CBCS SCHEME

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BME755D

Seventh Semester B.E./B.Tech. Degree Examination, Dec.2025/Jan.2026

Non Conventional Energy Resources

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.	Briefly explain the need for Non-Conventional Energy Sources.	05	L2	CO1
	b.	Illustrate and describe the principle of operation of a Water Power Plant.	07	L2	CO1
	c.	Discuss tar sands and oil shale as alternative sources of energy.	08	L2	CO1
		OR			
Q.2	a.	What are beam, diffuse and global radiations? How does the atmosphere influence solar radiation?	10	L2	CO2
	b.	With a neat sketch, describe the structure and operation of a pyranometer in measuring global and diffuse radiation.	10	L2	CO2
		Module – 2			
Q.3	a.	Define the following terms with respect to solar radiation: i) Latitude angle ii) Declination angle iii) Surface azimuth angle iv) Hour angle v) Zenith angle	10	L1	CO2
	b.	Determine the Local Solar time, declination and day length at a location with latitude 23° 15' N, longitude 77° 30' E at 12:30 IST on June 19. Consider the equation of time correction as - (1' 01")	10	L3	CO2
		OR			
Q.4	a.	Describe the working principles of cylindrical parabolic concentrators and paraboloidal dish collectors with neat sketches.	10	L2	CO2
	b.	With a neat sketch, explain the working principle and operation of a solar pond.	10	L2	CO2
		Module – 3			
Q.5	a.	With a neat sketch, explain the main components of a Liquid flat plate collector.	08	L2	CO2
	b.	Briefly explain the basic energy balance equation.	05	L1	CO2
	c.	Discuss the significance of the transmissivity – absorptivity product in the performance of a Liquid flat plate collector.	07	L1	CO2
		OR			
Q.6	a.	List and explain the various parameters that affect the performance of a solar collector.	10	L2	CO2
	b.	Explain the working principle of a solar PV cell and list its applications.	10	L2	CO2
		Module – 4			
Q.7	a.	Discuss the major problems associated with wind power generation.	04	L2	CO3
	b.	Briefly explain the working of a Vertical axis Windmill with a neat sketch.	06	L2	CO3
	c.	The following data were measured for a HAWT : Speed of wind = 20 m/s at 1 atm and 27°C Diameter of rotor = 80 m Speed of rotor = 40 rpm Given that Coefficient for a Maximum output = 0.593 and specific Gas Constant R = 287 J/kg K Calculate the torque produced at the shaft for maximum output of the turbine.	10	L3	CO3

		OR			
Q.8	**a.**	With a neat sketch, describe the closed-cycle OTEC System.	**08**	**L2**	**CO5**
	b.	Explain the method of harnessing tidal energy with a neat sketch.	**08**	**L2**	**CO5**
	c.	List the limitations of tidal power generation.	**04**	**L1**	**CO5**
		Module – 5			
Q.9	**a.**	With a neat sketch, describe the production of hydrogen by electrolysis of water.	**07**	**L2**	**CO5**
	b.	Briefly explain : i) Safe Utilization of hydrogen ii) Storage methods of hydrogen	**08**	**L2**	**CO5**
	c.	List the problems associated with geothermal energy conversion.	**05**	**L1**	**CO5**
		OR			
Q.10	**a.**	Explain with a neat sketch the construction details of a floating drum-type (KVIC) biogas plant.	**10**	**L2**	**CO4**
	b.	Discuss the applications of bio-gas in engines.	**06**	**L2**	**CO4**
	c.	List the advantages of bio-gas energy.	**04**	**L1**	**CO4**

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1.a Briefly explain the need for Non-Conventional Energy Sources.

1 The demand of energy is increasing by leaps & bounds due to rapid industrialization & population growth, the conventional sources of energy will not be sufficient to meet the growing demand.

2 Conventional sources (fossil fuels, nuclear) also cause pollution; there by their use degrade the environment.

3 Conventional sources (except hydro) are non-renewable & bound to finish one day.

4 Large hydro-resources affect wildlife, cause deforestation pose various social problems, due to construction of big dams.

5 Fossil fuels are also used as raw materials in the chemical industry (for chemicals, medicines, etc) & need to be conserved for future generations.

1.b Illustrate and describe the principle of operation of a Water Power Plant.

A **water power plant** converts the **potential energy of stored water** into **electrical energy**. The conversion sequence is:

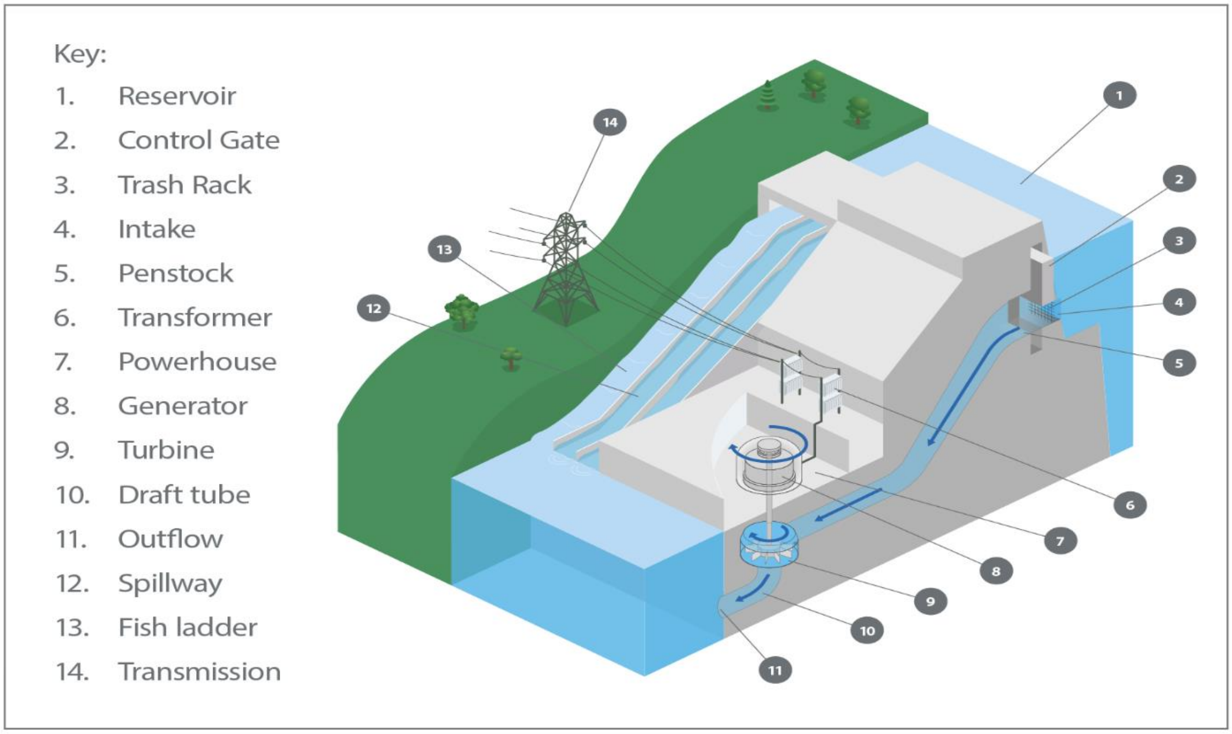
Potential Energy → Kinetic Energy → Mechanical Energy → Electrical Energy

This is achieved by allowing water stored at a height to flow through a turbine, which drives an electric generator.

Main Components

1. **Dam & Reservoir** – Stores water at a height, creating potential energy.
2. **Spillway** – Safely releases excess water during floods.
3. **Intake Gate** – Controls the amount of water entering the system.
4. **Penstock** – A large pipe that carries high-pressure water to the turbine.

5. **Turbine** – Converts water energy into mechanical rotational energy.
6. **Generator** – Converts mechanical energy into electrical energy.
7. **Draft Tube** – Discharges water from the turbine to the tailrace while recovering pressure.
8. **Tailrace** – Channel that carries water back to the river.
9. **Transformer & Switchyard** – Steps up voltage for transmission.



Principle of Operation

1. **Water Storage**
   Water is stored in a reservoir behind the dam at a height HHH, possessing potential energy:
   PE=mgHPE = m g HPE=mgH
2. **Controlled Water Flow**
   When the intake gate opens, water flows through the penstock due to gravity, gaining kinetic energy.

3. **Turbine Action**
   The high-speed water strikes the turbine blades (Pelton, Francis, or Kaplan type),

causing the turbine shaft to rotate.

4. **Power Generation**
   The rotating shaft drives the generator. According to **Faraday's law of electromagnetic induction**, mechanical rotation induces an electric voltage in the stator windings.

5. **Water Discharge**
   After transferring energy, water exits through the draft tube into the tailrace and rejoins the river.

6. **Power Transmission**
   Generated electricity is stepped up using transformers and transmitted to the grid.

1.c. Discuss tar sands and oil shale as alternative sources of energy.

1. Tar Sands (Oil Sands)

Tar sands are a mixture of **sand, clay, water, and bitumen** (a very heavy, viscous form of petroleum). Bitumen cannot flow naturally and must be processed to produce synthetic crude oil.

Methods of Extraction

- **Surface mining**: Used when deposits are near the surface; sand is excavated and bitumen is separated using hot water.

- **In-situ methods**: Used for deep deposits; steam is injected underground to reduce viscosity and allow bitumen to flow to the surface (e.g., steam-assisted gravity drainage).

Energy Use and Products

- Bitumen is **upgraded** into synthetic crude oil and refined into petrol, diesel, and other fuels.

- Requires significant **water and energy input** for extraction and upgrading.

Advantages

- Very large reserves; enhances long-term energy security

- Can be processed using existing refinery infrastructure

- Reliable baseload fossil energy source

2. Oil Shale

Oil shale is a fine-grained sedimentary rock containing **kerogen**, an organic material that can be converted into liquid hydrocarbons when heated.

Methods of Extraction

- **Surface or underground mining** followed by **retorting** (heating in absence of oxygen) to extract shale oil.
- **In-situ conversion**: Heating the rock underground over long periods and pumping out the released hydrocarbons.

Energy Use and Products

- Produces **shale oil**, which is refined into fuels similar to crude oil products.
- Energy-intensive due to high temperatures required for kerogen conversion.

Advantages

- Extremely large global resource base
- Can supplement declining conventional oil reserves
- Useful for long-term strategic energy planning

Q.2.a What are beam, diffuse and global radiations? How does the atmosphere influence solar radiation?

Types of Solar Radiation

When solar energy reaches the Earth, it is received in **three distinct forms** based on the path taken through the atmosphere.

(a) Beam Radiation (Direct Radiation)

- Also called **direct normal radiation (DNI)**.

- It is the portion of solar radiation that **travels in a straight line from the sun to the Earth's surface without being scattered**.
- Produces **sharp shadows**.
- Maximum on **clear sky days**.

(b) Diffuse Radiation

- Solar radiation that reaches the Earth's surface **after being scattered** by:
    - Air molecules
    - Dust particles
    - Water vapor
    - Clouds
- Arrives from **all directions in the sky**.
- Dominant on **cloudy or hazy days**

(c) Global Radiation

- The **total solar radiation** received on a horizontal surface.
- It is the **sum of beam and diffuse radiation**:

Global Radiation=Beam Radiation+Diffuse Radiation

 This is the **most commonly measured** solar radiation for PV system design.

Influence of Atmosphere on Solar Radiation

The Earth's atmosphere plays a crucial role in modifying solar radiation before it reaches the surface.

(a) Absorption

Certain atmospheric gases absorb specific wavelengths:

- **Ozone (O_3)** → absorbs ultraviolet radiation
- **Water vapor (H_2O)** → absorbs infrared radiation
- **Carbon dioxide (CO_2)** → absorbs heat radiation

 Result: **Reduction in total solar energy** reaching the surface.

(b) Scattering

- Caused by air molecules, dust, smoke, and aerosols.
- Converts part of beam radiation into **diffuse radiation**.
- Responsible for the **blue color of the sky**.

 More scattering → less beam, more diffuse radiation.

(c) Reflection

- Clouds and atmospheric particles reflect solar radiation **back to space**.
- Thick clouds significantly reduce global radiation at the ground level.

(d) Air Mass (AM) Effect

- Air mass represents the **path length** solar radiation travels through the atmosphere.
- When the sun is low (morning/evening), air mass is higher → **greater attenuation**.
- Standard condition: **AM = 1.5** (used for PV module ratings).

(e) Weather and Pollution

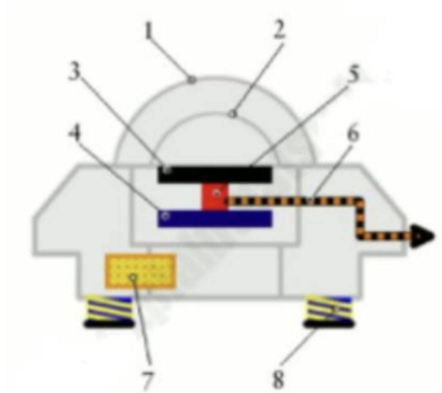
- Clouds, fog, humidity, and pollution reduce beam radiation.
- Urban pollution increases scattering and absorption.

2. b. With a neat sketch, describe the structure and operation of a pyranometer in measuring global and diffuse radiation.

Pyranometer

- A pyranometer is an instrument which measure's either global or diffuse radiation falling on a horizontal surface.
- Pyranometer are classified as 'A', 'B' or 'C' based on specifications such as response time, directional response, temperature response, tilt response and calibration method.
- Based on the Seebeck- or thermoelectric effect, a pyranometer is operated based on the measurement of a temperature difference between a clear surface and a dark surface.
- The main components of pyranometer are a thermopile, a glass dome, and an occultating disc.

- Outer dome made from a hemisphere of optical-quality glass.
- Inner dome made from a smaller hemisphere of optical glass.
- Black carbon disk (illuminated by the Sun) absorbs a broad range of wavelengths of solar radiation and acts as the sensing element.
- Control disk (not illuminated by the Sun) acts as a comparison.
- Thermopile temperature sensor compares the temperature rise of the two disks.
- Output lead (usually about 10m or 30ft long).
- Replaceable silica gel cartridge absorbs moisture to prevent dew forming inside on cold nights.
- Adjustable screw legs let you level the pyranometer.



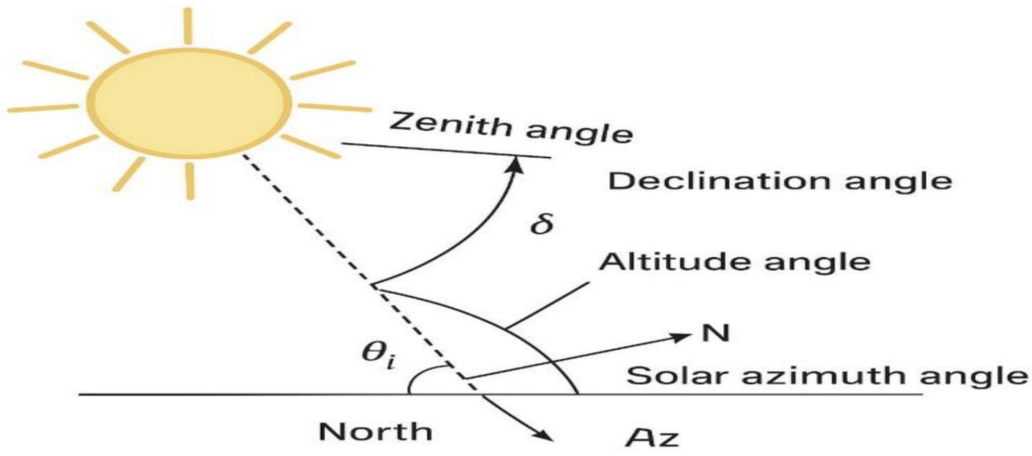
Q.3 Define the following terms with respect to solar radiation:

i) Latitude angle ii) Declination angle iii) Surface azimuth angle iv) Hour angle v) Zenith angle

i) Latitude Angle (ϕ\phiϕ)

- The **latitude angle** is the angular location of a place **north or south of the Earth's equator**.
- It is measured **along the meridian** from the equatorial plane to the location.

- **Range**:
  $-90^\circ \le \phi \le +90^\circ$ -90^\circ \le \phi \le +90^\circ $-90^\circ \le \phi \le +90^\circ$



ii) Declination Angle (δ)

- The **declination angle** is the angle between the **line joining the centers of the Earth and the Sun** and the **Earth's equatorial plane**.
- It varies due to the **tilt of the Earth's axis**.
- **Range**:

$$-23.45^\circ \le \delta \le +23.45^\circ$$

- Approximate relation:

$$\delta = 23.45^\circ \sin\left(\frac{360}{365}(284 + n)\right)$$

where n = day of the year.

iii) Surface Azimuth Angle (γ\gammaγ)

- The **surface azimuth angle** is the angle between the **projection of the normal to a surface on the horizontal plane** and the **local south direction**.
- Measured **east or west of south**.
- **Convention**:
  - $\gamma = 0^\circ$ \gamma = 0^\circ $\gamma = 0^\circ$ → surface faces due south

- ○ Positive → west of south
- ○ Negative → east of south

iv) Hour Angle (ω\omegaω)

- The **hour angle** represents the angular displacement of the sun **east or west of the local meridian** due to Earth's rotation.
- It is zero at **solar noon**.
- Relation:
  $\omega = 15^\circ \times (\text{Solar time} - 12)$

v) Zenith Angle (θz\theta_zθz)

- The **zenith angle** is the angle between the **sun's rays** and the **vertical (zenith) direction** at a location.
- It is complementary to the solar altitude angle α\alphaα:
  $\theta_z = 90^\circ - \alpha$

3. b. Determine the Local Solar time, deelination and day length at a location 10 L3 C with latitude 23° 15' N, longitude 77° 30' E at 12:30 1ST on June 19. Consider the equation of time correction as 1'01||

The Local solar time=IST- (standard time longitude-longitude of location) + Equation of time correction.

$=12^h30' - 4(82^0 30' - 77^0 30') - 1'01''$

$=12^h 8' 59''$

Declination δ can be calculated Cooper 's Equation i.e.,

$$\delta = 23.45\, Sin\left\{\frac{360}{365}(284 + n)\right\}$$

$$= 23.45 \sin\left\{\frac{360}{365}(284 + 170)\right\} = 23.45 \; \sin 86^0 = 23.43^0$$

Q. 4. a. Describe the working principles of cylindrical parabolic concentrators and 10 paraboloidal dish collectors with neat sketches.

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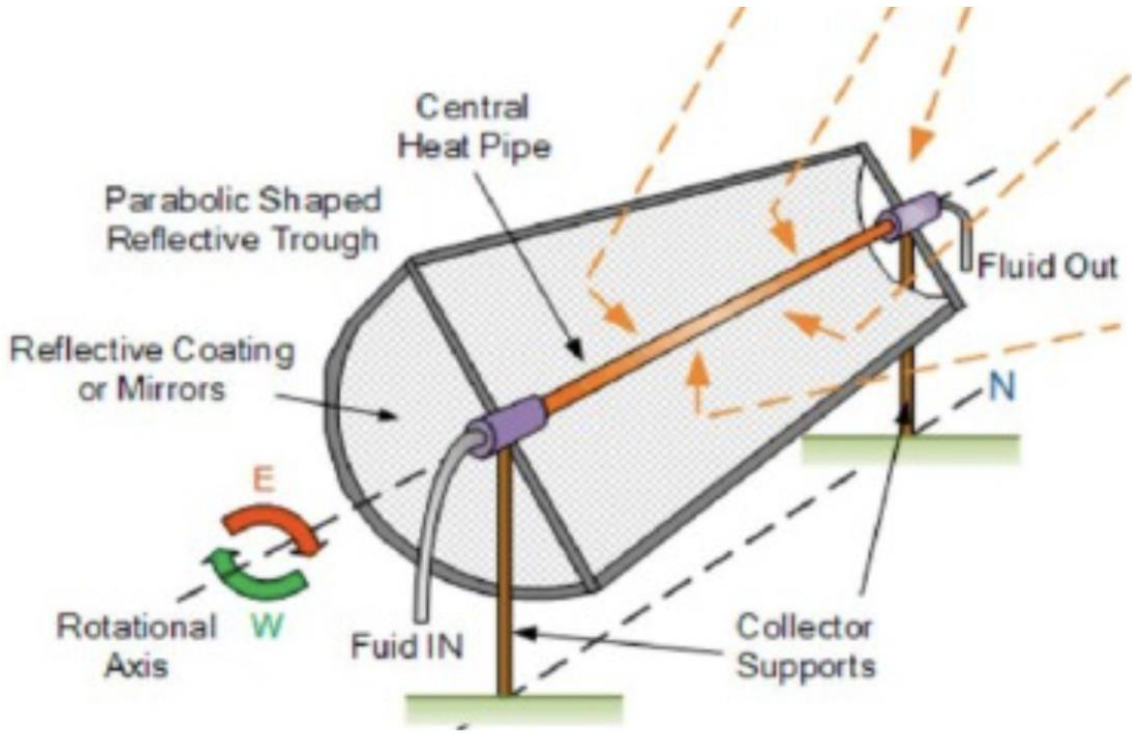


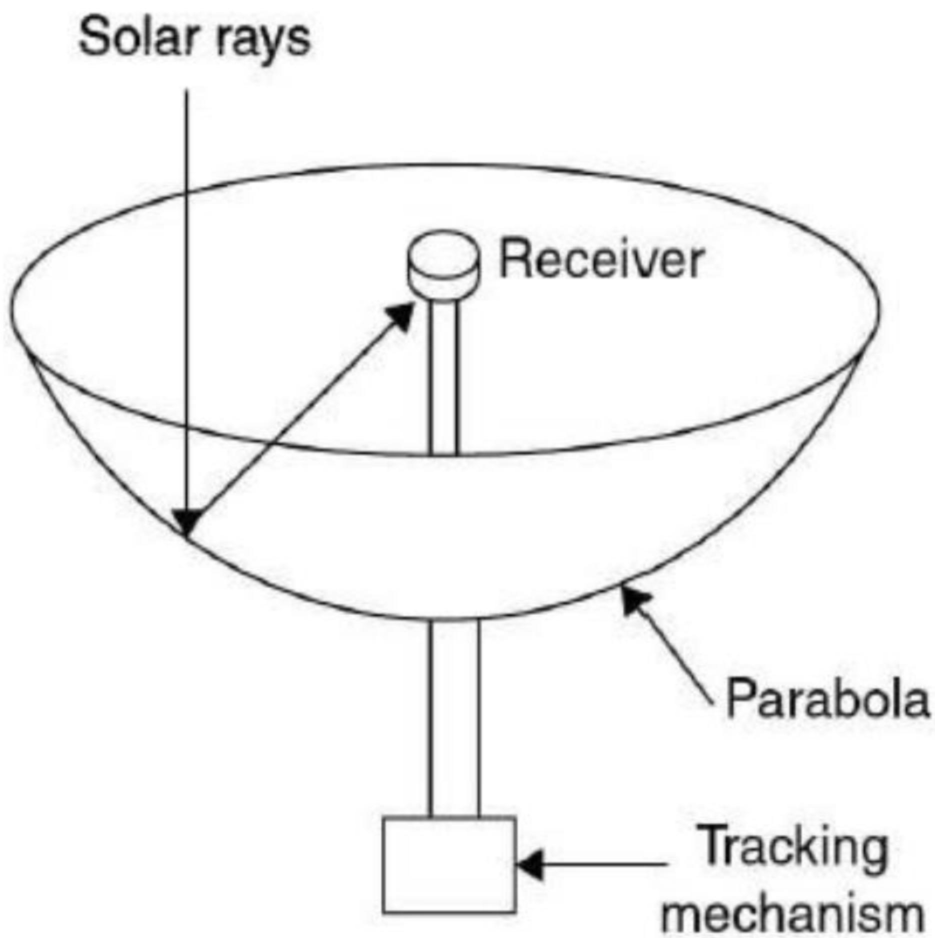
Construction

- A **parabolic-shaped reflector** curved in one direction (cylindrical).
- A **linear receiver (absorber tube)** placed along the **focal line**.
- Reflector surface made of polished aluminum or silvered glass.
- Usually mounted on a **single-axis tracking system** (east–west or north–south).

Working Principle

1. **Beam solar radiation** falls on the parabolic reflector.
2. Due to the parabolic geometry, all **parallel rays** are reflected toward the **focal line**.

3. The absorber tube located at the focal line absorbs the concentrated heat.
4. A **heat transfer fluid** (oil, molten salt, or water) flows through the tube and gets heated.
5. The collected thermal energy is used for:
    - Steam generation
    - Electricity production
    - Industrial process heat



Paraboloidal Dish Collector

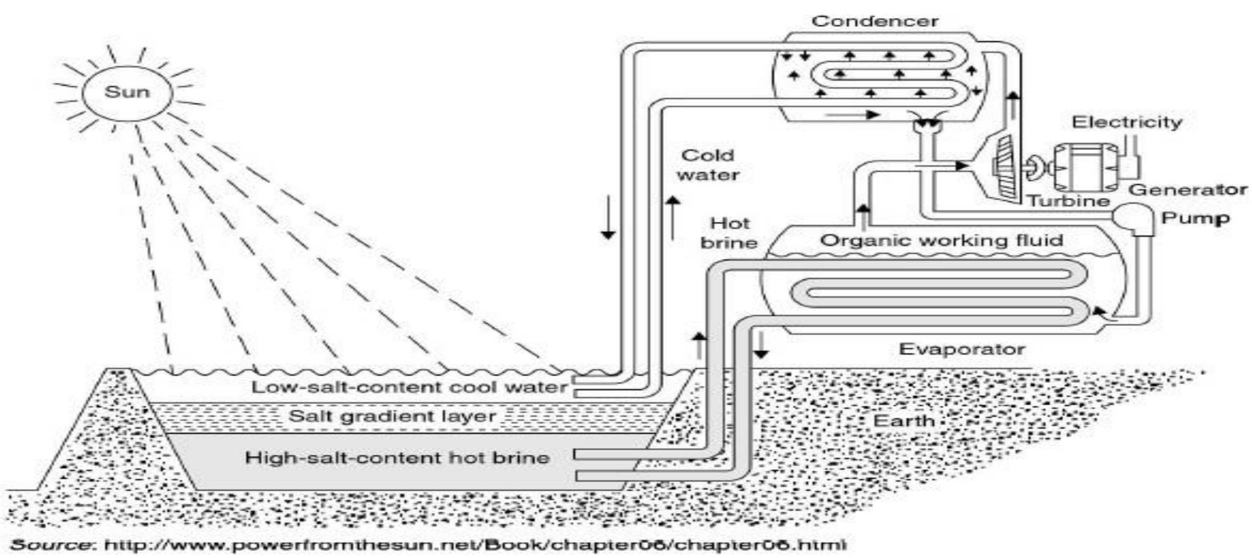
Construction

- A **three-dimensional paraboloid-shaped reflector** (dish).
- A **point-focus receiver** placed at the focal point.
- Mounted on a **two-axis solar tracking system**.
- Highly reflective mirror segments form the dish.

Working Principle

1. Sun's rays incident on the dish are reflected inward.
2. Due to paraboloidal geometry, all parallel rays converge at a **single focal point**.
3. The receiver at the focus absorbs highly concentrated solar energy.
4. Heat is transferred to:
    - A working fluid, or
    - A heat engine (e.g., Stirling engine) directly.
5. Electrical or thermal energy is produced at very high efficiency.

4. b. With a neat sketch, explain the working principle and operation of a solar pond.



Solar pond

- A pool of water that collects and also stores solar energy
- It has three different layers of water which differs by their density
- Density difference is achieved by adding salt solutions of different concentration
- Relatively cold top layer with low salt content
- Intermediate layer with salt gradient that maintains the density gradient , acts as the thermal insulator
- Hot bottom layer (up to 100 degree Celcius) with high salt content

- Difference in densities prevent convection currents which would have transferred heat to the surface of pond and then to air
- Heat is trapped in the highly dense , salty bottom layer which can be used
- But low solar to electricity conversion efficiency -15%

Q. 5.a. With a neat sketch, explain the main c

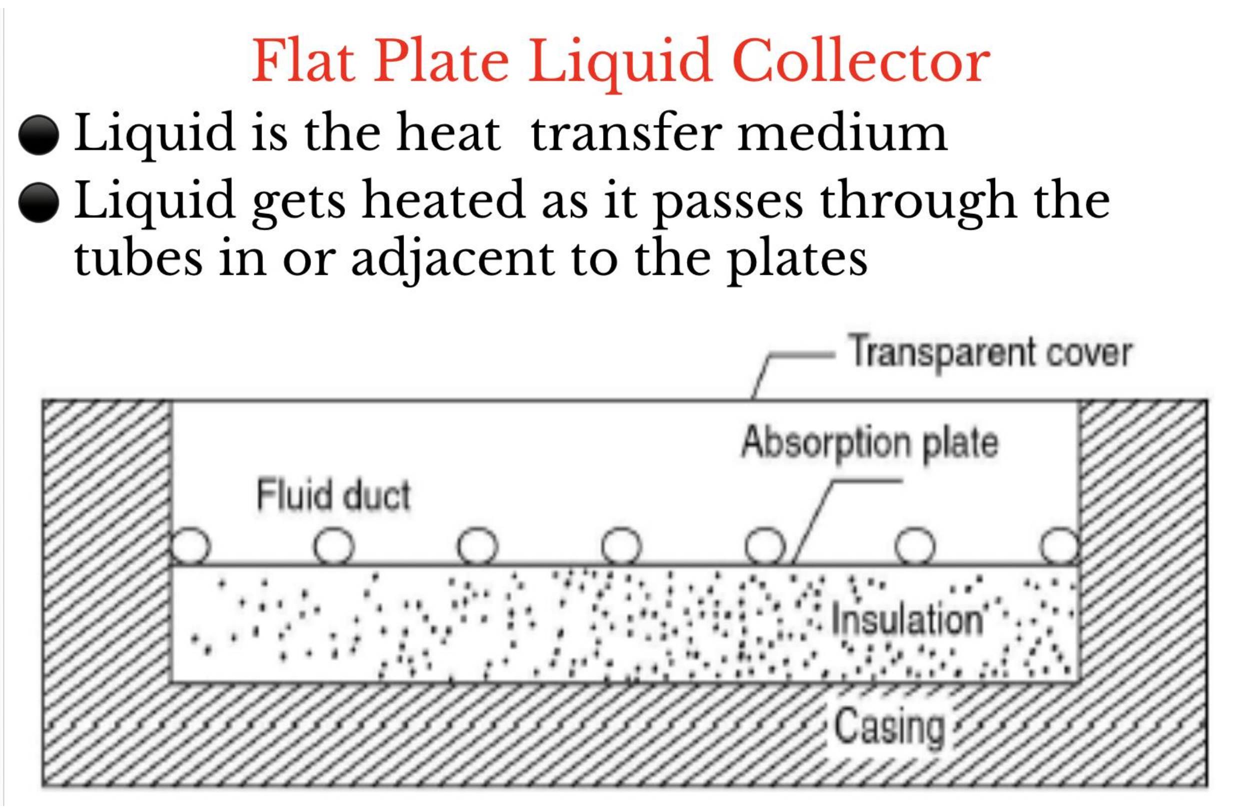
Flat Plate Collector

- Dark flat Plate Absorber of Solar energy
- ---consists of thin absorber sheet of thermally stable materials such as Al,Cu,steel,etc..
- Transparent Cover
- ---allows solar energy to pass through, but reduces heat losses
- ---reduces convection and radiation losses from
- absorber plate
- Heat Transport Fluid
- --air,water or antifreeze
- --To remove heat from absorber, fluid is usually circulated through tubing to transfer heat from absorber to an insulating tank
- Heat Insulation Backing
- Insulated casing of glass or polycarbonate cover

omponents of a Liquid flat plate collector.

Working Principle

1. Solar radiation passes through glazing.
2. Absorber plate absorbs radiation and heats up.
3. Heat is transferred to liquid flowing in tubes.
4. Heated liquid is circulated to storage tank or load.
5. Cooler liquid returns to collector for reheating.



5. b. Briefly explain the basic energy balance equation.

The **basic energy balance equation** for a **liquid flat plate solar collector** is obtained by applying the **first law of thermodynamics** to the collector under steady-state conditions.

Concept

For a solar collector:

Useful heat gained = **Solar energy absorbed** − **Thermal losses**

Energy Balance Equation

$$\boxed{Q_u = A_c \left[S - U_L (T_p - T_a) \right]}$$

where:

- Q_u = useful heat gained by the collector (W)
- A_c = collector area (m²)
- S = absorbed solar radiation per unit area (W/m²)
- U_L = overall heat loss coefficient (W/m²·K)
- T_p = average absorber plate temperature (°C or K)
- T_a = ambient air temperature (°C or K)

Meaning of Each Term

1. Absorbed Solar Energy (AcSA_c SAcS)

- **Represents the portion of incident solar radiation absorbed by the absorber plate.**
- **S=I (τα)S = I \, (\tau \alpha)S=I(τα)**
  where:

- **III = incident solar radiation**
- **τ\tauτ = transmittance of glazing**
- **α\alphaα = absorptance of absorber plate**

2. Heat Loss Term (AcUL(Tp−Ta)A_c U_L (T_p - T_a)AcUL(Tp−Ta))

- **Accounts for heat losses from the collector to surroundings due to:**
  - **Conduction**
  - **Convection**
  - **Radiation**
- **Losses increase when absorber temperature is much higher than ambient temperature.**

Useful Heat Gain in Terms of Fluid Parameters

Practically, useful heat gain is measured from the fluid:

$$\boxed{Q_u = \dot{m} c_p (T_o - T_i)}$$

where:

- $\dot{m}$ = mass flow rate of fluid (kg/s)
- c_p = specific heat of fluid (J/kg·K)
- T_o, T_i = outlet and inlet fluid temperatures

5. c. Discuss the significance of the transmissivity absorptivity product in the performance of a Liquid flat plate collector.

In a **liquid flat plate collector (FPC)**, not all the solar radiation falling on the collector surface is useful. Part of it is **reflected, absorbed by the glass cover, or lost** before reaching the absorber plate. The fraction that is actually converted into heat is determined by the **transmissivity–absorptivity product** (τα)(\tau \alpha)(τα).

1. Meaning of τ\tauτ and α\alphaα

- **Transmissivity (τ)(\tau)(τ)**
  Fraction of incident solar radiation that **passes through the transparent cover (glass)** and reaches the absorber.

- **Absorptivity (α)(\alpha)(α)**
  Fraction of the radiation **incident on the absorber plate** that is actually absorbed.

Therefore,

(τα)=Fraction of solar radiation incident on the collector that is finally absorbed by the plate

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2. Role in Collector Energy Gain

The absorbed solar energy per unit area of a flat plate collector is:

$$\boxed{S = I\,(\tau\alpha)}$$

where

I = solar radiation incident on the collector (W/m²)

The useful heat gain equation is:

$$Q_u = A_c\,[I(\tau\alpha) - U_L(T_p - T_a)]$$

This shows that $(\tau\alpha)$ **directly controls the amount of solar energy available for heating the fluid**.

A high (τα)(\tau \alpha)(τα) means:

- More radiation passes through the cover
- More radiation is absorbed by the absorber
- More heat is available for useful output

Hence,

Higher (τα)⇒Higher collector efficiency

A low (τα)(\tau \alpha)(τα) means:

- More reflection by glass
- More absorption by glazing instead of absorber
  More losses and reduced heat output

6. a. List and explain the various parameters that affect the performance of a solar collector.

The performance (useful heat output and efficiency) of a **solar collector** depends on several **optical, thermal, climatic, and operating parameters**.

1. Solar Radiation Intensity (I)

- Higher solar insolation → higher energy input.
- Cloudy, dusty, or hazy conditions reduce radiation.
- Beam radiation is more effective than diffuse radiation.

2. Transmissivity–Absorptivity Product (τα)(\tau \alpha)(τα)

- Determines how much of the incident radiation is actually absorbed.
- Higher (τα)(\tau \alpha)(τα) → more energy absorbed → better performance.
- Depends on glass quality and absorber coating.

3. Overall Heat Loss Coefficient (ULU_LUL)

- Represents heat loss due to:
    - Conduction
    - Convection
    - Radiation

- Higher losses (high ULU_LUL) reduce efficiency.

4. Temperature Difference (Tp−TaT_p - T_aTp−Ta)

- Difference between absorber plate temperature and ambient temperature.
- Larger difference → greater heat loss → lower efficiency.

5. Mass Flow Rate of Fluid (m˙\dot{m}m˙)

- Higher flow rate removes heat faster, keeping absorber cooler → lower losses.
  Too high flow reduces outlet temperature.

6. Collector Tilt and Orientation

- Correct tilt and direction maximize received radiation.
- Poor orientation leads to reduced solar capture.

7. Type of Glazing

- Number of glass covers
- Glass transmissivity
- Presence of anti-reflection coating

More glazing reduces losses but also reduces transmissivity.

8. Absorber Plate Material and Coating

- High thermal conductivity (copper, aluminum) improves heat transfer.

- Selective coatings improve absorption and reduce radiation loss.

9. Wind Speed

- Higher wind → higher convective losses → reduced performance.

10. Insulation Quality

- Good insulation reduces conduction losses from back and sides.

6. b. Explain the working principle of a solar PV cell and list its applications.

A **solar PV cell** converts **sunlight directly into electrical energy** using the **photovoltaic effect**.

Construction

A PV cell is made of a **semiconductor p–n junction**, usually silicon:

- **p-type layer** – rich in holes

- **n-type layer** – rich in electrons

An **electric field** is formed at the junction.

Operation

1. **Absorption of Sunlight**
   When sunlight falls on the PV cell, photons strike the semiconductor.

2. **Generation of Charge Carriers**
   Photon energy frees electrons from atoms, creating **electron–hole pairs**.

3. **Separation of Charges**
   The built-in electric field at the p–n junction drives:

- Electrons toward the n-side

- Holes toward the p-side

4. **Current Flow**
   When an external circuit is connected, electrons flow through the load, producing **DC electric power**.

This process is called the **photovoltaic effect**.

Applications of Solar PV Cells

1. Solar home lighting systems
2. Rooftop solar power plants
3. Solar street lights
4. Solar water pumping systems
5. Satellites and space stations
6. Calculators and watches
7. Mobile phone chargers

8. Traffic signals
9. Remote telecom towers
10. Off-grid rural electrification

7. a. Discuss the major problems associated with wind power generation.

Major Problems Associated with Wind Power Generation

Wind power is a clean and renewable source of energy, but it faces several **technical, economic, and environmental challenges** that limit its large-scale and reliable use.

1. Intermittent and Unpredictable Nature

- Wind does not blow continuously or at constant speed.
- Power output varies with wind speed:
  $P \propto V3$
- This causes **fluctuating electricity generation**, making grid management difficult.

2. Need for Energy Storage or Backup

- When wind speed is low or zero, power generation stops.
- Batteries, pumped hydro, or conventional power plants are needed as backup, increasing cost and complexity.

3. High Initial Investment

- Wind turbines, towers, foundations, and grid connection are expensive.
- Offshore wind farms are even more costly due to installation and maintenance.

4. Site Dependence

- Wind power is viable only in areas with **strong and consistent winds** (coastal areas, hill tops, open plains).
- Many regions cannot use wind power effectively.

5. Large Land Requirement

- Wind farms require large open areas.
- Land between turbines cannot always be used efficiently.

6. Noise and Visual Impact

- Turbine blades produce aerodynamic noise.
- Tall towers affect the natural landscape and may face public opposition.

7. Impact on Wildlife

- Rotating blades can cause bird and bat fatalities.
- Wind farms may disturb local ecosystems.

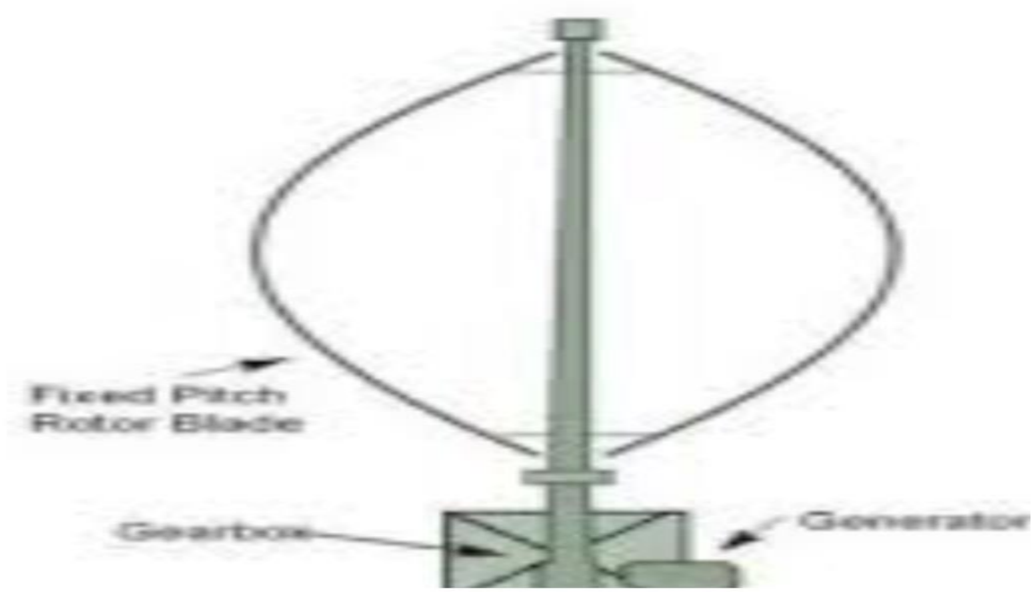
8. Grid Integration Issues

- Sudden changes in wind speed cause voltage and frequency fluctuations.
- Requires advanced grid control and forecasting systems.

9. Maintenance and Reliability

- Turbines operate in harsh weather conditions (rain, dust, storms).
- Gearboxes, blades, and generators require regular maintenance.

7. b. Briefly explain the working of a Vertical axis Windmill with a neat sketch



A **Vertical Axis Wind Turbine (VAWT)** is a windmill in which the **axis of rotation is vertical** (perpendicular to the ground).

It can rotate and generate power **regardless of wind direction**.

Main Types

1. **Savonius rotor** – drag type
2. **Darrieus rotor** – lift type

A vertical shaft stands upright. Curved or straight blades are attached around the shaft. The bottom of the shaft is connected to a **generator**. Wind from any direction strikes the blades and causes the shaft to rotate.

Working Principle

1. **Wind Flow**
   Wind strikes the blades from any direction.
2. **Force on Blades**

- In Savonius type, wind produces **drag difference** between advancing and returning blades.
- In Darrieus type, wind creates **lift force** on aerofoil-shaped blades.

3. **Rotation of Shaft**
 The unequal forces cause the rotor to rotate about the **vertical shaft**.

4. **Power Generation**
 The rotating shaft drives a **generator**, converting mechanical energy into electrical energy.

5. **Electric Output**
 Electricity is supplied to load or grid.

7. c . The following data were measured for a HAWT: Speed of wind 20 m/s at 1 atm and 27°C Diameter of rotor 80 m Speed of rotor-40 rp Given that Coefficient for a Maximum output 0.593 and specific Gas Constant R-287 J/kg K Calculate the torque produced at the shaft for maximum output of the turbine.

Wind speed,

$$V = 20 \text{ m/s}$$

Rotor diameter,

$$D = 80 \text{ m} \Rightarrow R = 40 \text{ m}$$

Rotor speed,

$$N = 40 \text{ rpm}$$

Pressure,

$$P = 1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$$

Temperature,

$$T = 27^\circ C = 300 \text{ K}$$

Gas constant,

$$R = 287 \text{ J/kg K}$$

Power coefficient (Betz limit),

$$C_p = 0.593$$

Using ideal gas equation:

$$\rho = \frac{P}{RT}$$

$$\rho = \frac{1.013 \times 10^5}{287 \times 300}$$

$$\rho = \frac{101300}{86100}$$

$$\rho = 1.177 \text{ kg/m}^3$$

$$A = \pi R^2 = \pi (40)^2$$

$$A = \pi \times 1600 = 5026.5 \text{ m}^2$$

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

$$P_{wind} = \frac{1}{2} \times 1.177 \times 5026.5 \times (20)^3$$

$$P_{wind} = 0.5885 \times 5026.5 \times 8000$$

$$P_{wind} = 2.37 \times 10^7 \text{ W}$$

$$P_{max} = C_p \times P_{wind}$$

$$P_{max} = 0.593 \times 2.37 \times 10^7$$

$$P_{max} = 1.405 \times 10^7 \text{ W}$$

$$P_{max} = 14.05 \text{ MW}$$

$$\omega = \frac{2\pi N}{60}$$

$$\omega = \frac{2\pi \times 40}{60}$$

$$\omega = 4.19 \text{ rad/s}$$

$$T = \frac{P}{\omega}$$

$$T = \frac{1.405 \times 10^7}{4.19}$$

$$T = 3.35 \times 10^6$$

N-M

Q.8 a. With a neat sketch, describe the closed-cycle OTEC System.

Closed cycle (Anderson cycle): Ocean Thermal Energy Conversion

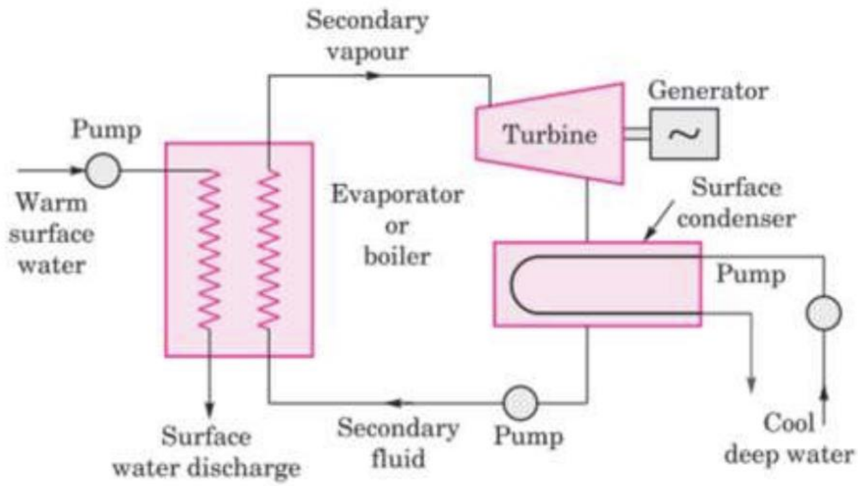


Fig. Closed cycle method

- In the closed cycle method, a working fluid with a low boiling point, such as ammonia, propane or Freon is pumped through a evaporator and vaporized by the warm seawater.
- This vaporized steam runs a turbine.
- Then the fluid now in the vapor state is brought in contact with cold water in the condenser.
- The cold water found at the depths of the ocean condenses the vapor back to a fluid in condenser, then it returns to the evaporator.

8. b Explain the method of harnessing tidal energy with a neat sketch.

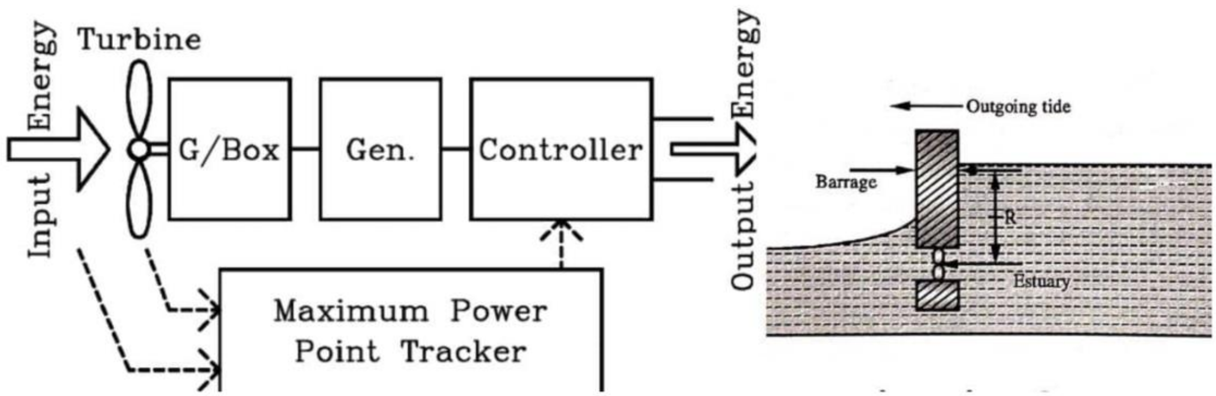
Principle of Tidal Energy

Tidal energy is obtained from the **periodic rise and fall of sea water** caused by the **gravitational pull of the Moon and Sun**.
The difference in water level between **high tide and low tide** is used to produce power.

Main Components

- **Barrage (dam)** built across a bay or estuary
- **Sluice gates** to control water flow
  Turbines (reversible)
- **Generator**
- **Basin**

Tidal energy | Working, Parts and Uses



Working

1. Flood Tide (Incoming Tide)

- Sea level rises.
- Sluice gates are opened.
- Water enters the basin through turbines.
- Turbines rotate and generate electricity.

2. High Tide

- Gates are closed when basin is full.

3. Ebb Tide (Outgoing Tide)

- Sea level falls.
- Stored water is released back to the sea through turbines.
- Turbines rotate again in opposite directions and generate power.

Thus power is generated during both **flood** and **ebb** tides.

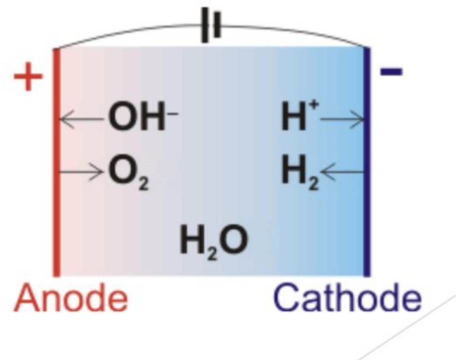
8. c. List the limitations of tidal power generation.

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. With a neat sketch, describe the production of hydrogen by electrolysis of water.

Electrolysis of water is a process in which **electrical energy** is used to split water into **hydrogen and oxygen gases**.

- Water is separated into hydrogen and oxygen by passing electric current through them
- Catalyst is added to improve the efficiency of the process
- Anode attracts oxygen cathode attracts hydrogen
- **Two methods** of electrolysis
- **Alkaline** electrolyser
  - $4H_2O + 4e^- = 2H_2 + 4OH^-$
  - $4OH^- = O_2 + 2H_2O + 4e^-$
- **PEM** electrolyser
  - $4H^+ + 4e^- = 2H_2$
  - $2H_2O = O_2 + 4H^+ + 4e^-$



9. b. Briefly explain:

i) Safe Utilization of hydrogen

ii) Storage methods of hydrogen

i) Safe Utilization of Hydrogen

Hydrogen is a **clean and high-energy fuel**, but it is **highly flammable** and must be handled carefully.

Safety Measures

1. **Leak Detection**
   Hydrogen is colorless and odorless. Sensors are used to detect leaks.

2. **Proper Ventilation**
   Since hydrogen is very light, it rises rapidly. Good ventilation prevents gas accumulation.

3. **Flame Control**
   Hydrogen burns with a nearly invisible flame. Flame detectors are used in hydrogen systems.

4. **Strong Storage Tanks**
   High-pressure and cryogenic tanks are designed to withstand stress and temperature changes.

5. **Safe Handling and Piping**
   Pipes and valves must be leak-proof and corrosion resistant.

6. **Electrical Safety**
   Spark-free electrical equipment is used near hydrogen installations.

ii) Storage Methods of Hydrogen

Hydrogen can be stored in different ways depending on application.

1. Compressed Gas Storage

- Hydrogen is stored in **high-pressure cylinders** (200–700 bar).

- Used in fuel cell vehicles and industrial use.

2. Liquid Hydrogen Storage

- Hydrogen is liquefied at **–253°C** and stored in cryogenic tanks.
- Provides high energy density.
- Used in rockets and space applications.

3. Metal Hydride Storage

- Hydrogen is absorbed into metals like **nickel or magnesium alloys**.
- Very safe and compact, but heavy.

4. Underground Storage

- Stored in **caverns, depleted gas fields, or salt domes** for large-scale use.

Q.9 c. List the problems associated with geothermal energy conversion.

Although geothermal energy is a **clean and reliable renewable source**, it has several **technical, economic, and environmental problems**.

1. High Initial Cost

- Drilling deep wells and installing turbines is expensive.
- Exploration and drilling may fail if suitable geothermal reservoirs are not found.

2. Limited Suitable Locations

- Geothermal plants can be built only in areas with **hot rocks, geysers, or volcanic activity**.
- This restricts widespread use.

3. Decline in Reservoir Pressure

- Continuous extraction of steam or hot water reduces underground pressure.
- This may lower power output over time.

4. Corrosion and Scaling

- Geothermal fluids contain **salts, minerals, and gases**.
- These cause corrosion, clogging, and scaling of pipes and turbines.

5. Environmental Issues

- Release of gases like **H_2S, CO_2, and methane**.
- Bad odor and slight air pollution may occur.

6. Land Subsidence

- Excessive extraction of underground fluids can cause the land to sink.

7. Seismic Activity

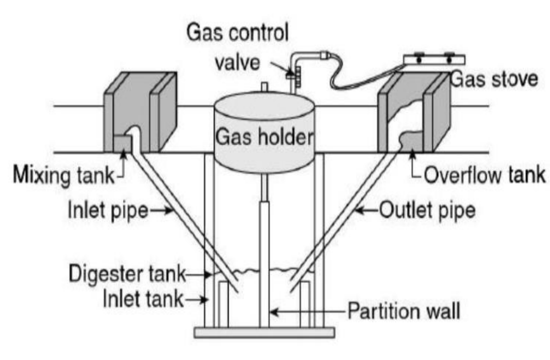
- Fluid injection and withdrawal may induce small earthquakes.

8. Disposal of Waste Water

- Hot geothermal water contains toxic minerals.
- Safe disposal is necessary to avoid soil and water pollution.

Q.10 a. Explain with a neat sketch the construction details of a floating drum-type (KVIC) biogas plant.

- The different parts are:
- 1.Mixing tank
- 2.Digester tank
- 3.Inlet pipe & inlet tank
- 4.Floating dome
- 5.Outlet pipe & overflow tank
- 6. Gas outlet pipe
- 7.Gas control valve



Working

- Slurry (mixture of equal quantities of biomass and water) is prepared in the mixing tank.
- The prepared slurry is fed into the inlet chamber of the digester through the inlet pipe.
- The plant is left unused for about two months and introduction of more slurry is stopped.
- During this period, anaerobic fermentation of biomass takes place in the presence of water and produces biogas in the digester.
- Biogas being lighter rises up and starts collecting in the gas holder. The gas holder now starts moving up.

- The gas holder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on the slurry.
- The spent slurry is now forced into the outlet chamber from the top of the inlet chamber.
- When the outlet chamber gets filled with the spent slurry, the excess is forced out through the outlet pipe into the overflow tank. This is later used as manure for plants.
- The gas valve of the gas outlet is opened to get a supply of biogas.
- Once the production of biogas begins, a continuous supply of gas can be ensured by regular removal of spent slurry and introduction of fresh slurry.

10.b. Discuss the applications of big gas in engines.

Biogas is a renewable fuel mainly containing **methane (CH_4)** and **carbon dioxide (CO_2)**. Because methane is combustible, biogas can be used efficiently in **internal combustion (IC) engines** for power and mechanical energy.

1. Power Generation (Biogas Engine–Generator Sets)

- Biogas is used in **spark ignition (SI) engines** connected to generators.

- The engine converts biogas into mechanical energy, which drives an alternator to produce electricity.
- Used in:
  - Rural electrification
  - Dairy farms
  - Sewage treatment plants
  - Small industries

2. Dual-Fuel Diesel Engines

- Biogas can be used along with **diesel**.
- Diesel is injected to start ignition and biogas acts as the main fuel.
- Reduces diesel consumption by **60–80%**.

3. Mechanical Power for Agriculture

Biogas engines can be used for:

- Water pumping
- Grain milling
- Chaff cutting
- Small farm machines

4. Combined Heat and Power (CHP) Systems

- Biogas engines produce **electricity and heat simultaneously**.
  Waste heat from exhaust and cooling water is used for:
  Water heating
  - Digester heating
  - Industrial processes

5. Vehicle Fuel (Upgraded Biogas)

- When purified to remove CO_2 and H_2S, biogas becomes **bio-CNG**.
- Can be used in:
  - Buses
  - Cars
  - Three-wheelers

Q.10.C. List the advantages of biogas energy.

- Clean fuel
- High calorific value
- Convenient ignition temperature
- No residue , smoke,dust
- Non polluting
- Economical
- High quality nutrient rich manure for plants