Gopalan College of Engineering and Management

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DEPARTMENT OF MECHANICAL ENGINEERING

ETC SUBJECT

Programme	**Bachelor of Engineering**		**Faculty Name**	**D.Sreenivasa Reddy**	
Academic Year	2023-2024	**Year / SEM**	III/VI	**Semester**	ODD
W.E.F.	**01/05/2023**	**Course Name**	**RENEWABLE ENERGY SOURCES (RES/NCE)**	**Course Code**	**BETCK105E/205E**

NOTES

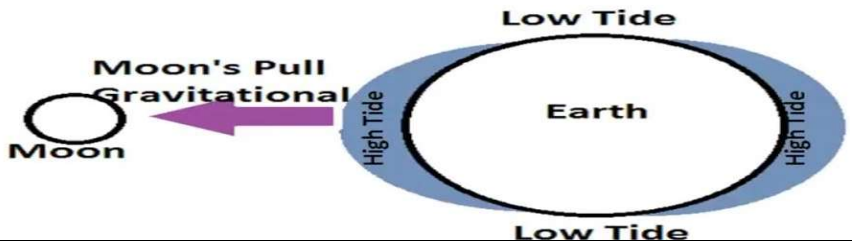
MODULE –4

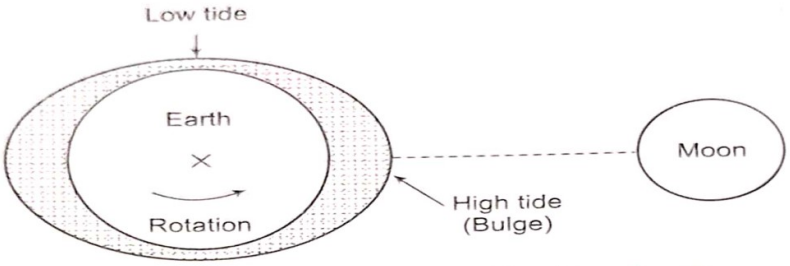
Tidal Power: Tides and waves as energy suppliers and their mechanics; fundamental characteristics of tidal power, harnessing tidal energy, advantages and limitations.

Ocean Thermal Energy Conversion: Principle of working, OTEC power stations in the world, problems associated with OTEC.

CO4	**Acquire the knowledge of wave power, tidal power and Ocean Thermal Energy Conversion and applications.**
	******* VERY IMPORTANT QUESTIONS*******
	TIDAL POWER
01	**Sketch and explain Double basin type tidal power plant**
02	**Sketch and explain single basin type (Flood tide &Ebb tide) tidal power plant.**
03	**Explain the Different Types Tidal Power Plants**
04	**What are the advantages and disadvantages of Tidal Power**
05	**With a neat sketch, Explain the operation of tidal power plant. (OR)Explain the working principal of tidal power plant.(OR) With a neat sketch, Explain the operation of Double Cycle tidal power plant system.**
06	Discuss the Problems Faced in exploiting Tidal Energy.

	Wave Energy
01	**Define wave energy, List out the advantages and disadvantages of Wave Energy**
02	**What is Wave energy? Explain the working Principal of Wav energy or Wave energy converters**
03	**Explain the Wave energy Conversion devices briefly.**
04	**With neat Sketch, Explain the Working principle of Dolphin type wave Energy Converter(Wave profile Devices).(or) With neat Sketch, Explain the Working principle of Any one type wave Energy Converter Device.**
	Ocean Thermal Energy Conversion:
01	**Describe the Working Principal with neat Diagram of open cycle OTEC System**
02	**Describe the Working Principal with neat Diagram of Closed cycle OTEC System**
03	**Describe the Working Principal with neat Diagram of Closed Rankine cycle OTEC System and Advantages over Open cycle OTEC .**
04	**What are the advantages and disadvantages of Ocean Thermal Energy Conversion(OTEC)**
05	**Describe the Working Principal with neat Diagram of Hybrid cycle OTEC System**
06	**What are the problems Associated With OTEC.**
07	**Explain about OTEC power stations in the world.**

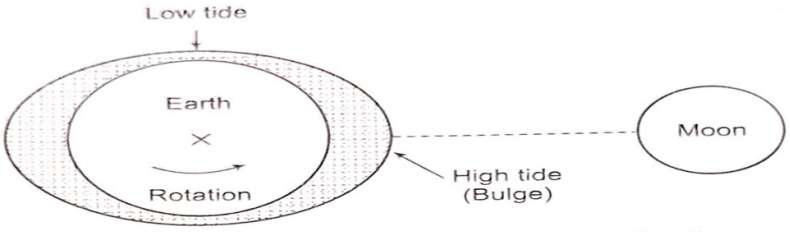
	Tidal Power: Tides and waves as energy suppliers and their mechanics; fundamental characteristics of tidal power, harnessing tidal energy, advantages and limitations.	
00	**Define Tides.**	
	Tides are periodic rise and fall of water level of sea which are caused by the action of sun and moon on the water on the earth.	
01	**What is Tidal Energy.**	
	Tidal Energy:- ➢ **Tidal Energy converts the energy of tides into the useful form of power,mainly in electricity.** ➢ **Tides are periodic rise and fall of water level of sea which are caused by the action of sun and moon on the water on the earth.** ➢ **They are mainly caused by the gravitational attraction of the moon&sun on the water of solid earth and Oceans.**	
		



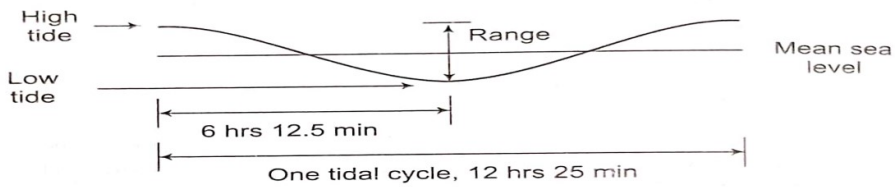
(a) Bulge on near and far sides of earth

02 **Define high tide and Low tide.**

- **The ocean level difference caused due to tides contains large amount of potential energy.**
- **The highest level of tidal water is known as flood tide or high tide.**
- **The lowest level is known as low tide or ebb tide.**
- **The level difference between the high tide and low tide is called tidal range.**



(a) Bulge on near and far sides of earth

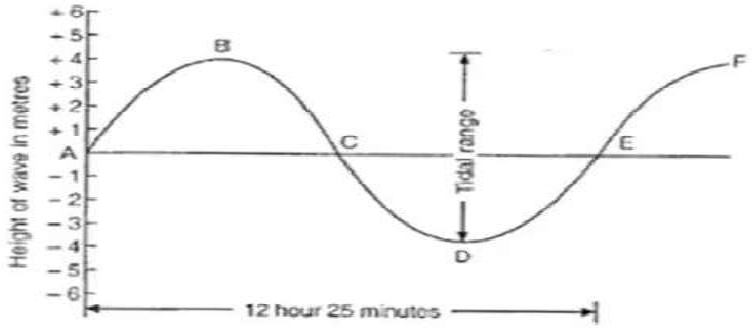


(b) Tidal wave

Figure 10.1 Origin of tides

03 **What is tidal Range and Explain its Significance-**

The level difference between the high tide and low tide is called tidal range



- It is the difference in water levels between two consecutive high tides and low tides.
- The rise and fall of water level in the sea during tides can be represented by a sine curve.

- Point B,a position of high tide,while the point D represents a position of low tide.
- One tidal day is of 24hours and 50minutes and there are two tidal cycles in one tidal day.
- Dialy tidal cycle follows a sinusoidal pattern.
- The tidal range varies greatly with location.
- Tidal range varies and depends upon the land situation against the sea.
- Only sites with large tidal range(about 5m or more)are considered suitable for power generation.

04 **Explain the Types of tides**

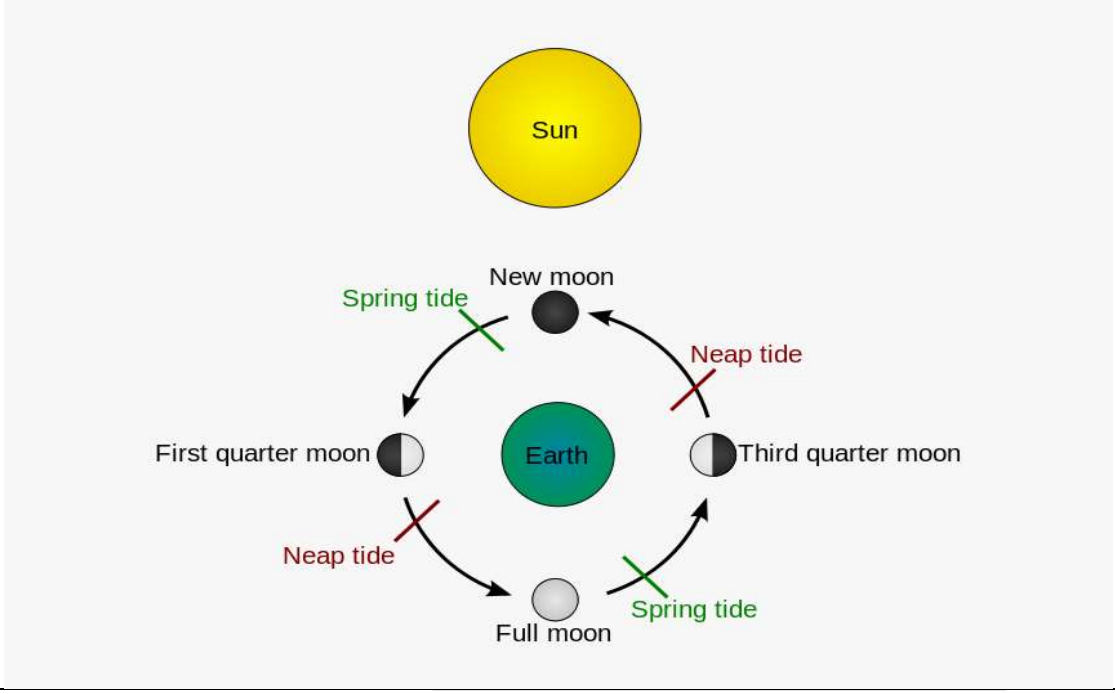
- Tides are observed as the rise and fall of water level in large water bodies on earth like seas and oceans.
- This is a natural phenomenon since it is actuated by the gravitational forces exerted by the moon and the sun.
- It also depends on the relative position of the earth, the moon, and the sun.

I)Tides Based on the Position of Earth, Sun, and the Moon.

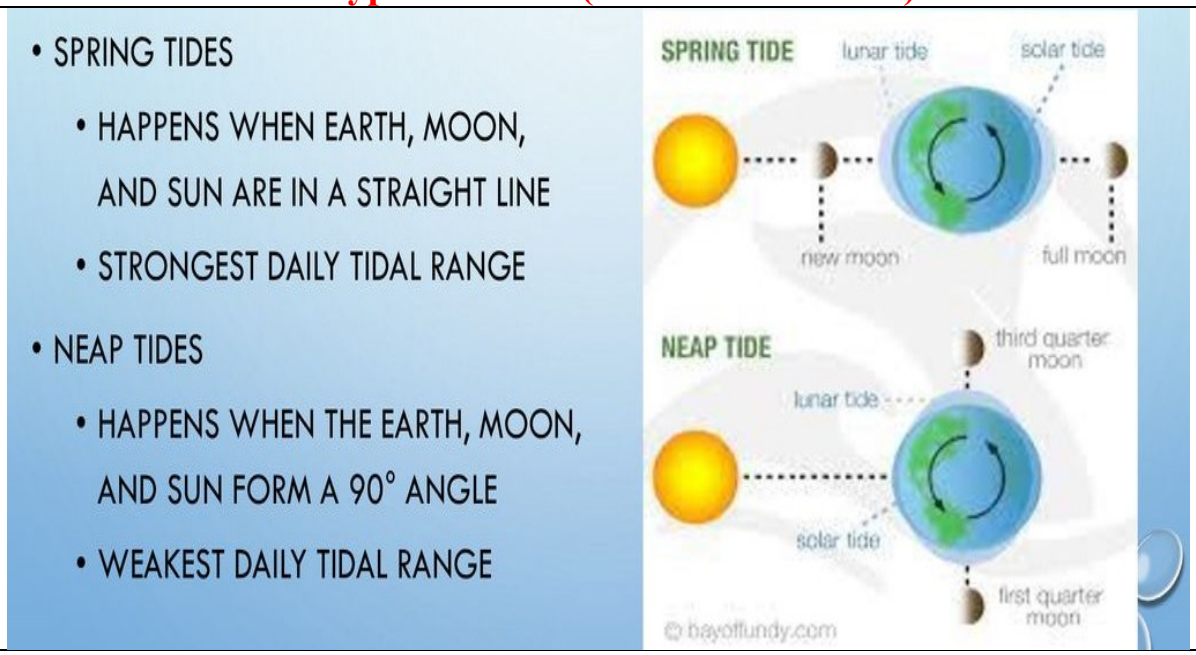
1. **Spring Tides**
2. **Neap Tides.**

II) Tides Based on Frequency

1. **Diurnal Tides**
2. **Semi-Diurnal Tides**
3. **Mixed Tides.**

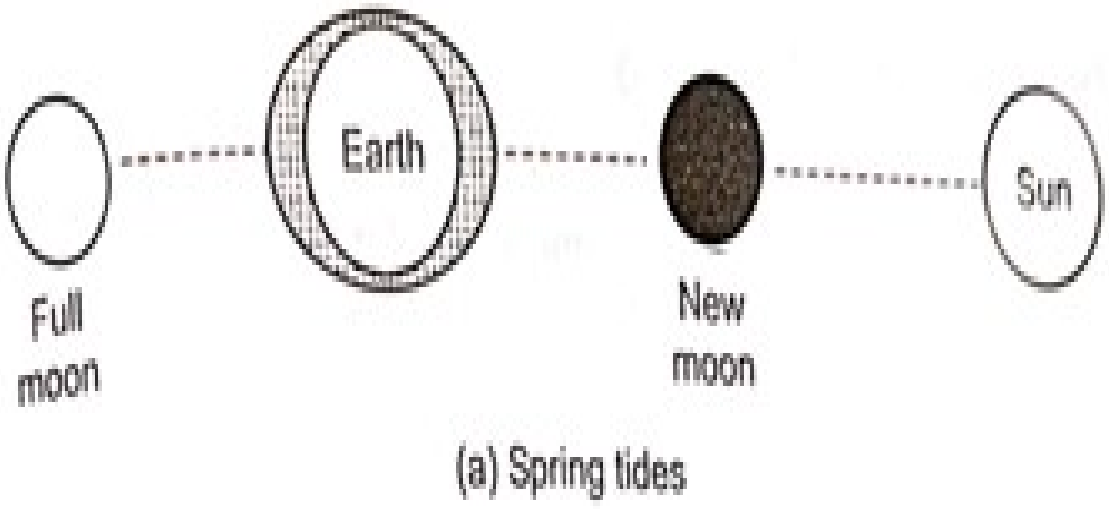


Types of Tides(LUNOR MONTH)

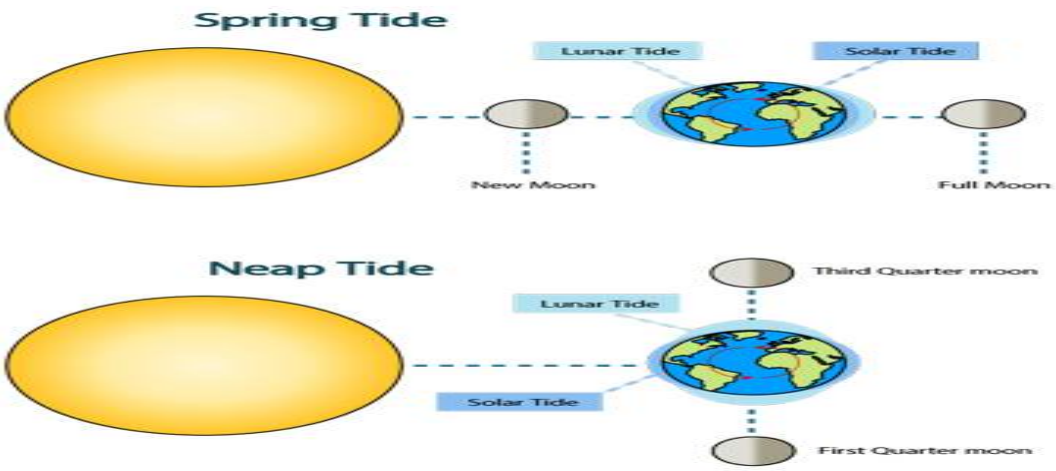


1. Spring Tides

- When the sun and the moon are in a straight line with each other and pull the ocean surface in the same direction, then Spring tides are caused.
- In a lunar month, it occurs twice.
- It is also known by the name of 'King Tide.'
- A Spring tide occurs on a full moon or new moon days.
- In spring tides, the difference between high tides and low tides is greatest.
- Spring Tides are the result of the sun and moon working together to exert more pull on the earth's oceans.



(a) Spring tides



2.Neap Tides

- When the sun and the moon are at a right angle with respect to the earth, Neap tides or low tides are caused.
- It occurs seven days after the spring tide.
- Neap Tides occur on quarter moon days.
- In Neap Tides, the difference between high tides and low tides is the least.
- Neap tides are the result of the moon and Sun working against each other.

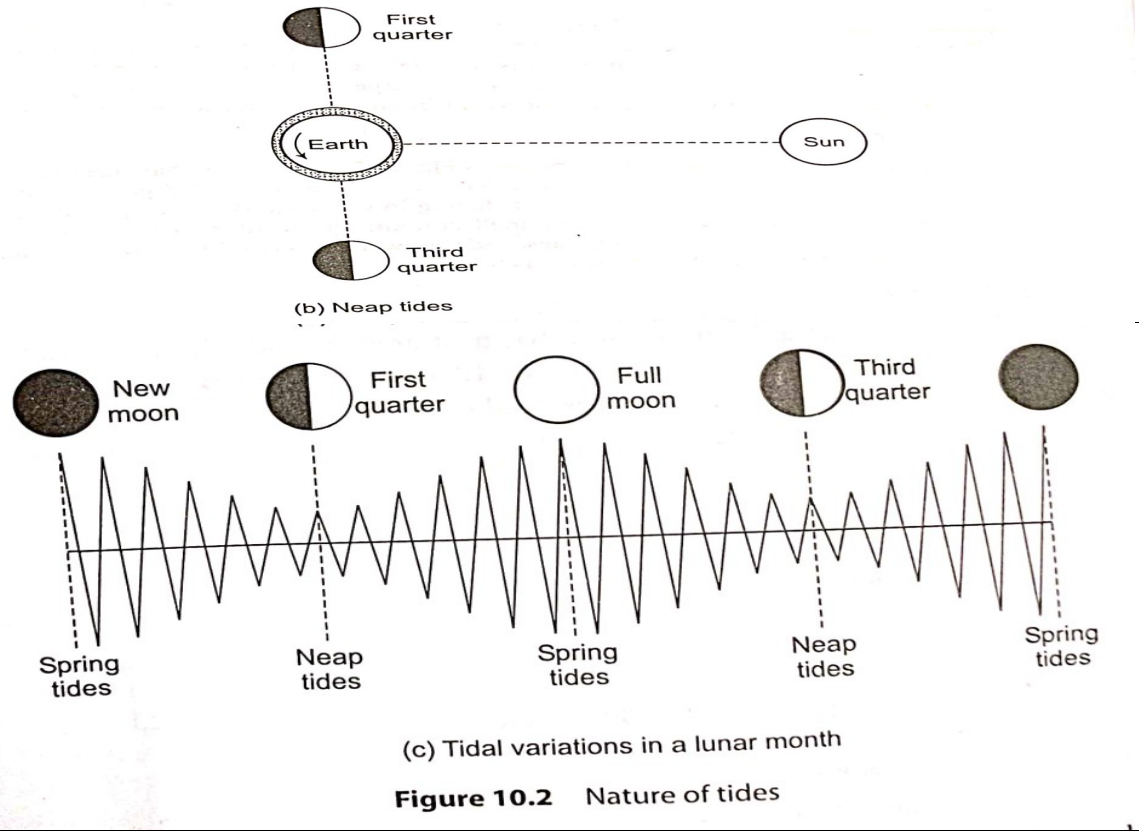
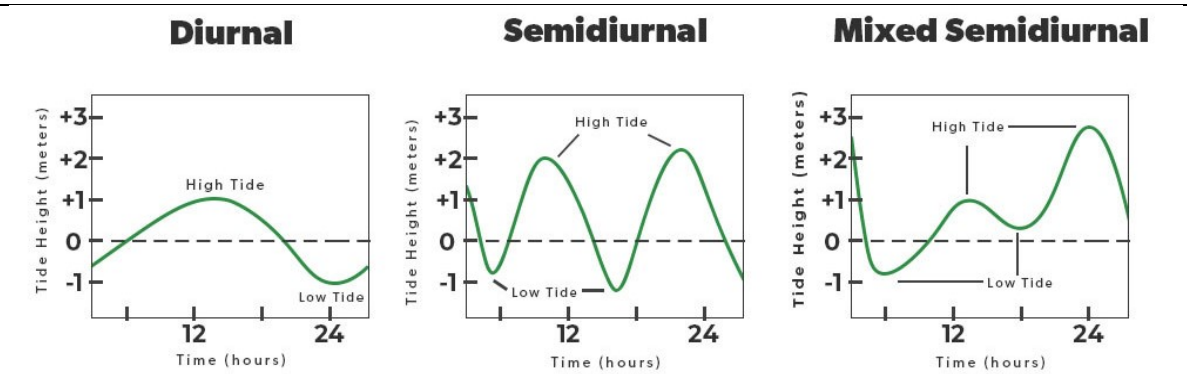
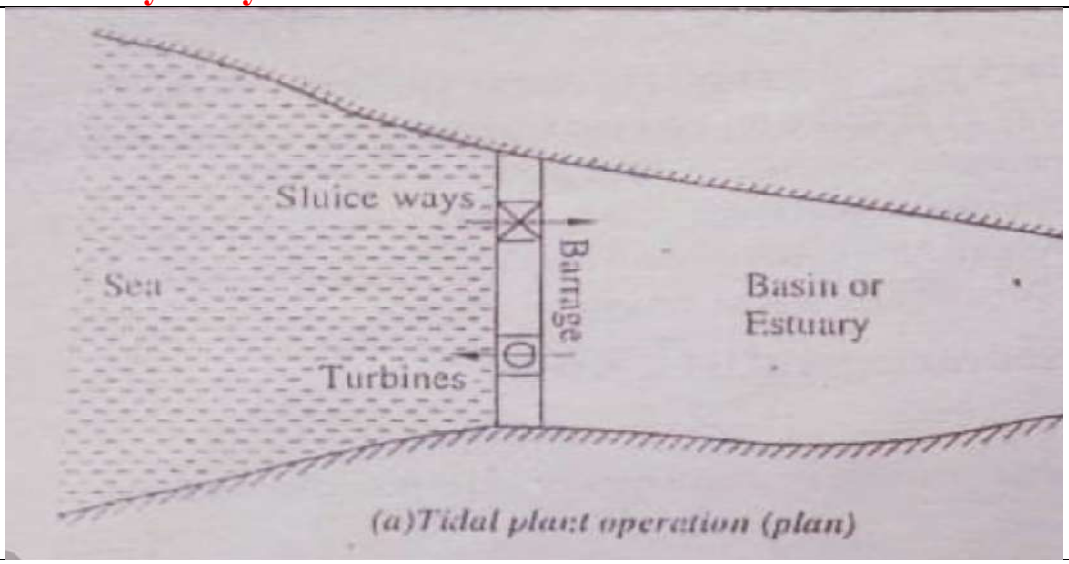


Figure 10.2 Nature of tides

		
	Diurnal tide cycle • **An area has a diurnal tidal cycle if it experiences one high and one low tide every lunar day.**	
	Semidiurnal tide cycle • **An area has a semidiurnal tidal cycle if it experiences two high and two low tides of approximately equal size every lunar day.**	
	Mixed Semidiurnal tide cycle • **An area has a mixed semidiurnal tidal cycle if it experiences two high and two low tides of different size every lunar day..**	
(5)	**Explain about different parts Tidal Power plant.**	
	Part of Tidal Power plant:- **A tidal Power plant Consists of Three Main parts.** **(1)Dam or barrage** **(2)Tidal Basin** **(3)Sluice Ways.** **(4)Turbine and Generator**	
	(1)Tidal barrage or Dam :- • **The function of dam is to form a barrier between the sea and the basin.(The dam is used to separate the dam and Tidal basin).** • **Dam or barrage is constructed with Reinforced Concrete.** • **Barrage needs to provide channels for the turbines in reinforced concrete.**	
	(2)Tidal Basin:-It is man made reservoir to store water during high tide and release water During the low tide.	
	(3)Sluice Ways:- • **These are gate controlled devices.They are used to fill basin during high tide and or emptying basin during low tide.** • **Sluice ways is gate which provides water to flow towards basin and towards Sea.** • **The sluice gates are left open during high tide and closed during low**	

	tide to create a water level differential ,creating a potential difference that powers the turbine when the water is released.	
	(4)Turbines and Generator:-	
	• Kinetic energy of water to mechanical in turbine and than mechanical to electrical energy in generator.	
(6)	**Explain about the Classification of Tidal Power Plants**	
	Classification of Tidal Power Plants **1.Single Basin System** (a)Single ebb-cycle System (b)Single Tide-cycle System. (c) Double Cycle System (d) Double Cycle with pump System **2.Double Basin System** (a) Simple Double Basin System (b)Double Basin System With Pump.	
(7)	**Define Flood tide and Ebb Tide.**	
	Flood Tide: Water comes towards land from rhe sea.	
	EBB TIDE:- Water goes towards sea from the land	
(8)	**Sketch and explain single basin type tidal power plant (or)** **Sketch and explain single basin type (Ebb tide) tidal power plant**	
	Single Ebb-Cycle System:	
		
	(1)Tidal barrage or Dam :- • The function of dam is to form a barrier between the sea and the basin.(The dam is used to separate the dam and Tidal basin). • Dam or barrage is constructed with Reinforced Concrete. • Barrage needs to provide channels for the turbines in reinforced	

concrete.

(2)Tidal Basin:-It is man made reservoir to store water during high tide and release water During the low tide.

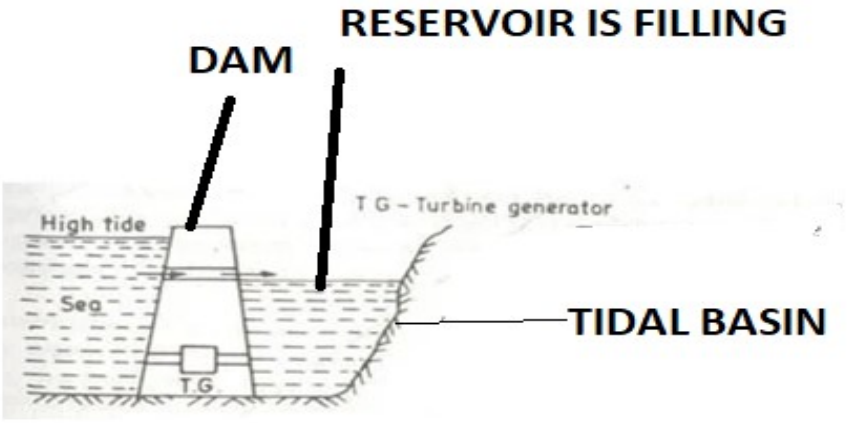
(3)Sluice Ways:-

- **These are gate controlled devices.They are used to fill basin during high tide and or emptying basin during low tide.**
- **Sluice ways is gate which provides water to flow towards basin and towards Sea.**

(4)Turbines and Generator:-

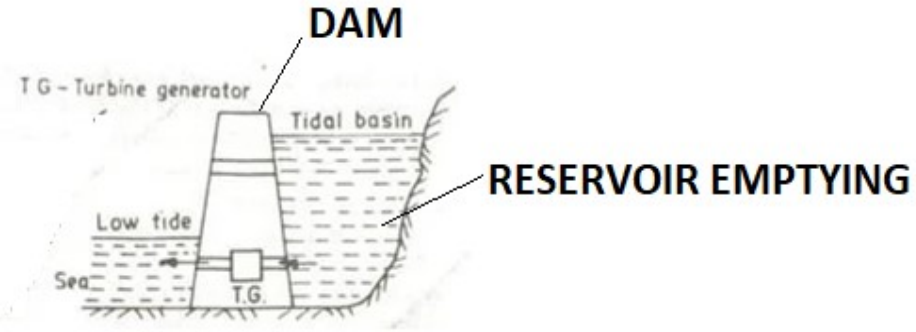
- **Kinetic energy of water to mechanical in turbine and than mechanical to electrical energy in generator.**

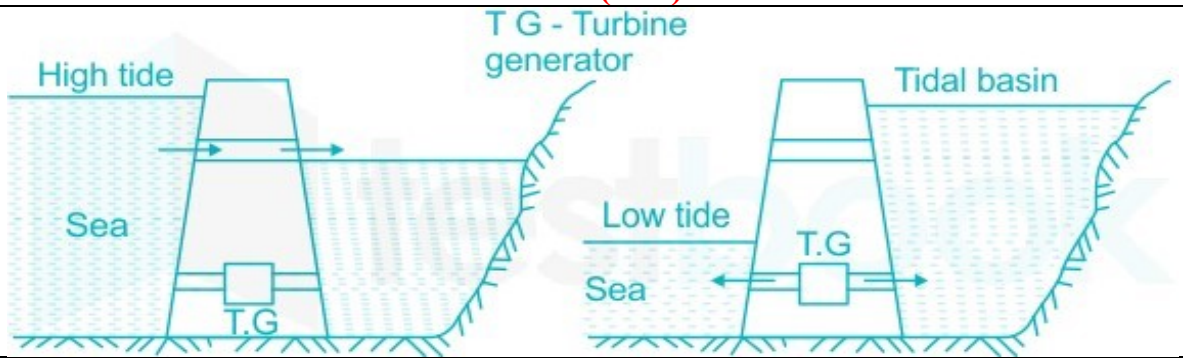
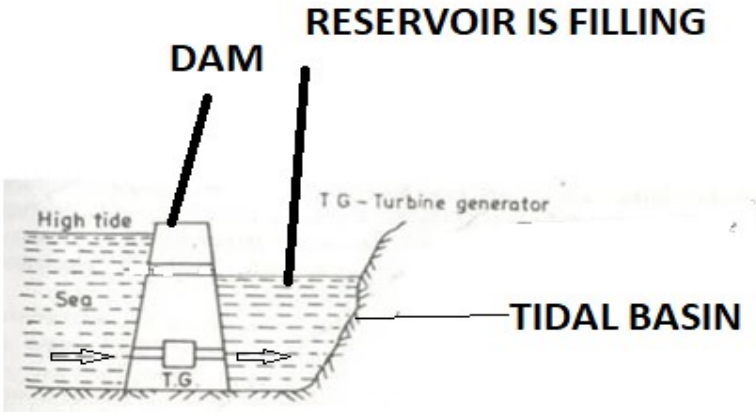
Working

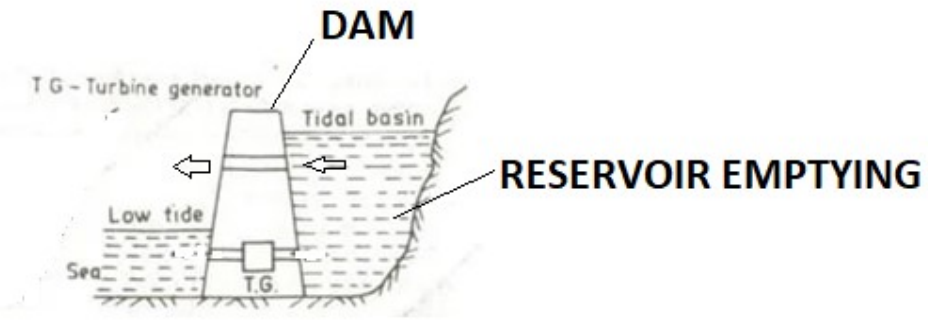


(b)Sluice gates open, Turbines Shut off(Section)&Tidal basin is Filling

- It has one Barrage and one water storage basin, one way system.
- When the Flood tide comes in, the Sluice gate are opened to permit sea water to enter the basin .While the turbine sets are Shut-off.
- The reservoir starts filling while its level rises till the maximum tide level is reached.
- Potential Energy of the water stored in the tidal basin is used to Drive the turbine.



	(b)Sluice gates Shut off , Turbines operation(Section)&Tidal basin is Emptying	
	➢ At the beginning of the ebb tide Sluice gates are closed. Than the power generation strats when sea is ebbing(water flows back to Sea.). ➢ The water flows from the basin to the sea passing through the turbine and generates power. ➢ After that water flows into the lower level of sea water.. ➢ The power is availble for a short duration during ebb tide	
	➢ **The ebb has a longer duration than the flood tide.The ebb cycle provides in increased of actual work.** ➢ **Ebb cycle output=1.5*Tidal cycle power generation.**	
	(OR)	
		
(9)	**Sketch and explain single basin type Flood tide tidal power plant**	
	Single Flood tide/Tide-cycle System.	
		
	(b)Sluice gates Closes, Turbines in operation(Section)&Tidal basin is Filling	
	➢ Power generation occurs at Flood tide. ➢ The water from the sea admitted into barrage (Basin) over the turbines. ➢ After the flood tide, Sea starts falling again. Generation is stopped. ➢ The basin drains into the sea through Sluice ways.	



(b)Sluice gates open, Turbines is shut-off(Section)&Tidal basin is Emptying

10 **Sketch and explain Double basin type tidal power plant**

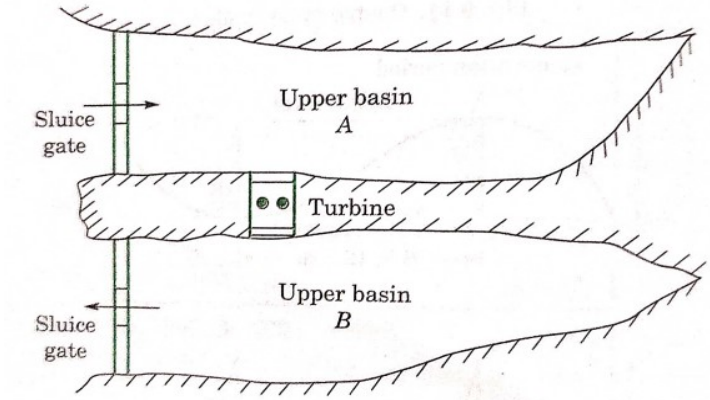


Fig. 9.13. Tidal power plant Double Basin Operation.

(or)

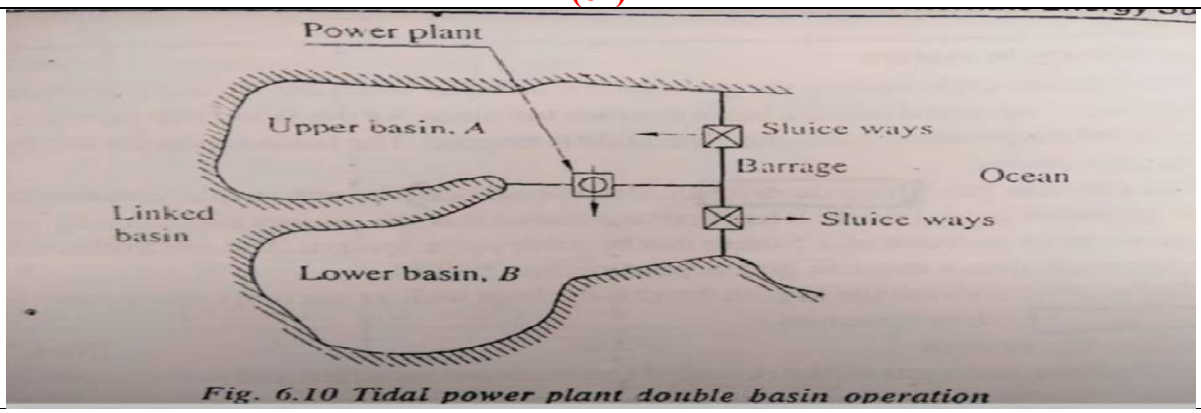
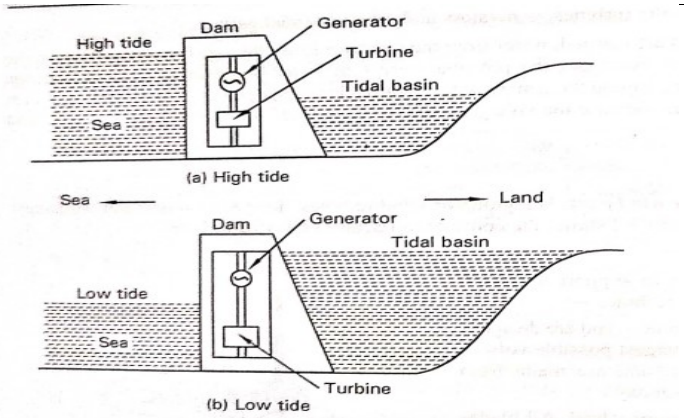


Fig. 6.10 Tidal power plant double basin operation

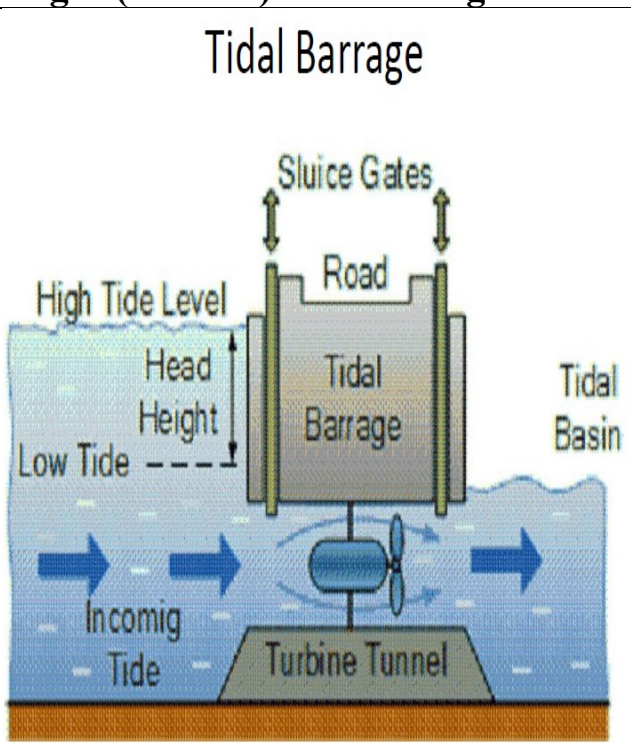
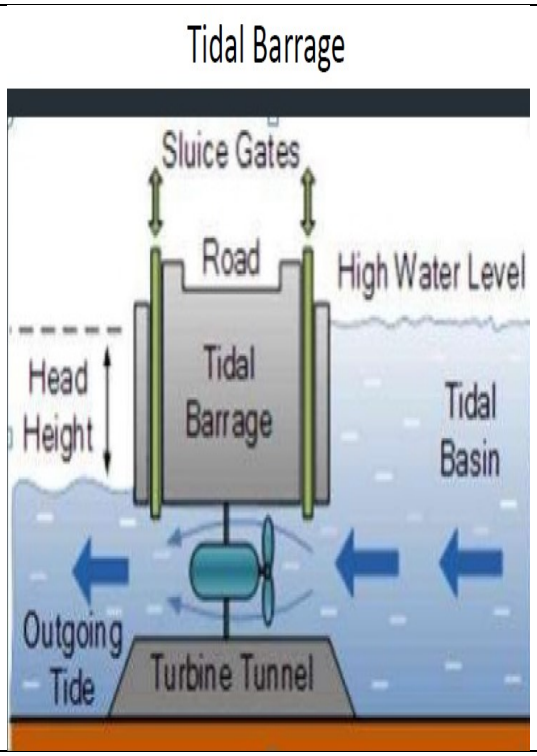
Double Basin Arrangement

- ❖ It requires two separate but adjacent basins.
- ❖ In one basin called "upper basin" (or high pool), the water level is maintained above that in the other, the low basin (or low pool).
- ❖ Because there is always a head between upper and lower basins, electricity can be generated continuously, although at a variable rate.
- ❖ In this system the turbines are located in between the two adjacent basins, while the sluice gates are as usual embodied in the dam across the mouths of the two estuaries or basins.
- ❖ At the beginning of the flood tide, the turbines are shut down, the gates of upper basin A are opened and those of the lower basin B are closed.

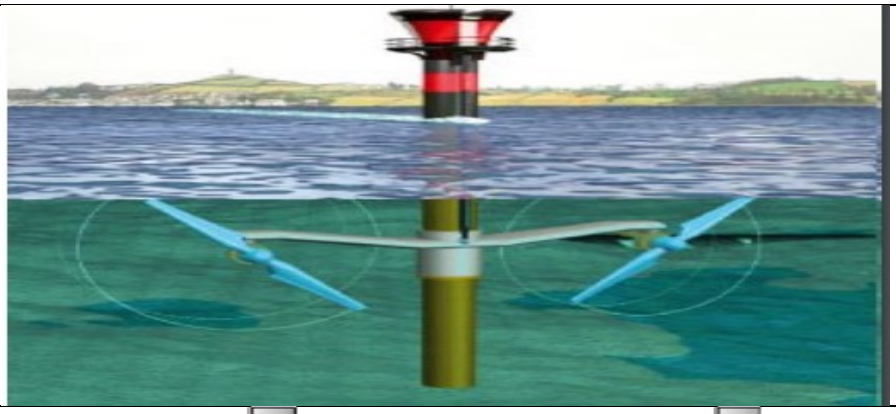
	❖ The Basin A is thus filled up while the basin B remains empty. ❖ As soon as the rising water level in A provides sufficient difference of head between the two basins, the turbines are Started. ❖ The water flows from A to B through the turbines, generating power. ❖ The power generation thus continues simultaneously with the filling up basin A. ❖ The end of the flood tide when A is full and the water level in it is the maximum; its sluice gates are closed. ❖ When the ebb tide level gets lower than the water level in B, its sluice gates are opened where by water level in B, which was arising and reducing the operating head, starts falling with ebb. ❖ This continues until the head and water level in A is sufficient to run turbines, ❖ With this twin basin system, a longer and more continuous period of generation per day is possible.	
	❖ **The operation of the two basin scheme can be controlled so that there is a continuous water flow from upper to lower basin.** ❖ **However since the water head between the basins varies during each tidal cycle, as well as from day to day, so also does the power generated.**	
	Double basin type with pumping tidal power plant	
	❖ Pump is used to lift the water from lower basin to upper basin to maintain head (Level difference) between the two basins at any time of the tide. ❖ The period of power production with this system is much longer than the other system.	
11	**With a neat sketch, Explain the operation of tidal power plant.** **(OR)Explain the working principal of tidal power plant.** **(or) With a neat sketch, Explain the operation of Double Cycle tidal power plant System.**	
	❖ Tides are the rise and fall of sea levels caused by the combined effects of the gravitational forces exerted by the moon and the Sun, and the rotation of the earth. ❖ Tidal power plant is a power-generating station that harnesses the energy of ocean tides, which contains a large amount of Potential energy. ❖ Tides are of two types: High Tide and Low Tide. ❖ When the level of water is above the mean sea level, it is called high tide or flood tide, and when the level of water is below the mean sea level, it is called low tide or ebb tidew.	
		

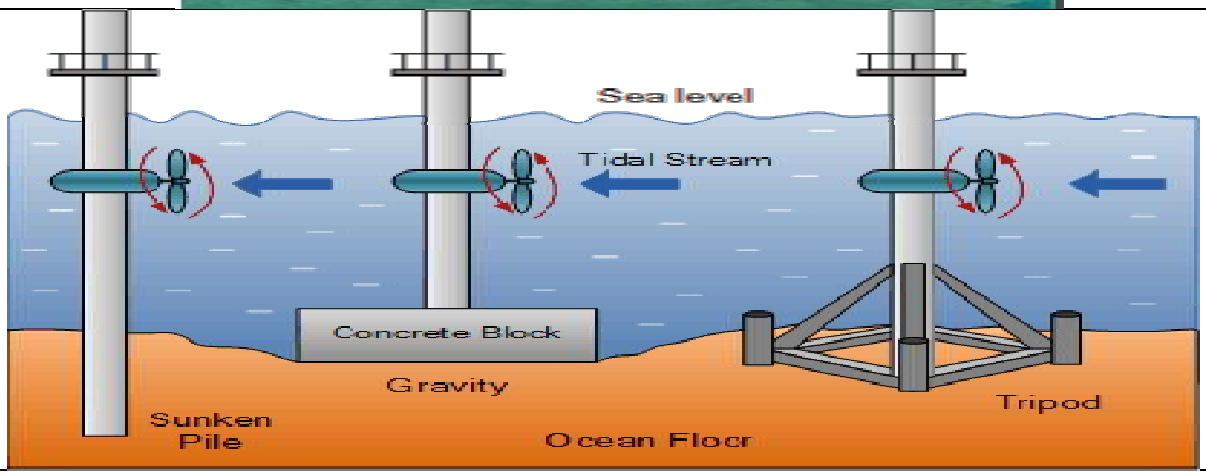
	Construction & Working ❖ **A** tidal dam or barrage is built in such a way that the basin gets separated from the sea resulting in a pressure difference in the water level between the basin and the sea. ❖ Inside the dam, water turbine and flood gates (Sluice gate) are installed as shown in the figure (a). **Hide Tide** ❖ During the high tide period, the level of tide in the sea is more than the level of water in the tidal basin. Refer figure. ❖ The opening of the flood gates (Sluice gate) thereby causes the tide to flow from the sea into the basin through the water turbine. ❖ The flowing water drives the turbine and in turn operates the generator to produce electricity. **Low Tide** ❖ During the low tide period, the level of water in the tidal basin is more than that of the tide in the sea. Refer figure (b). ❖ The opening of the flood gates causes the water to flow from the tidal basin to the sea through the water turbine. ❖ The flowing water drives the turbine and in turn operates the generator to produce electricity. ❖ The turbines are designed to be driven by the energy of the water in both the directions. ❖ The generation of electricity stops only when the level of water in the sea and the tidal basin are equal.	
	❖ Power generated during emptying and Filling the Basin. ❖ Reversible Turbine and Dual rotation generator are used in double cycle System.	
	Double Cycle tidal power plant with pump System.	
	➢ A part of the energy produced is used to operate (Run)the pump to maintain difference in the water levels between the basin and the sea at any time of the tide ➢ This is done by pumping water into the basin up or down with help of Pump. ➢ The period of power production with this system is much longer than the other system.	
12	**List out the advantages, disadvantages and Applications of Tidal plants.**	
	Some advantages of tidal energy are: ❖ About two-third of earth's surface is covered by water, there is scope to generate tidal energy on large scale. ❖ Environment-friendly ❖ A highly predictable energy source ❖ High energy density ❖ Operational and maintenance costs are low ❖ An inexhaustible source of energy. ❖ It's a Renewable Source of Energy. ❖ It Generates Energy at Low Speeds ❖ The life of tidal energy power plant is very long.	

	❖ Efficiency of tidal power generation is far greater when compared to coal, solar, or wind energy. Its efficiency is around 80%. **Some of the disadvantages of tidal energy are:** ❖ High tidal power plant construction costs ❖ Negative influence on marine life forms ❖ Location limits, can be constructed only if natural sites are available. ❖ The variable intensity of sea waves and also output of power varies with lunar cycle. ❖ The supply of power is not continuous as it depends upon timing of tides. ❖ Maintenance and Corrosion are an Issue. ❖ Economy recovery of energy from tides is not much feasible, it is manly site Specific. ❖ Tidal plant disrupts marine life at the location and can cause potential harm to ecology. ❖ The turbines are required to operate at variable heads. ❖ Changing tidal range in two weeks period produces changing power.. ❖ Location of sites may be distant from the demand centres. ❖ Only a very few ideal locations for construction of plant are available and they too are localized to coastal regions.	
	Uses of Tidal Energy/ Applications:- •Tidal Electricity •Grain Mills •Energy Storage- Tidal **Barrages** and reservoirs can be modified to store energy. •Provide Protection to Coast During High Storms-Tidal Barrages are capable to prevent damage to the coast during high storms.	
13	**Discuss the Problems Faced in exploiting Tidel Energy.**	
	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. Barrages may also destroy the habitat of the wildlife living near it. 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 disadvantage is the cost of those plants. Capital investment for construction of tidal power plant is high. This technology is still not cost effective and more technological advancements are required to make it commercially viable 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. ➢ Aquatic life is influenced adversely and can disrupt the migration of fish. 5. Only a very few ideal locations for construction of plant are available and they too are localized to coastal regions. 6. Unpredictable intensity of sea waves can cause damage to power generating units. 7. The energy generated is not much as high and low tides occur only twice a day and continuous energy production is not possible. 8. The actual generation is for a short period of time. The tides only happen twice a day so electricity can be produced only for that time, approximately for 12 h and 25 min..	
14	**Explain about different Types of Tidal Systems (or) Explain about Different technologies used in Tidal power plants for Power generation.**	
	1)Tidal Barrage 2) Tidal Stream Generators 3) Tidal Fence	
	(1)Tidal Barrage	
	Tidal barrages make use of the potential energy in the deference in height (or head) between high and low tides.	
	 	

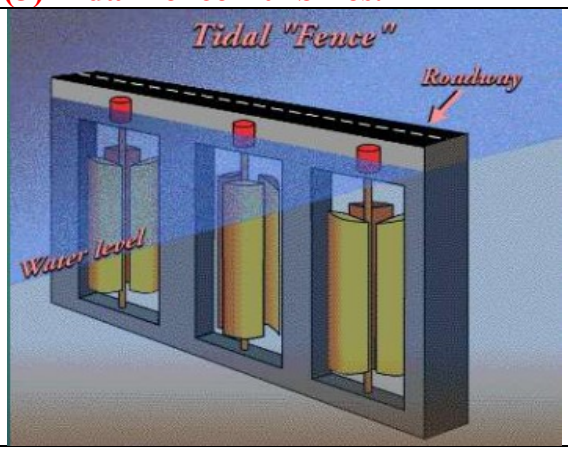
(2)Tidal Stream Generator.

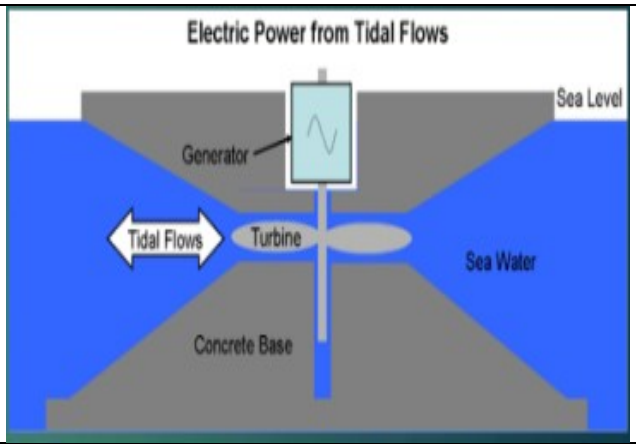




- Make use of the Kinetic Energy of moving water to power Turbines.
- A similar way to wind turbines that use wind to power turbines.
- Operate during flood and ebb tides.
- It consists of a rotor,gear box,and a generator.
- These three parts are mounted onto a support structure.
- There are mounted in three different method of support structures.
  (a)Gravity Structure(b)Piled Structure(c)Floating Structure.

(3) Tidal Fence Turbines.





- It is an man-made device used to harvest kinetic energy from the sea.
- They are entwined(Arranged) together like a fence.

- They are submerged in the sea.
- It contains vertical axis Turbine and Generator.

Working.

- Tidal fence is a series mounted in a row across a estuary or Basin.
- Each turbine has a vertical shaft attached.
- The shaft is mounted in the fence.
- The tidal currents spin the turbines.
- When the turbine is turned the attached generator shaft turns and produce electricity.
- The turbine and shaft are the only elements submerged.
- The generator and transformers are above water.

15 Expain about Different Tidal power (plants) stations in the world and India.

Table 10.1 Existing tidal plants

S.N.	Site	Mean tidal range (m)	Basin area (km^2)	Installed capacity (MWe)	Year of installation
1.	La Rance (France)	8	17	240	1966
2.	Kislaya Guba (near Murmansk, on Barents sea, Russia)	2.4	2	0.4	1968
3.	Jiangxia (China)	7.1	2	3.2	1980
4.	Annapolis (in Nova Scotia, Bay of Fundy, Canada)	6.4	6	17.8	1984

Table 11.3 Indian Tidal Energy Plant

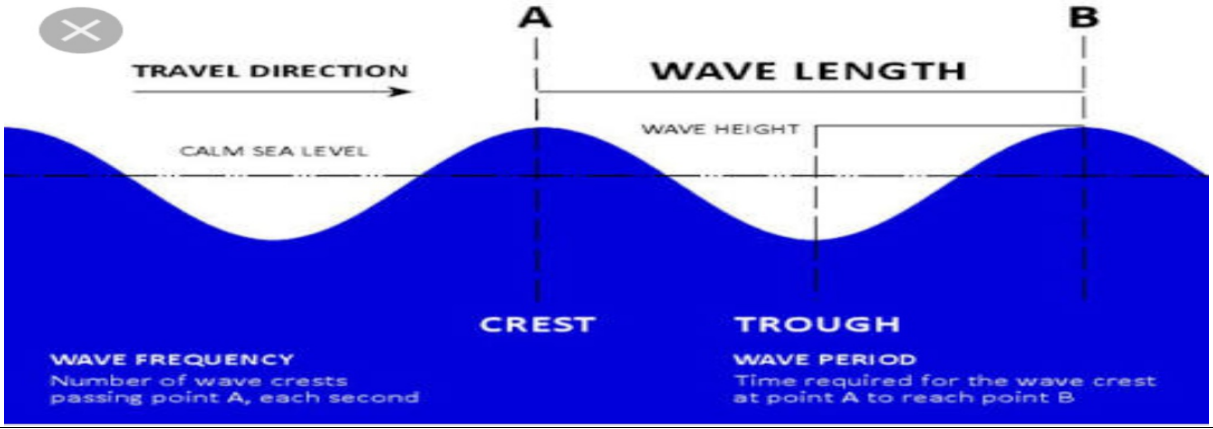
Site Location	Tide Heights (m)	Estimated Power Potential (MW)
The Gulf of Cambay, Gujarat	11 (6.7 av)	7,000
Gulf of Kutch, Gujarat	8 (5.23 av)	12,000
The Ganges Delta in the Sundarban, West Bengal	5 (2.97)	8,000

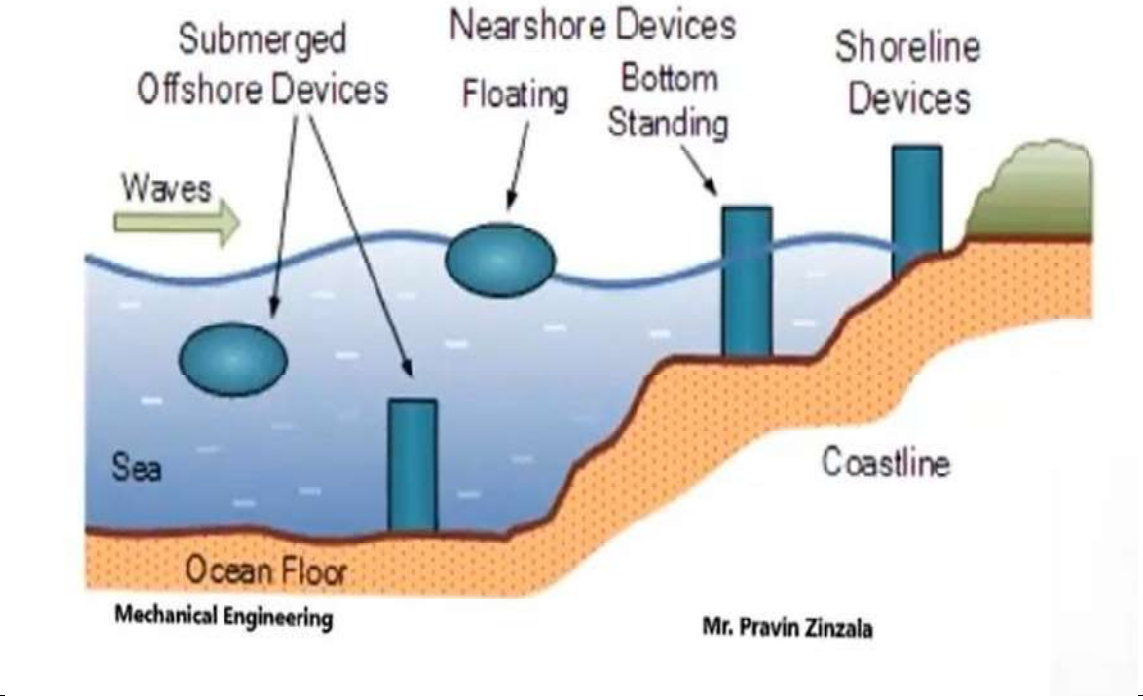
EXTRA NOTES

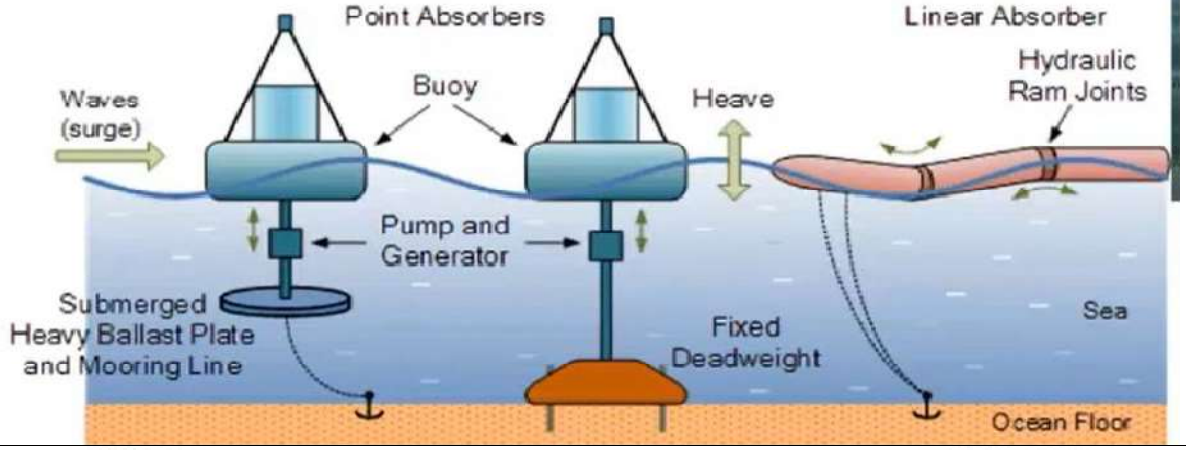
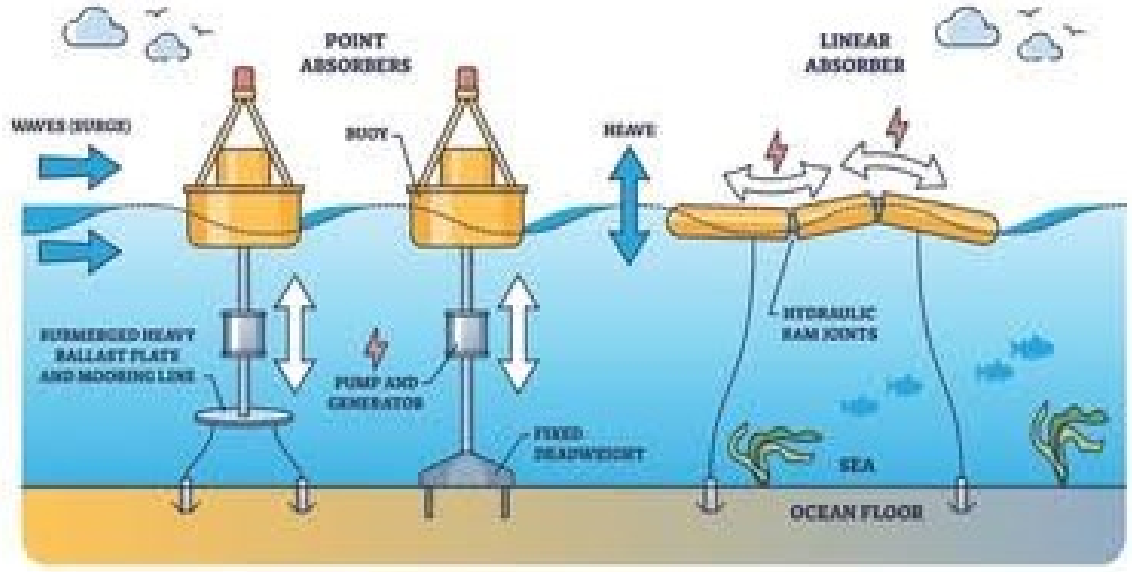
Table 11.2 A Few Potential Sites for Tidal Power Generation

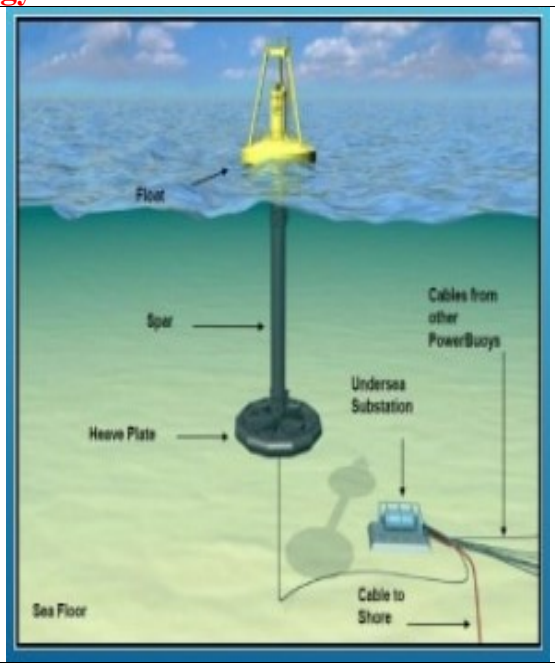
Country	Site	Average Tide Height (m)	Basin Area (m^2)	Estimated Power Potential (MW)
Argentina	San-Jose	6.0	780	7,000
Australia	Secure	8.4	130	570
Australia	Walcoti	8.4	260	1,750
Korea	Carolina Bay	4.7	90	480
Russia	Mezen	5.66	2,640	15,000
Russia	Tugur	5.38	1,080	6,790
UK	Severn	8.3	490	6,000
UK	Mersey	8.4	60	700
USA	Cook Inlet	4.35	3,100	18,000
USA	Passamaquoddy	5.55	300	400

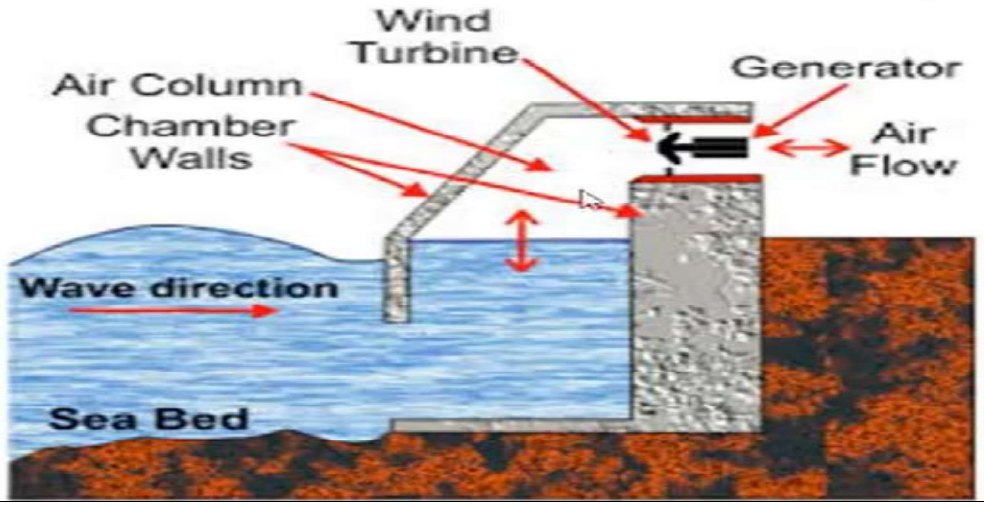
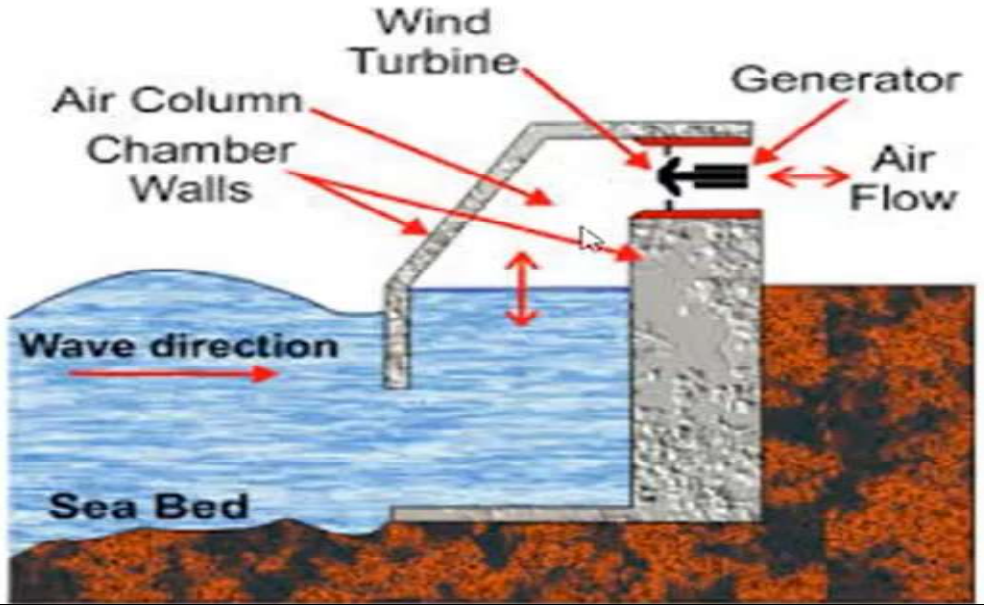
	Wave Energy	
01	**Define wave energy, List out the advantages and disadvantages of Wave Energy.**	
	➢ The unequal solar heating of the earth generates wind and wind blowing over water generates waves. (or) ➢ Differential warming of the earth causes pressure differences in the atmosphere, which generate winds. ➢ As the wind move across the surface of open bodies of water, they transfer some of their energy to the water and Create waves.	
	➢ Wave energy is one from of the renewable energy source that uses the power of the waves to generate electricity ➢ wave energy uses the vertical movement of the surface water that produces tidal wave ➢ wave power converts the periodic up-and-down movement of the oceans waves into electricity by placing the equipment on the surface of the oceans that capture the energy produced by the wave movement and converts this mechanical energy into electrical power	
	Advantages	
	➢ **Available 24/7 on 365 days-therefore power produced from them is much steadier and more predictable.** ➢ Waves can be accurately predicted 48 hours in advance and therefore forecast energy output (But irregularity in Wave amplitude, and direction). ➢ Good data on waves from wave monitoring buoys. ➢ Wave energy contains 1000 times Kinetic energy of Wind .(Can produce the same amount of power in Less space)	
	➢ Wave power is a renewable source of energy. ➢ A large amount of energy can be generated. ➢ It is a reliable source of energy. ➢ It is highly predictable. ➢ Wave Energy is a pollutant-free. ➢ Low operation cost. ➢ Sea waves have high energy densities and provide a consistent stream of electricity generation capacity. ➢ It has no greenhouse gas emissions or water pollutants. ➢ Operating cost is low and operating efficiency is optimal. ➢ Damage to ocean shoreline is reduced. ➢ Wave energy is clean source of energy with limited negative	

	environmental impacts.	
	Disadvantages:-	
	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. 5. Marine life impact. 6. Difficult to transmit wave energy. 7. Variable output. 8. Suitable to Certain locations only. 9 Create hazards for some of the animals near to it. 10. Depends on the waves-Sometimes you will get loads of energy, sometimes almost nothing. 11Needs a Suitable site, where waves are consistently Strong. 12. Weak performance in rough weather. 13. Maintenance and Weather effects. 14. Few implemented 15 Visual impacts.	
02	**Explain Applications of Wave Energy.**	
	• Electricity Generation. • Water pumping. • Employment and infrastructure opportunities. • Desalination plants can also benefit from wave devices. • Reduction of oil usage in island energy production.	**Elec**
03	**Explain the Characteristics of wave**	
		
	1. Crest: The peak point (the maximum height) on the wave is called the crest. **2. Trough: The valley point (the lowest point) on the wave is called the trough.** **3. Wave height (H): Wave height is a vertical distance between the wave crest and the next trough (m).**	

	4. Amplitude (a): It is defined as H/2 (m). **5. Wave length (l): It is the horizontal distance either between the two successive crests or troughs of the ocean waves (m).** **6. Wave propagation velocity (v): The motion of seawater in a direction (m/s).** **7. Wave period (T): It measures the size of the wave in time(s). It is the time required for two successive crests or two successive troughs to pass a point in space.** **8.Wave Frequency (f): The number of peaks (or troughs) that pass a fixed point per second is defined as the frequency of wave and is given by f = 1/T (cycle/s).**	
04	**Explain the basic kinds of wave Energy conversion System.**	
	THREE BASIC KINDS OF STYSTEMS	
	1. Offshore Devices or Submerged Offshore devices:- ➢ Deals with Swell energy (A series of mechanical or Gravity waves/Series of Continuous waves) not breaking waves. ➢ These devices are situated at more than 30m water Depth. **2. Near Shore Devices :-** ➢ Deals with maximum wave Amplitude waves. ➢ Near shore devices are Floating type and Bottom standing Devices. **3.Embedded Devices or Shore line Devices:-** ➢ **Deals with breaking waves (Receive breaking waves).** ➢ **These devices are built near the Shore line.** ➢ **These devices are fixed or embedded to the Shore line.** ➢ **These devices are both in and out of the water.**	
		

05	**Explain the Wave energy Conversion devices briefly.**	
	WAVE ENERGY CONVERSION DEVICES	
	➢ **Wave Profile Devices:** They turn the oscillating height of the oceans surface into mechanical energy. ➢ **Oscillating Water Columns:** They convert the energy of the waves into air pressure. ➢ **Wave Capture Devices:** They convert the energy of the waves into potential energy.	
06	**With neat Sketch, Explain the Working principle of Float type wave energy converters(Wave profile Devices)**	
	➢ **Float type wave energy converters** 	
		

	Float Type Wave Energy convertor	
		
	➢ This device floats on the surface of the Water,Held in place by cables connected to the Seabed. ➢ Buoys use the rise and fall of Swells (waves) to drive Hydraulic/Air pumps and Generate Electricity. ➢ EMF generated by electrical transimission cables and acoustic of these devices may be a concern for marine organisms. ➢ The prsence of the buoys may affect fish,marine mammals(Animals),and birds as potential minor collisions risk and roosting sites(Resting place for Birds or Sea animals).	
07	**What is Wave energy? Exaplin the working Principal of Wav energy or Wave energy converters**	
	➢ Wave energy is one from of the renewable energy source that uses the power of the waves to generate electricity ➢ wave energy uses the vertical movement of the surface water that produces tidal wave	
	Wave energy converters (WECs) are devices that convert the kinetic and potential energy associated with a moving ocean wave into useful mechanical or electrical energy. **Working principle of WEC** It's an enclosed chamber with an opening under the sea, which allows strong sea waves to flow into the chamber and back. The water level in the chamber rises and falls with the rhythm of the wave, and so air is forced forwards and backward via the turbines joined to an upper opening in the chamber. The compressed and decompressed air has enough power to propel the turbines. The turbine is propelled in the same direction by the back and	

	forth airflow through the turbine. The propelling turbine turns a shaft connected to a generator.	
		
08	**With neat Sketch, Explain the Working principle of oscillating water column (OWC)wave energy conversion System**	
	➢ **Oscillating water column type** 	
	➢ This device Comprise a partly submerged concrete or Steel structure,which has an opening to the sea below the water line ,thereby enclosing a column of air above a column of water.	
	➢ The wave impinging on the device causes the water column to rise and fall,which alternately compresses and depressurizes the air column. ➢ The air is allowed to flow through a turbine ,which drives the generator. ➢ The specially developed axial flow well's turbine ,which operates with either directions of air flow,is used to extract energy.	

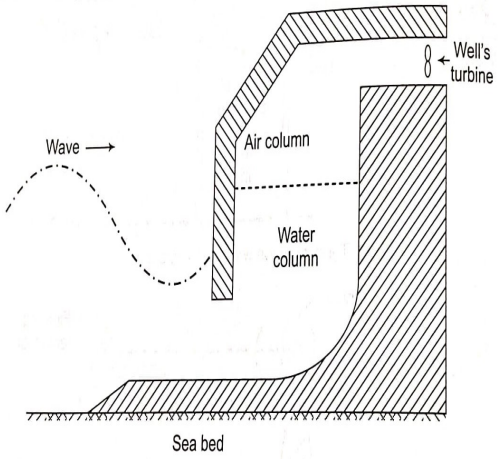


Figure 10.14 Oscillating water column device

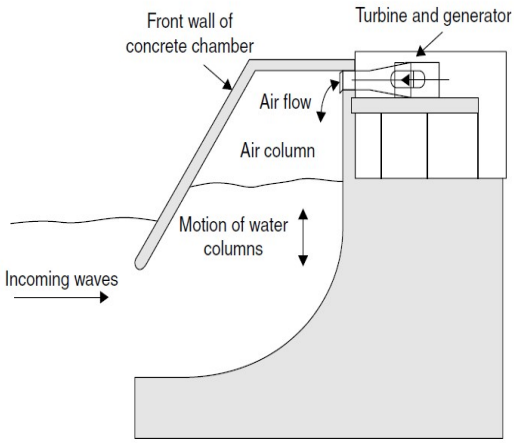
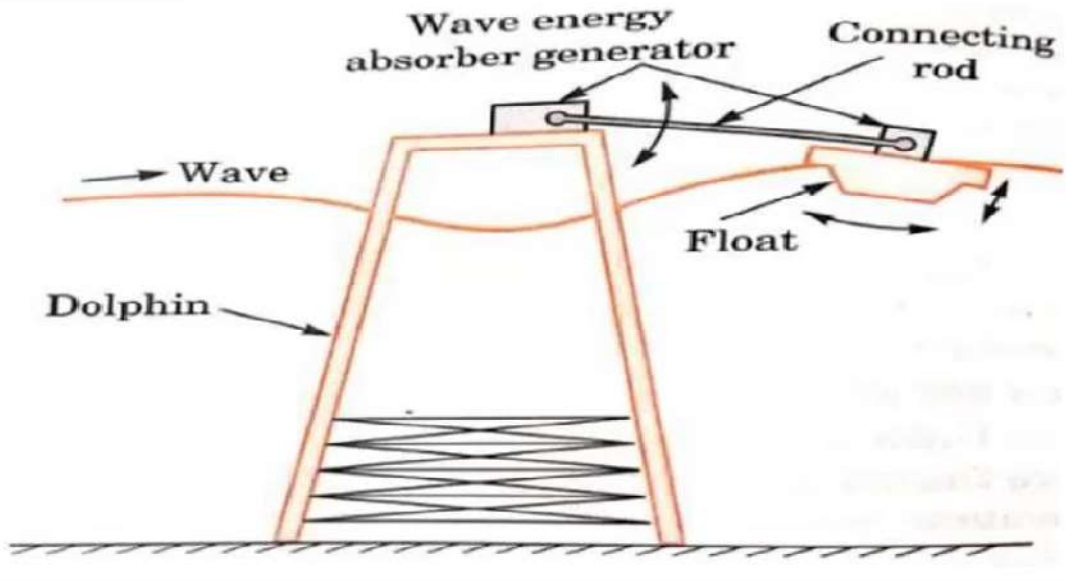


Figure 12.5 Schematic of an oscillating water column device

09 **With neat Sketch, Explain the Working principle of Dolphin type wave Energy Converter(Wave profile Devices).**

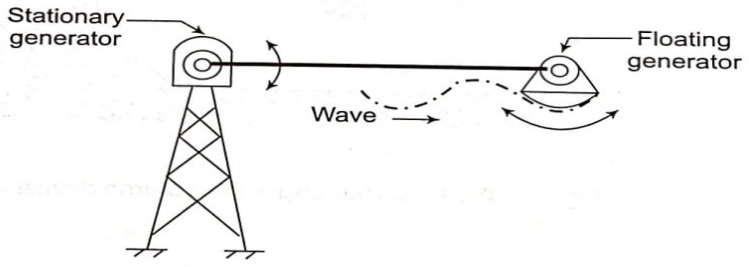
➢ Dolphin type wave energy converters



- ➢ This Type of wave generator,which is designed by Tsu Research laboratories in Japan.
- ➢ This System Consists of Following major Components.

(i)A Dolphin (ii) A Float(iii)A connecting rod and (iv)Two Electrical generators.

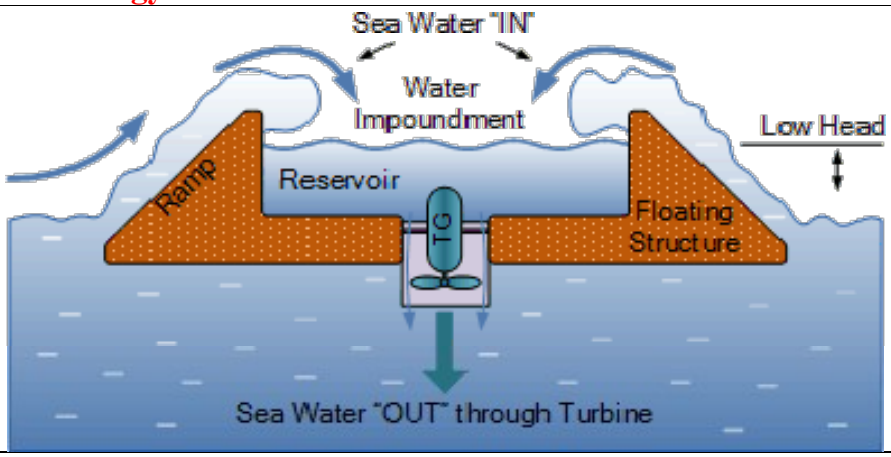
- ➢ **This devices uses the float which has Two motions.**
- ➢ **The first is a rolling motion about its own fulcrum with its connecting rod.**
- ➢ **Revolving movements are caused between the float and the connecting rod.**
- ➢ **The other is nearly vertical or heaving motion about the Connecting rod Fulcrum.It causes relative revolving movements between the connecting rod and the stationary dolphin.**
- ➢ **In both the cases,the movements are amplified and converted by gears into contionuous rotary motions that drive the two Electrical Generators.**



(b) Buoy dolphin

10 **With neat Sketch, Explain the Working principle of Wave Capture Energy Devices.**

Wave Capture Energy Devices



- A wave capture Device also known as a Overtopping Wave power Device.
- It is a Shoreline to near shore wave energy device that captures the movements of tides and waves and converts it into Potential Energy.
- Wave energy is converted into potential energy by lifting the water up onto a higher level.
- The wave capture device,or more commonaly an overtopping devices ,elevates ocean waves to a holding reservoir above sea level.
- It require sufficient wave power to fill the impoundedment reservoir.

Working:-

- The basic impoundment structure can be either fixed or a floating structure tethered to the sea bed.
- The wave overtopping device uses a ramp design on the device to elevate part of the incoming waves above their natural height.
- As the waves hit the structure they flow up a ramp and over the top (hence the name "overtopping"), into a raised water impoundment reservoir on the device in order to fill it.
- Once captured, the potential energy of the trapped water in the reservoir is extracted using gravity as the water returns to the sea via a low-head Kaplan turbine generator located at the bottom of the wave capture device.

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DEPARTMENT OF MECHANICAL ENGINEERING

ETC SUBJECT

Programme	**Bachelor of Engineering**		**Faculty Name**	**D.Sreenivasa Reddy**	
Academic Year	2023-2024	**Year / SEM**	III/VI	**Semester**	ODD
W.E.F.	**01/05/2023**	**Course Name**	**RENEWABLE ENERGY SOURCES (RES/NCE)**	**Course Code**	**BETCK105E/205E**

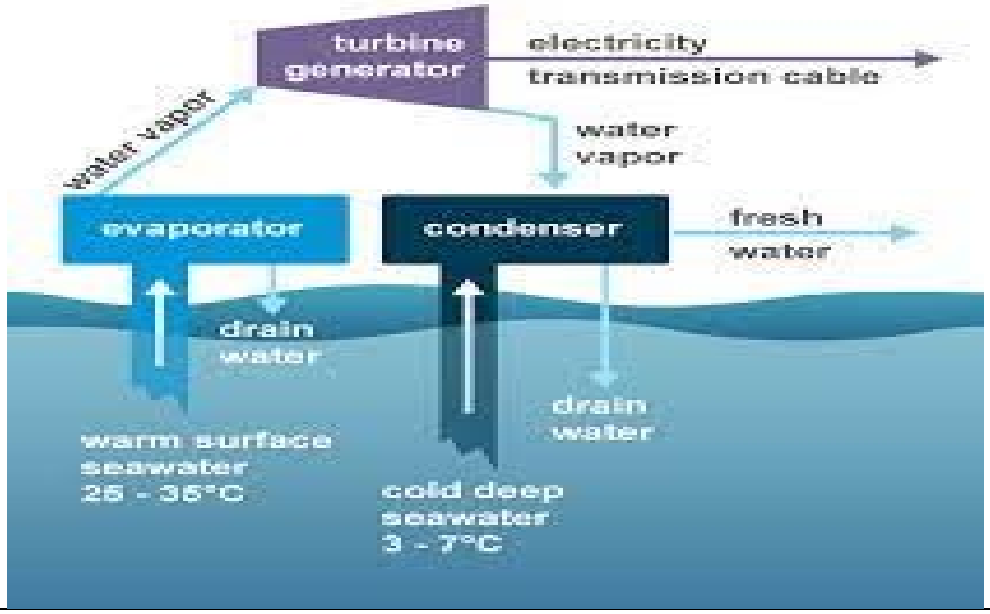
NOTES

MODULE –4

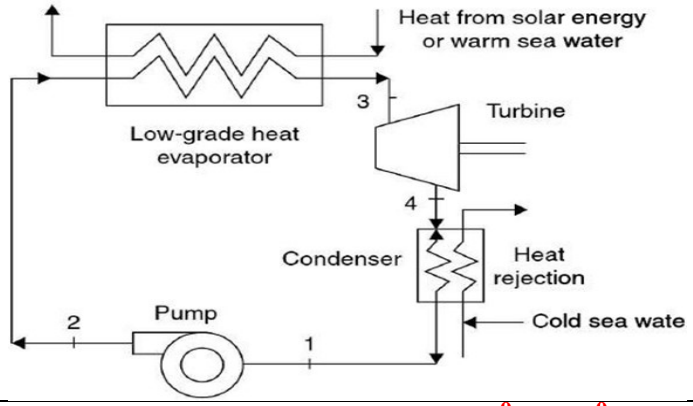
Tidal Power: Tides and waves as energy suppliers and their mechanics; fundamental characteristics of tidal power, harnessing tidal energy, advantages and limitations.

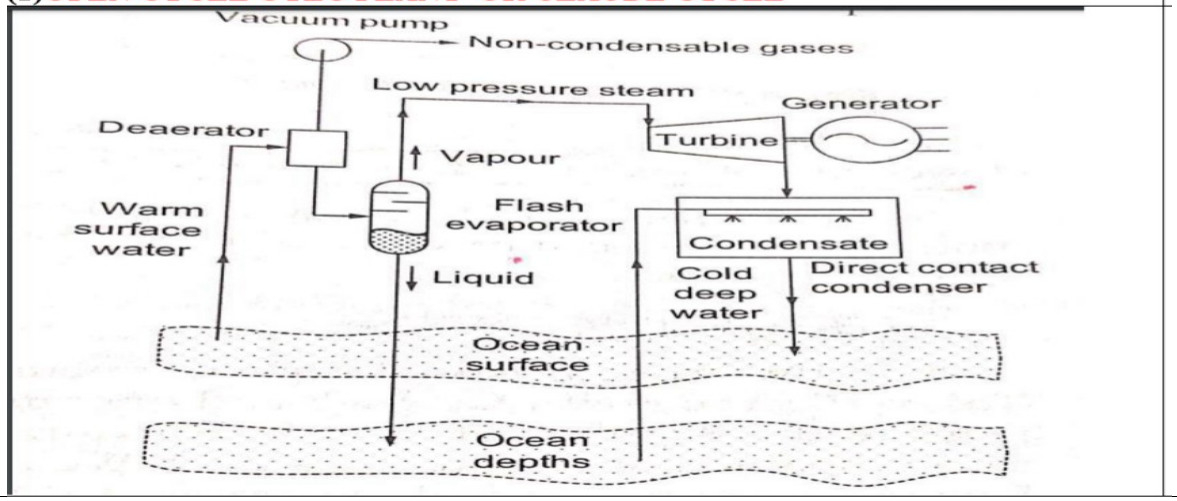
Ocean Thermal Energy Conversion: Principle of working, OTEC power stations in the world, problems associated with OTEC.

CO4	**Acquire the knowledge of wave power, tidal power and Ocean Thermal Energy Conversion and applications.**
	********* VERY IMPORTANT QUESTIONS*********
	Ocean Thermal Energy Conversion:
01	**Describe the Working Principal with neat Diagram of open cycle OTEC System**
02	**Describe the Working Principal with neat Diagram of Closed cycle OTEC System**
03	**Describe the Working Principal with neat Diagram of Closed Rankine cycle OTEC System and Advantages over Open cycle OTEC .**
04	**What are the advantages and disadvantages of Ocean Thermal Energy Conversion(OTEC)**
05	**Describe the Working Principal with neat Diagram of Hybrid cycle OTEC System**
06	**What are the problems Associated With OTEC.**
07	**Explain about OTEC power stations in the world.**

	OCEAN THERMAL ENERGY CONVERSION(OTEC)	
	• **About 70% of the earth's surface is covered by oceans, which are continuously heated by sun** • **OTEC extracts this solar thermal energy from oceans** • **OTEC is a method to produce electricity by using the temperature differences between warm ocean surface and cool deep ocean water to run a Turbine(heat engine) coupled to a generator** • **More the temperature difference ,more energy is produced** • **Ocean water with more than 5 degree temperature gradient is known as ocean thermal energy.**	
01	**What is OTEC?**	
		
	➢ Ocean Thermal energy Conversion(OTEC) is a form of Renewable energy technology that harnesses the solar energy absorbed by the oceans to generate electric power. ➢ Energy from the Sun heats the surface water of the ocean. ➢ Surface water can be much warmer than deep water. This temperature difference can be used to produce electricity.	
02	**Describe the Working Principal of OTEC System with neat diagram**	
	PRINCIPLE OF OTEC(closed cycle)	
	❖ **Temperature of Surface water of sea is around 25^0C-35^0C**	
	❖ **Temperature of Deep water of sea is around 3^0C-7^0C(1000m depth)**	
	❖ **This temperature difference between Surface water and Deep water of sea is used to produce Electricity.**	

	➢ The warm water in the ocean surface is collected and pumped through the heat exchanger to heat and vaporise a working fluid ,and it develops pressure in a secondary cycle ➢ The working fluid vapour expands through a turbine(heat engine) coupled to an electrical generator ➢ Working fluid vapour coming out of the turbine (heat engine) is condensed back by a condenser which uses the cold deep sea water ➢ The vapour is cooled to liquid state and is recycled. ➢ This is known as closed cycle OTEC.	
03	**Explain the Principal of Lamberts law of Absorption.of ocean Sea water.**	
	Lamberts law of Absorption. $I(h) = I_o e^{-\mu h}$ I_o**=Intensity of Surface when h=0.** $I(h)$**=Intensity at depth of h** $\mu = Absorption\ Coefficient$ $\mu = 0.05 \quad for\ Clean\ water$ $\mu = 0.5 \quad for\ Salty\ water$ $\mu = 0.275 \quad for\ Turbid\ water$ **h=Depth from top.** **95% radiation is absorbed with 6m depth** **Deep ocean remains Cool.** **Temperature of water in ocean at the Surface is 25^0 to 30^0** **Temperature of water in ocean at the 1000m depth is around 5^0 .**	
	❖ **Normally used working fluids are** ▪ **Propane for high temperature ocean surface water** ▪ **Low boiling point liquid ammonia for low temperature ocean surface water** ▪ **In open cycle OTEC, warm ocean surface water**	
04	**Describe the Working Principal of OTEC System with neat diagram**	
	PRINCIPLE OF OTEC(Open cycle)	
	❖ **Temperature of Surface water of sea is around 25^0C-35^0C**	
	❖ **Temperature of Deep water of sea is around 3^0C-7^0C(1000m depth)**	
	❖ **This temperature difference between Surface water and Deep water of sea is used to produce Electricity.**	
	➢ **In open cycle OTEC, warm ocean surface water is pumped into a low pressure Evaporator to boil water and produce steam.**	

	➢ **Then, the steam is used to drive steam turbine to produce electricity** ➢ **To condense steam, cold deep sea water is used**	
	❖ Normally used working fluids are ➢ In open cycle OTEC, warm ocean surface water	
05	**Describe the Working Principal of Rankine Cycle OTEC System with neat diagram**	
	BASIC RANKINE CYCLE	
	Basic Rankine cycle consists of the following **1.An evaporator** **2.A turbine expander** **3.A condenser** **4.A pump** **5.A working fluid** ➢ **Steam Rankine Cycle** ➢ **Organic Rankine cycle**	
		
	❖ **Temperature of Surface water of sea is around 25^0C-35^0C**	
	❖ **Temperature of Deep water of sea is around 3^0C-7^0C(1000m depth)**	
	❖ **This temperature difference between Surface water and Deep water of sea is used to produce Electricity.**	
	• The basic Rankine cycle shown in the below Figure that consists of an evaporator, a turbine expander, a condenser, a pump, a working fluid • In open-cycle OTEC, warm sea water is used as working fluid, whereas in closed-cycle type, low-boiling point ammonia or propane is used. • Warm ocean surface water flows into the evaporator which is the high-temperature heat source. A fluid pump is utilized to force the fluid in a heat evaporator where liquid fluid vaporizes. • Then, the vapor of boiling fluid enters the turbine expander coupled with an electrical generator to generate electrical power. • The vapor released from the turbine enters into condenser where it	

	condenses. The cold deep sea water is pumped through the condenser for heat rejection from vapor fluid and condenses it as liquid fluid. • The liquid fluid is again pumped through evaporator and cycle repeats. As temperature difference between high- and low-temperature ends is large enough, the cycle will continue to operate and generate power.	
06	**Describe the Working Principal of an open cycle OTEC System with neat diagram**	
	❖ **Temperature of Surface water of sea is around 25^0C-35^0C**	
	❖ **Temperature of Deep water of sea is around 3^0C-7^0C(1000m depth)**	
	❖ **This temperature difference between Surface water and Deep water of sea is used to produce Electricity.**	
	(1)OPEN CYCLE OTEC PLANT OR CLAUDE CYCLE  	
	Major Components 1. **Evaporator:** A flash evaporator is used in which the warm sea water instantly boils or flash in the chamber that has reduced pressure than the atmosphere 2. **Turbine coupled to a generator** A prime mover that converts kinetic and pressure energy of a fluid into shaft power which is then converted into electrical energy by the help of rotating the generator with the generated shaft power. **3. Condenser :**Condensor is heat-exchager to transfer heat from high temprator Fluid to low Temprature fluid(Latent heat Trnsfer). **4. Pumps :** Pump-1 is used suply hot ocean surface water to flash evaporator. Pump-2 is used supply deep cold water to condense the steam coming from Turbine. Vacuum pump is used to maintain a low pressure in Flash evaporator and	

	remove the Non-Condensable gasses in hot surface water of sea. **5.Deaerator:-** A deaerator is a device that is used for the removal of dissolved gases like oxygen from a liquid.	
	Open cycle System or Claude Cycle	
	➢ The Sea water plays a Multiple role of a Heat Source(Source for Supplying Heat),Working fluid,coolant and heat sink(Source for Rejecting the Heat). ➢ Warm surface water enters an evaporator where the water is flash evaporated to steam under partial vacuum. ➢ Low pressure is maintained in the evaporator by a Vacuum Pump. ➢ The Low pressure so maintained removes the non-condensable gases from the evaporator. ➢ In the evaporator the pressure is maintained at a value(0.0317 bar)slightly lower than the saturation presure of warm surface water at 27^0C(0.0356 bar). (Water turns into steam (boils) at 27^0C at the pressure of 0.0356 bar.) (Water turns into steam (boils) at 100^0C at the Atmosperic pressure of 1.01325 bar.)	
	Working Principle of Open Cycle OTEC.	
	1.The warm ocean surface water is pumped into flash evaporator where it is partially flased into steam at a very low preuure.The remaining warm sea water is discharged into the sea.	
	2.The low-presure vapour(Steam) expands in turbine to drive a coupled electrical generator to produce Electricity. 3.A portion of Elecricity generated is consumed in plants to run pumps and for other work,and the remaining large amount of elecricity is stored as net electrical power.	
	4.The exhaust from the turbine is mixed with cold water from deap ocean in a direct contact condensor and is dischared to the ocean. If direct contact condensor is replaced by costiler indirect(Surface) Condensor,Condensate can be used as desalinated water.	
	5.The non-condensable gases are compressed to presure and exhausted simultaneously. The warm ocean surface water is continuously pumped into evaporator and cycle repeats.	
07	**Describe the Working Principal of an closed cycle OTEC System with neat diagram**	
	❖ **Temperature of Surface water of sea is around 25^0C-35^0C**	
	❖ **Temperature of Deep water of sea is around 3^0C-7^0C(1000m**	

depth)

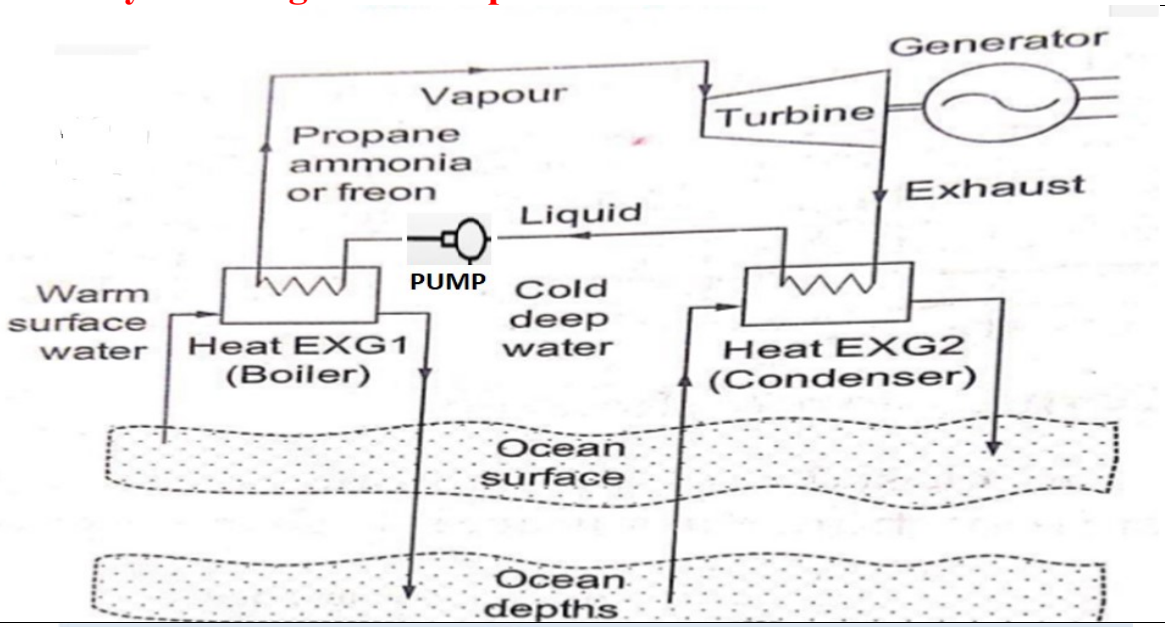
- **This temperature difference between Surface water and Deep water of sea is used to produce Electricity.**

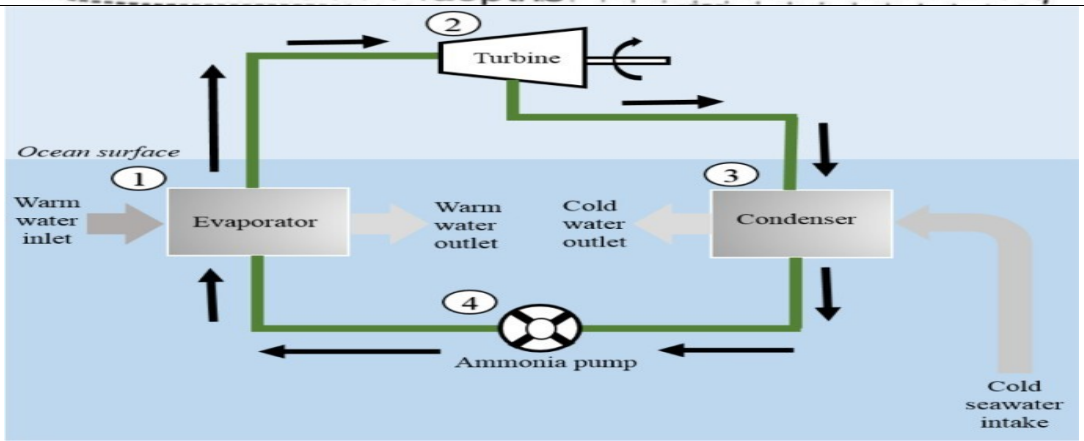
Major Components

1.Heat exchabger-1(Boiler)
2. Turbine coupled to a generator
3. Heat exchabger 2(Condenser)
4. Pumps

Primary Working Fluid:-Hot Sea Water

Secondary Working fluid:-Propane or Amonia or Freon



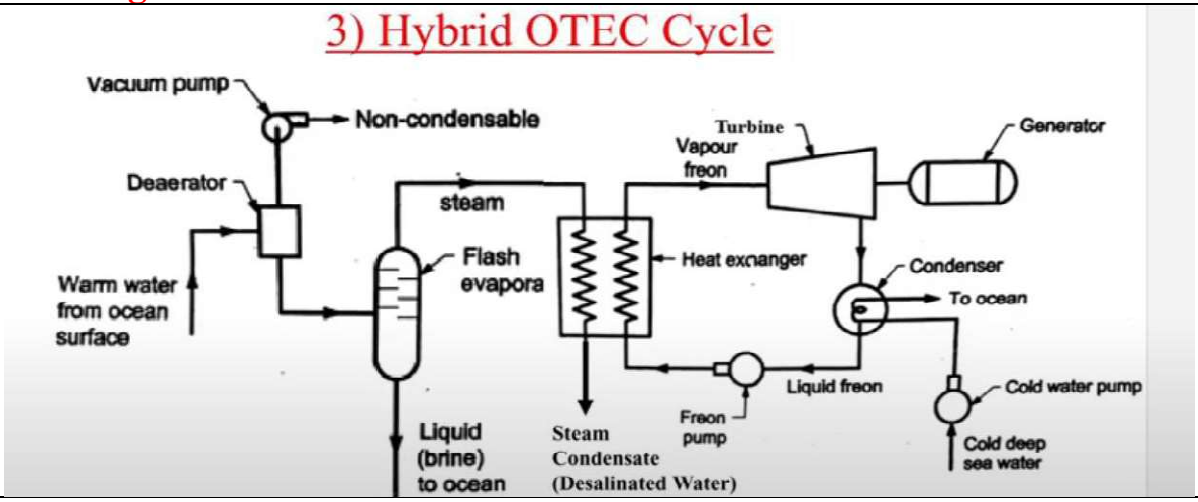


Closed cycle system or Anderson Cycle

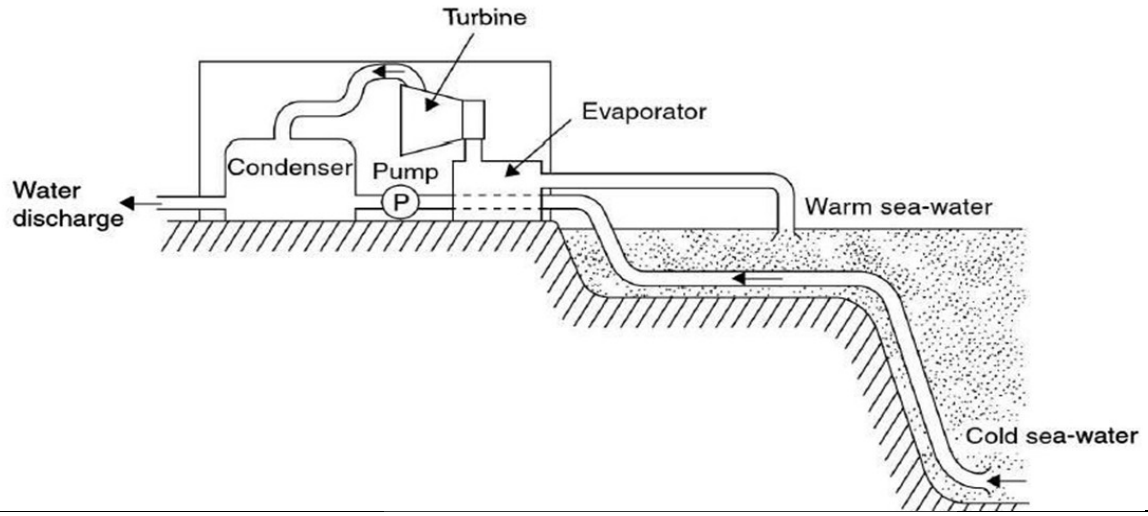
In closed cycle ,a separate working fluid such as ammonia or propane or freon is used in addition to water

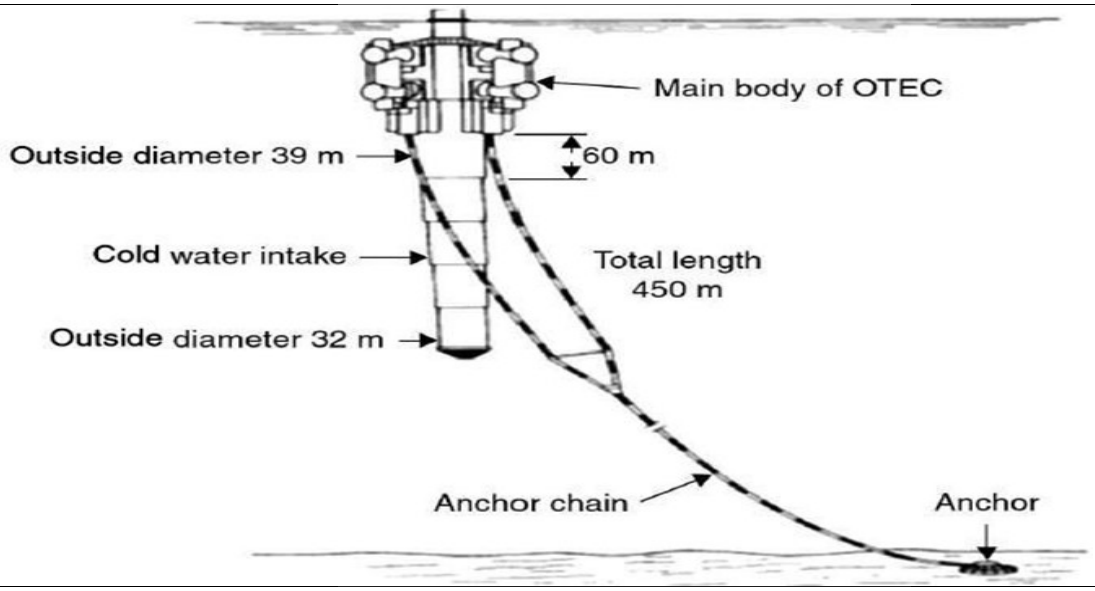
The warm surface water is pumped to a boiler by a pump.

This warm surface water gives up its heat to the secondary working fluid(Ammonia or Freon) thereby losing its energy and is dischrged back

	to the surface of the ocean.	
	The vapours of the secondary working fluid generated in the boiler,drive a turbine for generating power.	
	The exhaust from the turbine is cooled in a surface condensor by using cold deep sea water,and is then circulated back to the boiler by a pump.	
08	**Describe the Working Principal of Hybrid OTEC Cycle System with neat diagram**	
		
	• **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.	
09	**What are the advantages and disadvantages of Ocean Thermal Energy Conversion(OTEC)**	
	ADVANTAGES of OTEC 1)Renewable , clean natural resource. 2)Available in abundance. 3)Pollution free. 4)No green house effects. 5)Good source of fresh water 6)Used for marine culture plants	

	7)Power developed is continuous. 8)Very clean-no air pollution.	
	Disadvantages:- 1) Capital investment is very high. 2)Efficiency is very low,about 2.5%,as compared to 30-40% efficiency for conventional power plants. 3)Large setup size. 4) The low efficiency of these plants coupled with high capital cost and maintenance cost makes them uneconomical for small plants. 5)OTEC Plants will damage the Eco System. 6)Electricity generated by OTEC plants is more expensive than electricity generated by chemicls and nueclear fuels. 7)Harmful on Marine life. 8)Obstruct with navigation. 9) Location of OTEC plants is more Complex. 10)For the large scale production of electricity,OTEC Plants are poorly acceptable due to their high costs.	
	APPLICATIONS OF OTEC :- □ Electricity generation □ **Hydrogen Production** □ Ammonia and methanol production □ Desalinated water □ Aquaculture □ Chilled soil agriculture □ Air conditioning	
10	**What is the BENEFITS OF OTEC**	
	1. It is a clean, renewable natural resource available in plenty. 2. It has no environmental problems and greenhouse effects. 3. It is a source of base load electricity and fuels such as hydrogen, methanol, and ammonia. 4. It provides freshwater for drinking, agriculture, and industry. 5. It encourages chilled agriculture and aquaculture. 6. Self-sufficiency, no environmental effects, and improved sanitation and nutrition are the added benefits for island.	

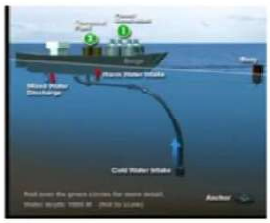
11	**Write the Classifixation of OTEC plants/**	
	(i)Based on the Type of Cycle **(a)Closed Cycle OTEC.** **(b) Open Cycle OTEC.** **(C)Hybrid Cycle OTEC** **(ii)Based on Location of plants** **(a) Land Based Power Plant** **(b) Floating Power Plant**	
12	**Explain about the OTEC plants with respect to Location.**	
	OTEC Plants	
	Two different types:	
	1)Land Based Power Plant 2) Floating Power Plant	
	Land Based Power Plant ➢ **Will consist of a building constructed on the shore** ➢ **It requires laying of pipes** ➢ **One pipe to collect warm ocean water** ➢ **Second pipe lay down on the slope deep into the ocean to** ➢ **collect cold water** ➢ **Third pipe is used as outlet to discharge used water again to deep down ocean**	
		
	2) Floating Power Plant	
	➢ **Built on a ship platform** ➢ **Same principle as that of land based power plant** ➢ **Cost savings on piping,but electricity transmission is difficult**	



Location

Can be located Near sea Shore
(Land based)

Floating Plant
(Water Based)



12 What are the problems Associated With OTEC.

PROBLEMS ASSOCIATED WITH OTEC

• **High cost**: Electricity generated by OTEC plants is more expensive than electricity produced by chemical and nuclear fuels.

• **Complexity**: OTEC plants must be located where a difference of about 20°C occurs year round. Ocean depths must be available fairly close to shore-based facilities for economic operation. Floating plant ships could provide more flexibility.

• **Acceptability:** For the large-scale production of electricity and other products, OTEC plants are poorly acceptable due to their high costs.

• **Ecosystem damage**: It is obvious by setting OTEC plants.

• **Lower efficiency**: A higher temperature difference between ocean surface warm water and cold deep ocean water is required for highly efficient operation of plant.

13 What are the environmental impacts of OTEC

(i) It is feared that biota including eggs, larvae and fish could be entrained and destroyed due to intake and expulsion of large volumes of water. Appropriate siting of intake may reduce the problem.

(ii) Changes in local temperature and salinity might also effects the local ecosystem, impact coral and influence ocean currents and climate.

(iii) In open cycle OTEC system, CO_2 dissolved in warm water is released to atmosphere. However, the quantity of CO_2 released is very small and under worst conditions would be only 1/15 that of oil or 1/25 that of coal based generation of same power. It could be reinjected into warm water discharge.

(iv) Release of large quantities of cold water into warmer surface environment will also have biological effects, which are yet to be known. Actual environmental impacts will have to be estimated from small-scale trials.

14 Explain about OTEC power stations in the world.

SNo	Location	Nominal power out put(Capacity of plant)	Type of plant
1	Hawali	50KW	Closed Cycle
2	Japan/Nauru	120KW	Closed Cycle
3	Hawali	1MW	Open Cycle
4	Japan/Okinawa	100KW	Closed Cycle
5	Hawali	10MW	Closed Cycle
6	India /Tuticorin	1MW	Closed Cycle
7	South china/ Hainan Island	10MW	Closed Cycle
8	Martinique/ Bellefontaine	10MW	Closed Cycle
9	Makai's	100KW	Closed Cycle
10	India / Kavaratti	65KW	Closed Cycle

**********END**********