The disadvantages of using tidal and wave energy must be considered before jumping* to conclusion that this renewable, clean resource is the answer to all our problems. The main detriment is the cost of those plants.

4. *Altering the ecosystem at the bay: Damages such as reduced flushing, winter icing, and erosion* can change the vegetation of the area and disrupt the balance. Similar to other ocean energies, tidal energy has several prerequisites that make it only available in a small number of regions.

Q.9.a

Motion in the sea waves

- Sea waves origin happens because of 3 forces

1. Gravity

2. Sea surface tension

3. Wind intensity

A storm generates winds that impact a region over open water. The area impacted by the wind is called a "sea." The waves generated by the storm will move out and away from sea are called "swell"

- **Wave** is **forward motion** of **energy** not the water itself
- Waves are characterised as follows
    - **Crest**: peak point
    - **Trough(m)**: lowest point
    - **Wave height(H)** : vertical distance b/w **Crest & Trough**
    - **Amplitude(a) : H/2**
    - **Wavelength (λ):** horizontal distance b/w **Crests**
    - **Frequency(f):** number of peaks at a particular point
    - **Wave propagation velocity (v): λf**
    - **Wave period(T):** time for two successive Crests to pass a point

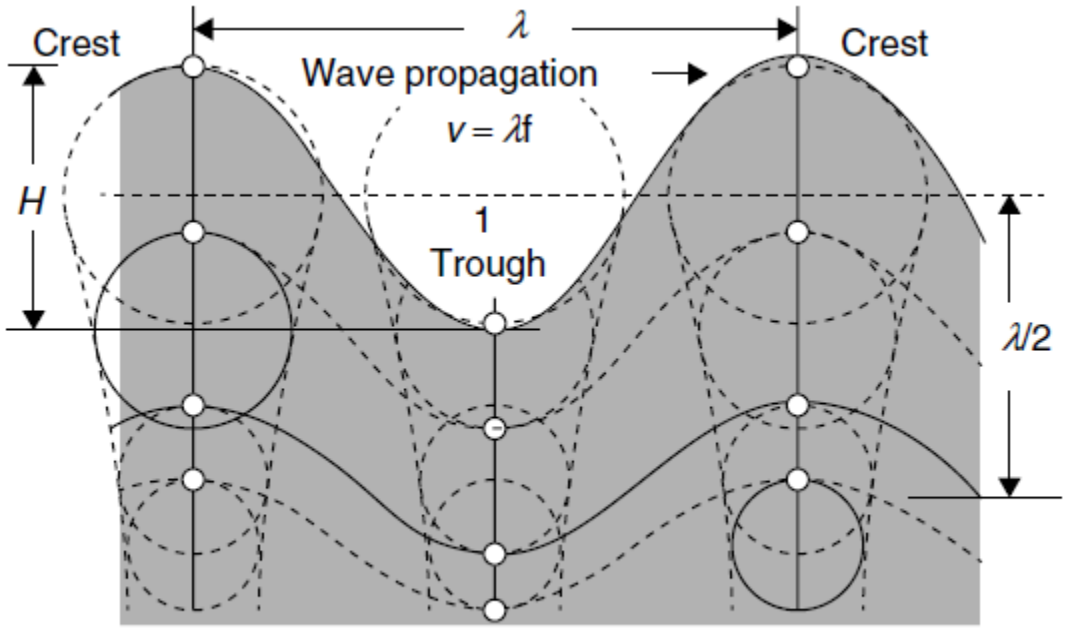


Figure Sea wave propagation

Q.9.b

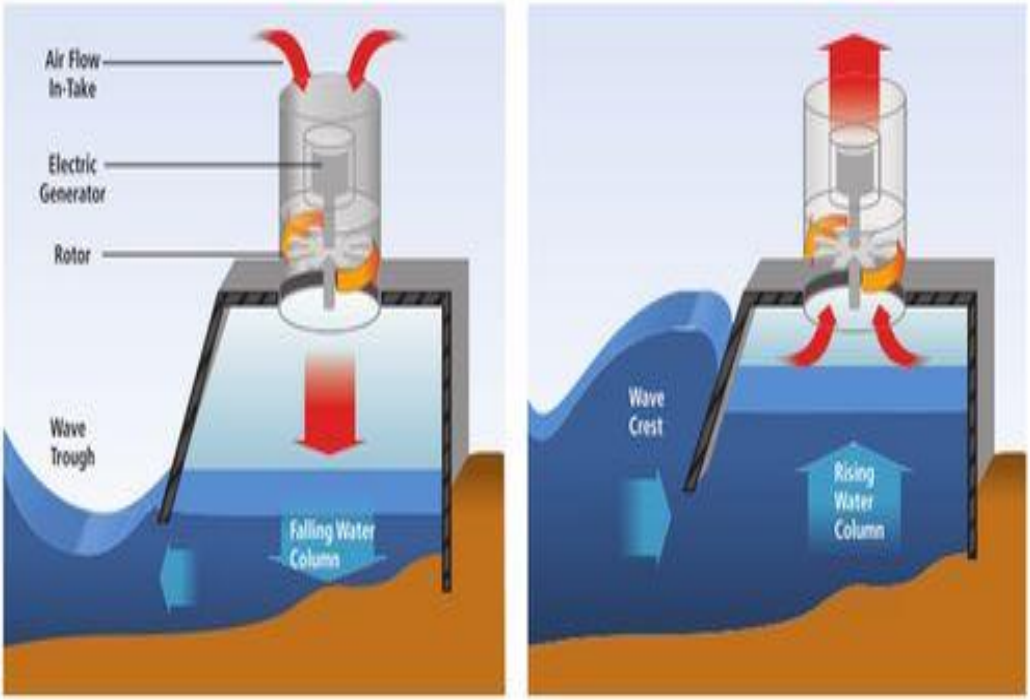
DEVICES FOR HARNESSING WAVE ENERGY

- There are three basic technologies for converting wave energy to electricity.

1. *Terminator devices*:

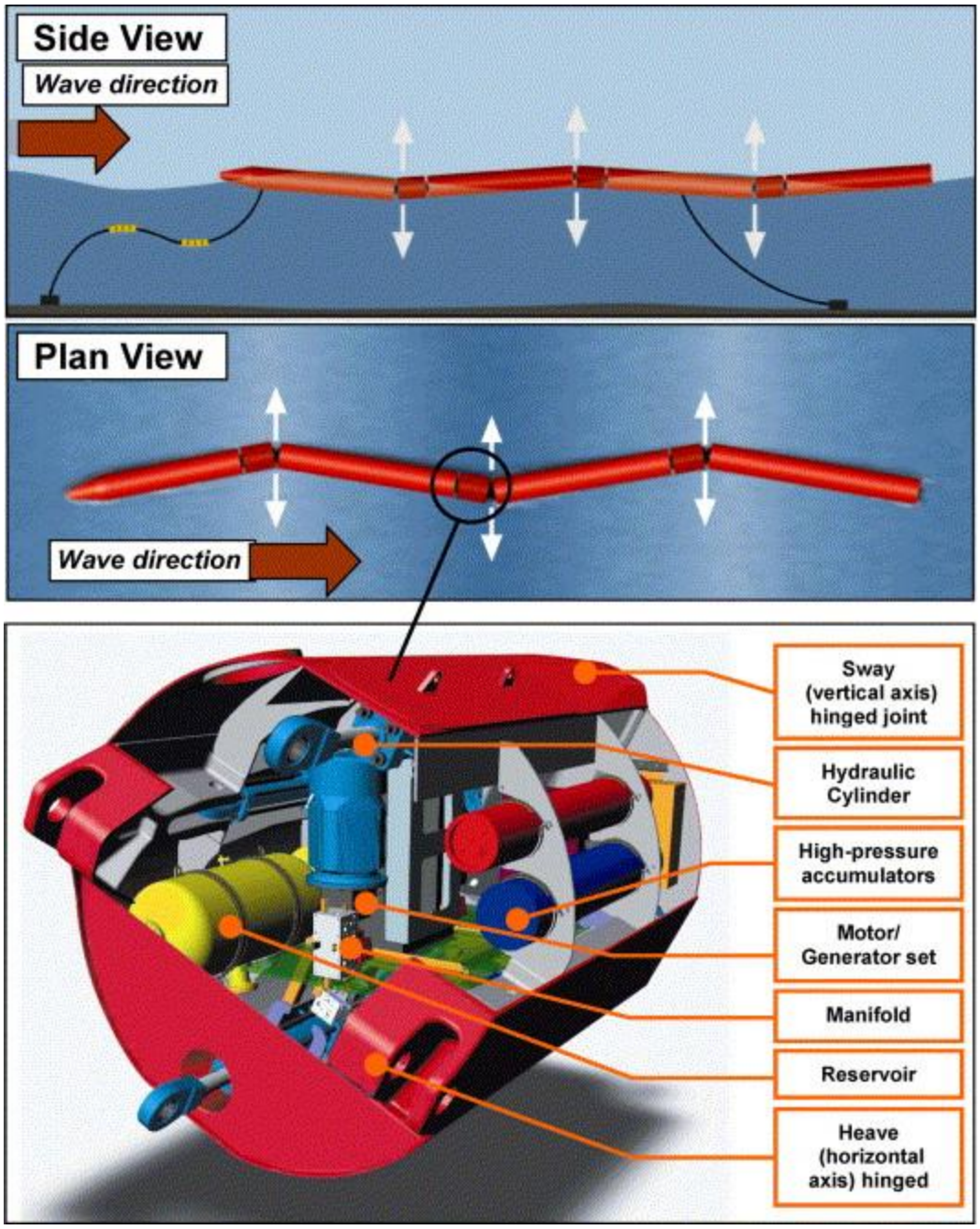
- It is a wave energy device oriented perpendicular to the direction of the wave and has one stationary and one moving part.

- The moving part moves up and down like a car piston in response to ocean waves and pressurizes air or oil to drive a turbine.
- An oscillating water column (OWC) converter is an example of terminator device.
- These devices generally have power ratings of 500 kW to 2 MW, depending on the wave parameters and the device dimensions.



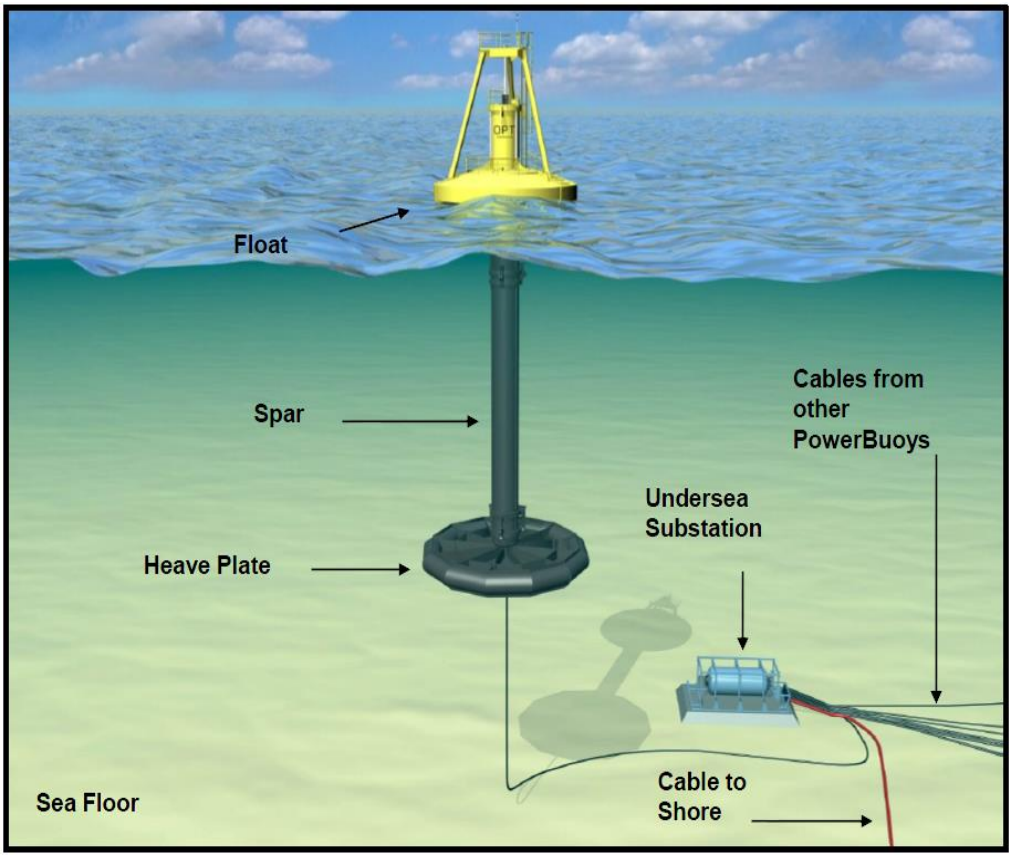
Attenuator devices:

- These devices are oriented parallel to the direction of the waves and are long multi-segment floating structures.
- It has a series of long cylindrical floating devices connected to each other with hinges and anchored to the seabed.
- They ride the waves like a ship, extracting energy by using restraints at the bow of the device and along its length.
- The segments are connected to hydraulic pumps or other converters to generate power as the waves move across.
- Pelamis wave energy converter is one of the known examples of attenuator devices.

- 

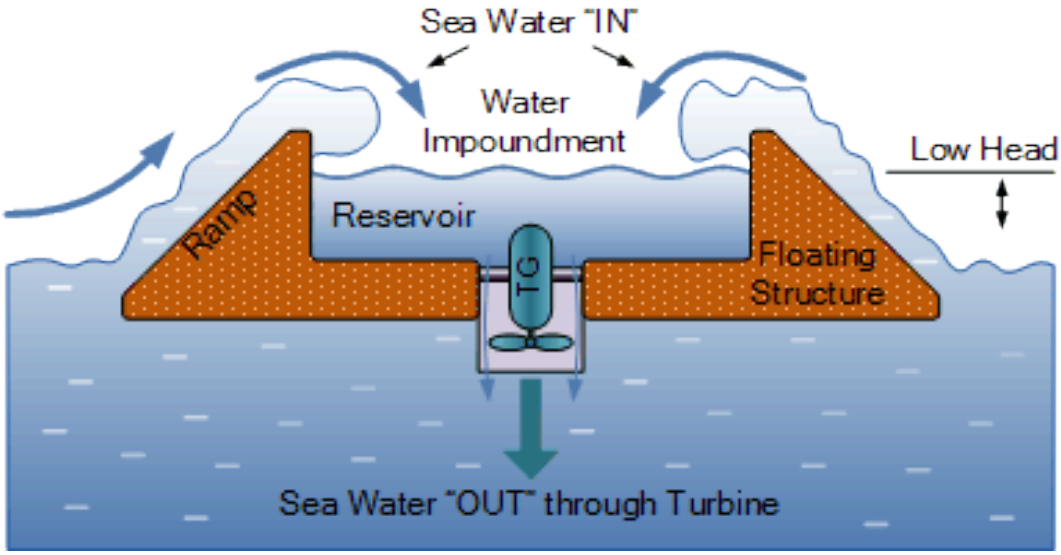
Point absorber:

- It is a floating structure with parts moving relative to each other owing to wave action but it has no orientation in any defined way towards the waves instead absorbs the wave energy coming from any direction.
- It utilizes the rise and fall of the wave height at a single point for energy conversion.
- The pressurized water creates up and down bobbin type motion and drives a built-in turbine generator system to generate electricity.
- AquaBuOY WEC is an example of point absorber devices.



Overtopping devices:

- These devices have reservoirs like a dam that are filled by incoming waves, causing a slight build-up of water pressure.
- Gravity causes released water from reservoir to flow back into the ocean through turbine coupled to an electrical generator.
- Salter Duck WEC is the example of overtopping devices.



Q.9.c

Land-Based Power Plant:

Land-based and near-shore facilities offer three main advantages over those located in deep water. Power plants constructed on or near land do not require sophisticated mooring, lengthy power cables, or the more extensive maintenance associated with open-ocean environments.

They can be installed in sheltered areas so that they are relatively safe from storms and heavy seas. Electricity, desalinated water, and cold, nutrient-rich sea water could be transmitted from near-shore facilities via trestle bridges or causeways. In addition, land-based, or near-shore sites allow OTEC power plants to operate with related industries such as mariculture or those that need desalinated water.

Favoured locations include those with narrow shelves (volcanic islands) steep (15-20 degrees) offshore slopes, and relatively smooth sea floors. These sites reduce the length of the cold-water in take pipe. A land-based power plant could be built well inland from the shore, offering more protection from storms, or on the beach, where the pipes would be shorter. In either case, easy access for construction and operation helps lower the costs.

Land-based or near-shore sites can also support mariculture. Mariculture tanks or lagoons built on shore allow workers to monitor and control miniature marine environments. Mariculture products can be delivered to market with relative ease via standard transport (rail roads or highways).

One disadvantage of land-based facilities arises from the turbulent wave action in the surf zone. Unless the OTEC power plants water supply and discharge pipes are buried in protective trenches, they will be subject to extreme stress during storms and prolonged periods of heavy seas. Also, the mixed discharge of cold and warm seawater may need to be carried several hundred meters offshore to reach the proper depth before it is released. This arrangement needs additional expense in construction and maintenance.

Floating Power Plant:

Floating OTEC facilities could be designed to operate off-shore. Although potentially preferred for systems with a large power capacity, floating facilities present several

difficulties. This type of power plant is more difficult to stabilize, and the difficulty of mooring it in very deep water may cause problems with power delivery.

Cables attached to floating platforms are more susceptible to damage, especially during storms cables at depth exceeding 1,000 m are difficult to maintain and repair. Riser cables, which span the distance between the sea bed and the plant, need to be constructed to resist entanglement.

As with shelf-mounted plants, floating plants require a stable base for continuous OTEC operation. Major storms and heavy seas can break the vertically suspended cold-water pipe and interrupt the intake of warm water as well. To reduce such problems pipes can be made of relatively flexible polyethylene attached to the bottom of the platform and gimbaled with joints or collars.

Pipes may need to be uncoupled from the plant to prevent storm damage. As an alternative to a warm-water pipe, surface water can be drawn directly into the platform; however, it is necessary to prevent the intake flow from being interrupted during violent motions caused by heavy seas.

If a floating power plant is to be connected to power delivery cables, it requires the plant to remain relatively stationary. Mooring is an acceptable method, but current mooring technology is limited to depths of about 2,000 metres. Even at shallower depths, the cost of mooring may prohibit commercial OTEC ventures.

Q. 10.a

Advantages of Wave Power

1.Sea waves have high energy densities and provide a consistent stream of electricity generation capacity.

2. Wave energy is clean source of renewable energy with limited negative environmental impacts.

3. It has no greenhouse gas emissions or water pollutants.

4. Operating cost is low and operating efficiency is optimal.

5. Damage to ocean shoreline is reduced.

Disadvantages of Wave Power

1.High construction costs.

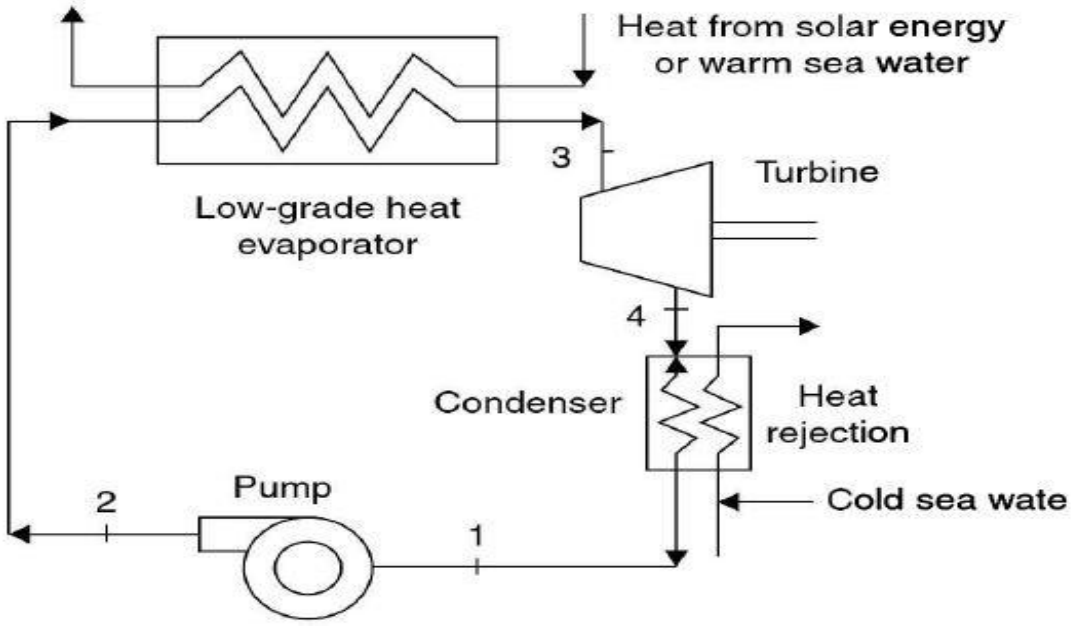
2. Marine life is disrupted and displaced.

3. Damage to the devices from strong storms and corrosion create problems.

4. Wave energy devices could have an effect on marine and recreation environment**.**

Q.10.b

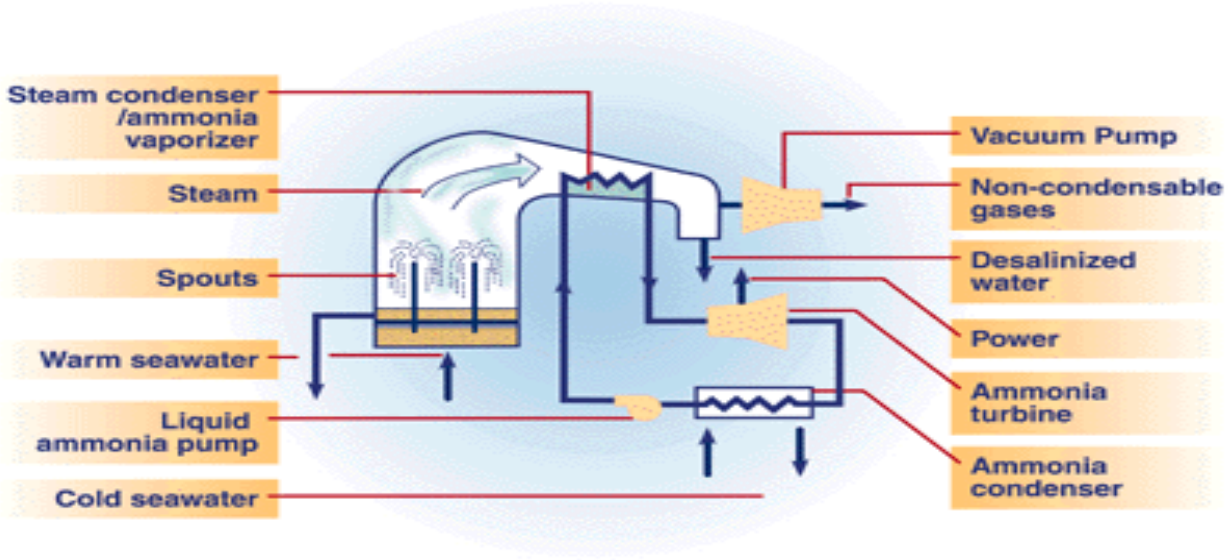
CLOSED CYCLE OTEC



WORKING PRINCIPLE OF CLOSED CYCLE OTEC

1. Working fluid is pumped through heat exchangers in a closed loop cycle which is perfectly leakage proof.
2. Warm sea surface water is pumped through separate pipe in heat exchanger in close contact with fluid closed loop cycle
3. Warm sea water transfer its heat energy to working fluid in heat exchanger and working fluid vapourizes.
4. The fluid vapour makes the turbine to rotate and drive an electrical generator to produce electricity.
5. Fluid vapour leaving the turbine is cooled and condensed as liquid fluid and is pumped again to repeat cycle.
6. Cold deep sea water is pumped through a separate pipe in condenser for providing efficient cooling of working fluid.

* **HYBRID OTEC**



Hybrid cycle combines the features of both open and closed cycle OTEC s

* **Warm sea water is pumped into vacuum chamber where it is flashed to steam**
* **The steam produced will vapourise a working fluid**
* **The vaporized working fluid will rotate the turbine and drive the generator to produce electricity**
* **The fluid vapour will be condensed by cold sea water in a**

condenser and re circulated in a closed cycle

* **The condensed steam or desalinated water is used for marine culture plants**
* **Non condensable gases are exhausted**

Q. 10.c

APPLICATIONS OF OTEC

1. **Hydrogen Production**
2. **Ammonia and methanol production**
3. **Desalinated water**
4. **Aquaculture**
5. **Chilled soil agriculture**
6. **Air conditioning**