CMR INSTITUTE OF TECHNOLOGY	USN											

Internal Assesment Test –III

Sub:	Renewable Energy Resources							Code:	18EE653
Date:	2/08/2021	Duration:	90 mins	Max Marks:	50	Sem:	6th	Branch:	ISE/CSE

Answer Any FIVE FULL Questions

		Marks	OBE	
			CO	RBT
1	Explain the different ways of utilizing the geothermal resource. With a neat sketch, explain the operation of a binary cycle based geothermal power plant.	[10]	CO4	L2
2	Give comparison between the incineration and pyrolysis process. With a neat block diagram, explain the waste recovery management scheme.	[10]	CO4	L2
3	With a neat sketch, explain the following fixed bed gasifiers (i) Updraft; (ii) downdraft; and (iii) Cross draft. Mention their applications.	[10]	CO5	L2
4(a)	With a neat diagram, explain the different parts and working principle of biogas plant.	[5]	CO5	L2
4(b)	Compare the features of floating drum and fixed dome digesters.	[5]	CO5	L2
5	With a neat diagram, explain the single-basin and two-basin systems of harnessing tidal power.	[10]	CO5	L2
6	Classify wave energy devices. With neat sketches, explain the different types of wave energy devices used to harness wave energy.	[10]	CO6	L2
7	With a neat sketch, explain the working of a basic Rankine cycle. Explain Carnot efficiency for an OTEC plant with the help of a thermodynamic cycle on a T-S plane.	[10]	CO6	L2

CCI HOD/EEE

1) Explain the different ways of utilizing the geothermal resource. With a neat sketch, explain the operation of a binary cycle based geothermal power plant. [10 Marks]

GEOTHERMAL RESOURCE UTILIZATION

a)Direct Use of Low Grade Geothermal Energy

1. Aquaculture and horticulture: Geothermal renewable energy is used in aquaculture and horticulture in order to raise plants and marine life that require a tropical environment. The steam and heat are all supplied by geothermal energy. Many farmers use geothermal power to heat their greenhouses. In Tuscany, Italy, farmers have used water heated by geothermal energy for hundreds of years to grow vegetables in the winter. Hungary is also a major user of geothermal power. Eighty percentage of the energy demand from vegetable growers is met by using geothermal energy. It is also used in fishing farms. The warm water spurs the growth of animals ranging from alligators, shellfish, tropical fish, and amphibians to catfish and trout. Fish growers from countries like Oregon, Idaho, China, Japan, and even Iceland use geothermal power. 2. Industry and agriculture: Industries are another consumers of geothermal energy. Their uses vary from drying fruits, vegetables, and wood, dying wool to extracting gold and silver from ore. It is also used to heat sidewalks and roads to prevent freezing in the winter. Thus, geothermal power generation is playing a major role in industry and agriculture. Timber is dried using heat acquired from geothermal energy, and paper mills use it for all stages of processing. There are many potential uses of geothermal energy in the industry. 3. Food processing: The earth naturally contains an endless supply of heat and steam, which can be utilized to sterilize equipment and rooms. This would put an end to the use of chemicals for this purpose. There are many potential uses of geothermal energy in food processing, but as yet, this renewable energy source has yet to be utilized to a large degree in this sector. 4. Providing heat for residential use: The most common use of geothermal energy is for heating residential districts and businesses. The first uses of geothermal fluid for heating a district in United States dates back to 1893. However, the French dominance, by almost 500 years as per the records, indicates that they were using geothermal energy in the 15th century. In the last few years, this renewable energy has caught the interest of an increasing number of house owners. Geothermal power generation provides more than just heat in summer; but a complete temperature control system that enables you to cool your home in winter as well. This significantly reduces heating and cooling bills, and keeps the home at a comfortable temperature year round. Direct geothermal heating systems contain pumps and compressors, which may consume energy from a polluting source. This parasitic load is normally a fraction of the heat output, so it is always less polluting than electric heating. However, if the electricity is produced by burning fossil fuels, then the net emissions of geothermal heating may be comparable to directly burning the fuel for heat. For example, a geothermal heat pump powered by electricity from a combined-cycle natural gas plant would produce about as much pollution as a natural gas condensing furnace of the same size Therefore, the environmental value of direct geothermal heating applications is highly dependent on the emissions intensity of the neighbouring electric grid. Low temperature means temperatures of 149°C or less. Low-temperature geothermal resources are typically used in direct-use applications, such as district heating, greenhouses, fisheries, mineral recovery, and industrial process heating. Approximately 70 countries made direct use of 270 petajoules (PJ) of geothermal heating in the beginning of this century. More than half went for space heating, and another third for heated pools. The remainder supported industrial and agricultural applications. Global installed capacity was 28 GW, but capacity factors tend to be low (30% on average) since heat is mostly needed in winter. The abovementioned figures are dominated by 88 PJ of space heating extracted by an estimated 1.3 million geothermal heat pumps with a total capacity of 15 GW. Heat pumps for home heating are the fastest growing means of exploiting geothermal energy, with a global annual growth rate of 30% in energy production. Direct heating appliances of geothermal energy

are more efficient than electricity generation, as the former requires low temperature heat resources. Heat may come from co-generation via a geothermal electrical plant or from smaller wells or heat exchangers buried in shallow ground. As a result, geothermal heating is economic at many more sites than geothermal electricity generation. Where natural hot springs are available, the heated water can be piped directly into radiators. If the ground is hot and dry, heat exchangers can collect the heat. However, even in areas where the ground is colder than room temperature, heat can still be extracted with a geothermal heat pump more cost-effectively and cleanly than by conventional furnaces. These devices draw on much shallower and colder resources than traditional geothermal techniques, and they frequently combine a variety of functions, including air conditioning, seasonal energy storage, solar energy collection, and electric heating. Geothermal heat pumps can be used for space heating essentially anywhere. Geothermal heat supports many applications. District heating applications use networks of piped hot water to heat many buildings across entire communities. In the USSR, the energy that is represented by geothermal hot water is used for heating of buildings, soil warming.

green houses, and medical baths, and it is amounted to 15 million tons coal equivalent in 1970. In

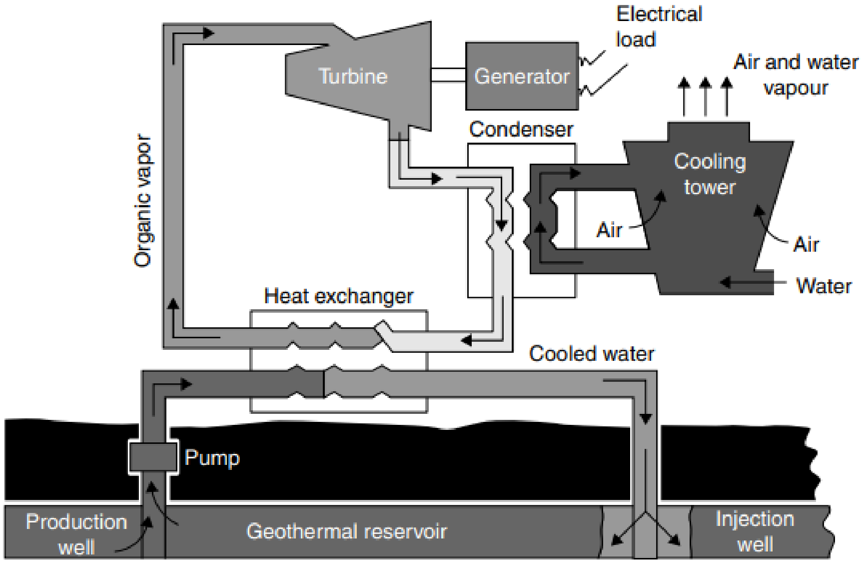
b)Electricity Generation

It provides not just heat and steam, but electricity itself. Geothermal power generation is completely clean, and releases no harmful gas emissions whatsoever. Geothermal fluid is a good electricity generator as well. Conversion technology for electricity generation is as follows: 1. Flashed Steam Plants: The water 'flash' boils and the steam is used to turn turbines. 2. Dry steam plants: These plants rely on the natural steam that comes from the underground reservoirs to generate electricity. 3. Binary power plants: These plants use the water to heat a 'secondary liquid' that vaporizes and turns the turbines. The vaporized liquid is then condensed and reused. 4. Hybrid power plants: In these plants, binary and flash techniques are utilized simultaneously. Low-temperature resources can generate electricity using binary cycle electricity-generating technology. Utilization of the earth's geothermal energy resources for production of electric power has been commercially developed in North America at the Geysers, north of San Francisco. A 12-MW unit commercial operation was started in 1960. Geothermal electric plants were traditionally built exclusively on the edges of tectonic plates where high temperature geothermal resources are available near the surface. The development of binary cycle power plants and improvements in drilling and extraction technology enable enhanced geothermal systems over a much greater geographical range. Demonstration projects are operational in LandauPfalz, Germany, and Soultz-sous-Forêst, France, while an earlier effort in Basel, Switzerland was shut down after it triggered earthquakes. Other demonstration projects are under construction in Australia, the United Kingdom, and the United States of America. Presently, it has an installed capacity of 11,000 MW approximately. Although the total installed capacity of geothermal power plant throughout the world presently is only around 11,000 MW, DE White of Geological Survey of America has estimated that world's geothermal field will be capable of producing more than 60,000 MW of electricity. At Larderello, boric acid is an important gaseous by-product of electricity generation while this field also demonstrated the feasibility of commercially producing carbon dioxide, sulphur, ammonium sulphate, and ammonium carbonate. A dual-purpose application at Panzhetsho (USSR) generates electricity from steam and employs separated hot water for heating purpose in the local settlement. The success achieved by these activities has stimulated further exploitation in the USA, the USSR, Iceland, Japan, EI Salvador, and the Philippines, while reconnaissance programs have been inaugurated in Chile, EI Salvador, India, Kenya, and Ethiopia.

Binary Cycle-based Geothermal Plants

In the binary process, the geothermal fluid, which can be either hot water, steam, or a mixture of the two, heats another liquid such as isopentane or isobutane (known as the 'working fluid'), that boils at a lower temperature than water. The two liquids are kept completely separate through the use of a heat exchanger that is used to transfer heat energy from the geothermal water to the working fluid. When heated, the working fluid vaporizes into gas and (like steam) the force of the expanding gas turns the turbines that power the generators. Technology developments during the 1980s have advanced lower temperature geothermal electricity production. These plants, known as ‘binary’ geothermal plants, today make use of resource temperatures as low as 74°C (assuming certain parameters are in place) and as high as 177°C. Approximately 15% of all geothermal power plants utilize binary conversion technology.

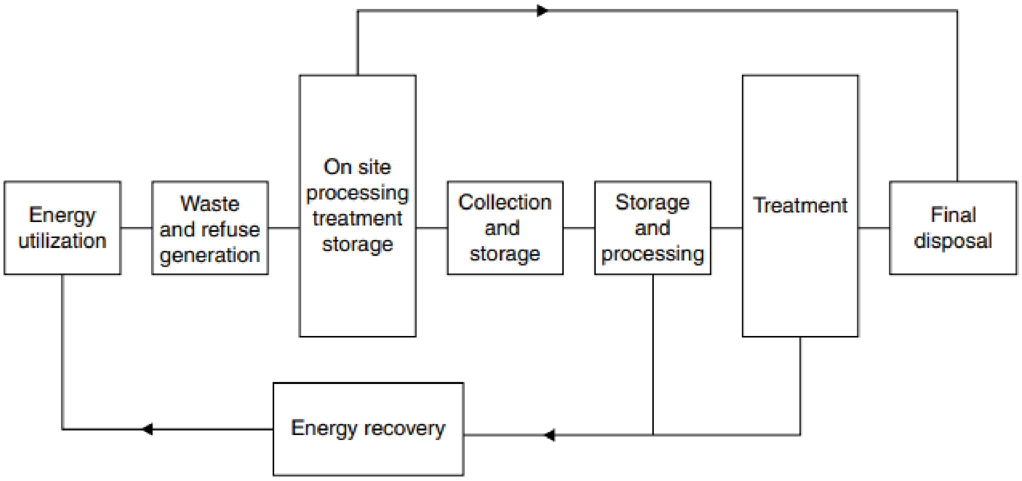
Source: Geo-Heat center



2) Give comparison between the incineration and pyrolysis process. With a neat block diagram, explain the waste recovery management scheme. [10 Marks]

Pyrolysis	Incineration
It is the thermal degradation in the absence of oxygen.	It requires oxygen in the form of air.
Pyrolysis is carried out at lower temperatures, 450°C–500°C and there is no combustion.	Incineration is carried out at higher temperatures (about 850°C or higher) and combustion takes place.
It produces the liquid fuel of useful high quality although the syngas is quite rich in carbon monoxide and hydrogen as well.	Incineration produces energy as heat (low level) that can be used to create steam for generating electrical power, industrial process, or district heating.
Pyrolysis is a controlled chemical process (temperature, pressure, batch or continuous system, catalyst, etc.) in order to produce valuable secondary raw materials (solid, liquid, or gas) or energy.	Incineration is to reduce the quantity of waste to be landfilled.
The pyrolysis system for treatment of MSW and other wastes demonstrates excellent practical performance in controlling the emission of harmful substances like dioxins.	Like coal combustion, the incineration of MSW produces carbon dioxide, as well as nitrogen and sulphur oxides and a range of other gas phase organic and inorganic air emissions.

WASTE RECOVERY MANAGEMENT SCHEME



The major part of waste obtained after the energy utilization are non-organic that have diversified nature and characteristics, and thus, their identification and separation from the main waste stream by improved techniques are an essential parameter of any energy recovery scheme. On-site processing of waste for the reduction of in-home compactors and industrial shredders through improved technology should be employed, which may be environmentally acceptable. Collection and transportation components of the waste energy conversion scheme are the most expensive components owing to many varying social, technical, and other reasons. A careful cost analysis and implementation of this vital component will minimize the running cost of the scheme. The storage of waste for resource recovery and final disposal after suitable treatment is another component of scheme and selection of storage station and other associated problems invite careful attention. Normally, two types of energy recovery systems are used:

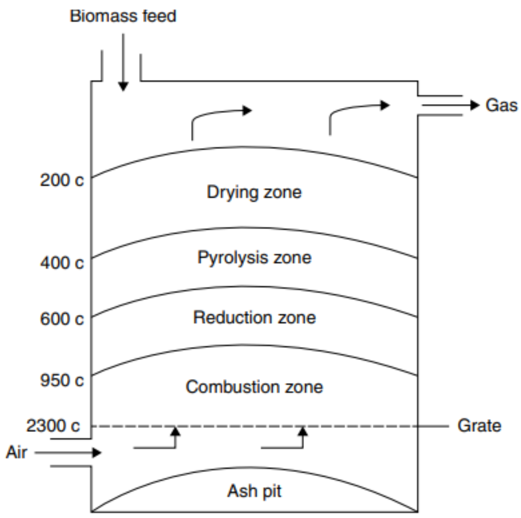
1. Separation of metals, paper, and glass from the remaining waste through the process such as size reduction, screening, vibrating sorting, and electronic scanning; however, a truly homogeneous, inexpensive separation system will provide competitive input to waste energy utilization. 2. Conversion of the remaining waste product to usable form of energy and energy conversion may include the following: (a) Generation of methane gas (biogas conversion) or other fuels (biological conversion) (b) Generation of electricity either from (a) or through thermo-mechanical process (c) Composting of fertilizer.

3)With a neat sketch, explain the following fixed bed gasifiers (i) Updraft; (ii) downdraft; and (iii) Cross draft. Mention their applications. [10 Marks]

UPDRAFT GASIFIERS

The oldest and simplest type of gasifier is the counter current or updraft gasifier shown schematically in Figure 9.3. The air intake is at the bottom and gas leaves at the top (the counter current flow). The reactive agent is injected at the bottom of the reactor and ascends to the top, while the fuel is introduced at the top and descends to the bottom. The combustion reactions occur near the grate at the bottom that are followed by reduction reactions somewhat higher up in the gasifier. In the upper part of the gasifier, heating and pyrolysis of the feedstock occur as a result of heat transfer by forced convection and radiation from the lower zones. Gases, tar, and other volatile compounds are dispersed at the top of the reactor, while ash is removed at the bottom. The syngas typically contains high levels of tar, which must be removed or further converted to syngas for use in applications other than direct heating. Updraft gasifiers are widely used to gasify biomass resources and generally use steam as the reactive agent, but slagging can be severe if high ash fuels are used. They are unsuitable for use with fluffy, low-density fuels.

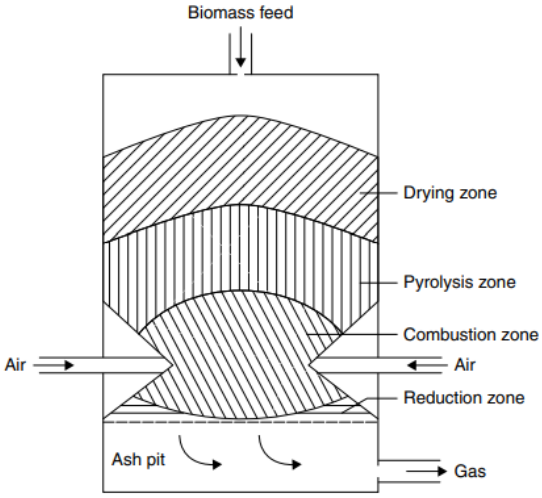
These gasifiers are best suited for applications where moderate amounts of dust in the fuel gas are acceptable and a high flame temperature is required. Typical applications where the updraft gasifiers have been successfully used are as follows: 1. Packaged boilers 2. Thermal fluid heaters 3. Aluminium melting/annealing furnaces 4. All kinds of fryer roaster



DOWNDRAFT GASIFIER

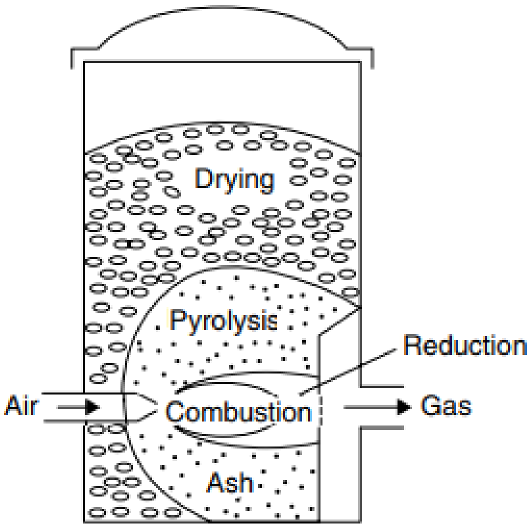
In this gasifiers, the primary gasification air is introduced at or above the oxidation zone in the gasifier and the producer gas is removed at the bottom of the apparatus, so that fuel and gas move in the same direction. The biomass feed (such as wood waste) and its gasification air both flow in the same downward direction through the gasifiers' fuel bed. The biomass feed is admitted at the top similar to the updraft gasifier. As the feed progresses down through the gasifier, it dries and its volatiles are pyrolysed. The char is directed into a reduceddiameter cylindrical throat section at the bottom of the gasifier. Gasification air is injected into the throat through openings in the throat wall. Due to the high temperatures existing at the throat section, tars and oils could be cracked, which tend to form in producer gas, particularly when the biomass is wetter than about 20% moisture content (wet basis). The producer gas leaves at the bottom of the gasifier. The start-up time of about 5–10 min is necessary to ignite and bring plant to working temperature with good gas quality is shorter than updraft gas producer. Downdraft gasifiers are widely used in the following applications:

1. Continuous baking ovens (bread, biscuits, and paint) 2. Batch type baking oven (rotary oven for bread) 3. Dryers and curing (tea, coffee, mosquito coil, and paper drying) 4. Boilers 5. Thermal fluid heater.



CROSS-DRAFT GASIFIER

Unlike downdraft and updraft gasifiers, the ash bin, fire, and reduction zone in cross-draft gasifiers are separated. These design characteristics limit the type of fuel for operation to low ash fuels such as wood, charcoal, and coke. The relatively high temperature in cross-draft gas producer has an obvious effect on gas composition such as high carbon monoxide, and low hydrogen and methane content when dry fuel like charcoal is used. Cross-draft gasifier operates well on dry air blast and dry fuel. Typically, the gasifier is a vertical cylindrical vessel of varying cross section. The biomass is fed in at the top at regular intervals of time and is converted through a series of processes into producer gas and ash, as it moves down slowly through various zones of the gasifier.



4 a) With a neat diagram, explain the different parts and working principle of biogas plant. [5 Marks]

It is a brick and cement structure having
the following five sections:
1. Mixing tank

2. Digester tank
3. Dome or gas holder
4. Inlet chamber
5. Outlet chamber

a) Mixing Tank It is the first part of biogas plants located above the ground level in which the water and cow dung are mixed together in equal proportions (the ratio of 1:1) to form the slurry that is fed into the inlet chamber.

b) Digester Tank It is a deep underground well-like structure and is divided into two chambers by a partition wall in between. It is the most important part of the cow dung biogas plants where all the important chemical processes or fermentation of cow dung and production of biogas takes place. The digester is also called as fermentation tank. It is cylindrical in shape and made up of bricks, sand, and cement built underground over the solid foundation. Two openings are provided on the opposite sides and at the specified height of digester for inflow of fresh cow dung slurry and outflow of used slurry as manure. The two long cement pipes are used as follows: 1. Inlet pipe opening into the inlet chamber for inputting the slurry in digester tank. 2. Outlet pipe opening into the overflow tank (outlet chamber) for the removal of spent slurry from the digester tank. A separator is also placed in the middle of digester tank to improve effective fermentations of feedstock.

c)Dome or Gas Holder

The hemispherical top portion of the digester is called dome. It has fixed height in which all the gas generated within the digester is collected. The gas collected in the dome exerts pressure on the slurry in the digester. The dome or gas holder is made either fixed dome or floating dome type. Cement and bricks are used in the construction of fixed dome, and it is constructed using approximately at the ground surface. Floating dome type is an inverted steel drum resting on the digester above the ground surface. The drum floats over the digester and moves up and down with biogas pressure.

d) Inlet Chamber

The cow dung slurry is supplied to the digester of the biogas plant via inlet chamber, which is made at the ground level so that the slurry can be poured easily. It has bell mouth sort of shape and is made up of bricks, cement, and sand. The outlet wall of the inlet chamber is made inclined so that the slurry easily flows into the digester.

e) Outlet Chamber

The digested slurry from the biogas plants is removed through the outlet chamber. The opening of the outlet chamber is also at the ground level. The slurry from the outlet chamber flows to the pit made especially for this purpose.

f) Gas Outlet Pipe and Valve The gas holder has an outlet at the top which could be connected to gas stoves for cooking or gas-lighting equipments or any other purpose. Flow of the gas from the dome via gas pipe can be controlled by valve. The gas taken from the pipe can be transferred to the point of use.

g) Foundation The foundation forms the base of the digester where the most important processes of biogas plant occur. It is made up of cement, concrete, and bricks strong enough so that it should be able to provide stable foundation for the digester walls and be able to sustain the full load of slurry filled in it. The foundation should be waterproof so that there is no percolation and leakage of water.

Working of Biogas Plant

The working principle of biogas plant can be explained in Figure 10.2. The various steps of working principle of biogas plants are as follows: 1. Cattle dung and water are mixed together thoroughly in equal proportion (in the ratio of 1:1) to form the slurry in the mixing tank. Then, this slurry is poured into the digester via inlet chamber up to the cylindrical portion level of the digester.

2. The fermentation of slurry starts in the digester tank, and after completion of different anaerobic digestion processes, biogas is formed.
The gas continuously produced in digester tank is accumulated at the top of the digester in the dome or gas holder. Normally, the outlet gas valve remains closed, and hence, the accumulated biogas in the dome exerts pressure on the slurry which starts moving in the inlet and outlet chamber due to which the level of slurry drops in digester and increases in the outlet chamber. This process continues till the slurry reaches to highest possible level in the inlet and outlet chamber because of increased gas pressure. 4. If the gas valve is still kept closed the biogas will further get accumulated in the dome and develop high pressure enough in the gas to start escaping through the inlet and outlet chambers to the atmosphere. The biogas creates bubbles in the slurry in inlet and outlet chambers during its escape, and froth is also formed. 5. An increase in the volume of slurry in the inlet and outlet chambers helps to calculate the amount of biogas generated within the digester. 6. Gas pipe valve can be opened partly or fully to provide biogas for different applications. Under this situation, slurry level in the digester increases while the level in inlet and outlet chambers reduces. 7. When the gas is being taken out from the gas outlet at the top of the dome, the slurry from the outlet chamber is removed and equivalent amount of fresh slurry is inducted into the digester to continue the process of fermentation and the formation of the biogas. Therefore, more is the biogas required, more continuous will be the fresh slurry of cow dung and water required. The size of the digester tank also decides the amount of the gas that can be generated by the biogas plant.

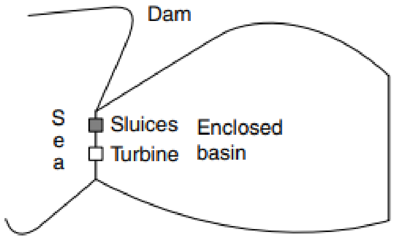
4 B) Compare the features of floating drum and fixed dome digesters. [5 Marks]

Fixed dome	Floating drum
• masonry of concrete structure entirely	masonry digester with steel, plastic or composite based gas holder
• low costs	high costs (20-30 per cent higher)
• low maintenance	frequent maintenance
• low reliability	high reliability
• high masonry and supervisory skill required	low masonry and fabricating skills
• variable gas pressure complicates appliance design	constant gas pressure simplifies appliance design and usage

5. With a neat diagram, explain the single-basin and two-basin systems of harnessing tidal power. [10 Marks]

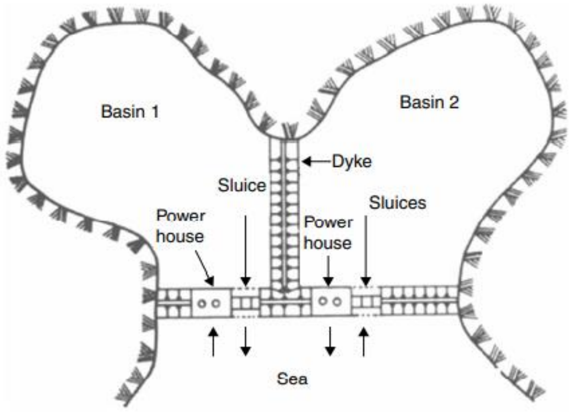
Single-basin System
Single water reservoir is closed off by constructing dam or barrage. Sluice (gate), large enough to admit the water during tide so that the loss of head is small, is provided in the dam The single-basin system has two configurations, namely: 1. One-way single-basin system: The basin is filled by seawater passing through the sluice gate during the high tide period. When the water level in the basin is higher than the sea level at low tide period, then power is generated by emptying the basin water through turbine generators. This type of systems can allow power generation only for about 5 h and is followed by the refilling of the basin. Power is generated till the level of falling

tides coincides with the level of the next rising tide. 2. Two-way single basin: This system allows power generation from the water moving from the sea to the basin, and then, at low tide, moving back to the sea. This process requires bigger and more expensive turbine. Single-basin system has the drawbacks of intermittent power supply and harnessing of only about 50% of available tidal energy.



Two-basin System

An improvement over the single-basin system is the two-basin system. In this system, a constant and continuous output is maintained by suitable adjustment of the turbine valves to suit the head under which these turbines are operating. A two-basin system regulates power output of an individual tide, but it cannot take care of the great difference in outputs between spring and neap tides. Therefore, this system provides a partial solution to the problem of getting a steady output of power from a tidal scheme. This disadvantage can be overcome by the joint operation of tidal power and pumped storage plant. During the period, when the tidal power plant is producing more energy than required, the pumped storage plant utilizes the surplus power for pumping water to the upper reservoir. When the output of the tidal power plant is low, the pumped storage plant generates electric power and feeds it to the system. This arrangement, even though technically feasible, is much more expensive, as it calls for high installed capacity for meeting a particular load. This basic principle of joint operation of tidal power with steam plant is also possible when it is connected to a grid. In this case, whenever tidal power is available, the output of the steam plant will be reduced by that extent that leads to saving in fuel and reduced wear and tear of steam plant. This operation requires the capacity of steam power plant to be equal to that of tidal power plant and makes the overall cost of power obtained from such a combined scheme very high. In the system shown in Figure 11.2, the two basins close to each other, operate alternatively. One basin generates power when the tide is rising (basin getting filled up) and the other basin generates power while the tide is falling (basin getting emptied). The two basins may have a common power house or may have separate power house for each basin. In both the cases, the power can be generated continuously. The system could be thought of as a combination of two single-basin systems, in which one is generating power during tiding cycle, and the other is generating power during emptying.



6) Classify wave energy devices. With neat sketches, explain the different types of wave energy devices used to harness wave energy.[10 Marks]

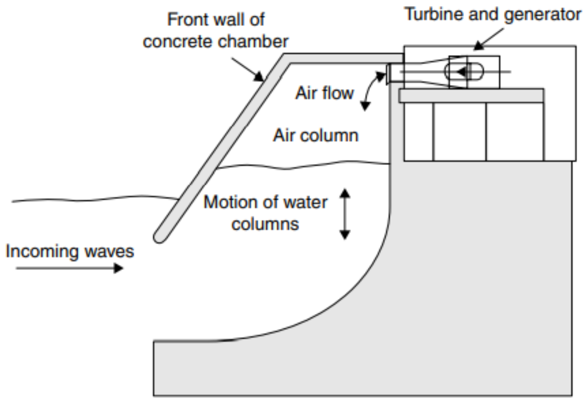
There are three basic technologies for converting wave energy to electricity. They are as follows: 1. Terminator devices: It is a wave energy device oriented perpendicular to the direction of the wave and has one stationary and one moving part. The moving part moves up and down like a car piston in response to ocean waves and pressurizes air or oil to drive a turbine. An oscillating water column (OWC) converter is an example of terminator device. These devices generally have power ratings of 500 kW to 2 MW, depending on the wave parameters and the device dimensions. 2. Attenuator devices: These devices are oriented parallel to the direction of the waves and are long multi-segment floating structures. It has a series of long cylindrical floating devices connected to each other with hinges and anchored to the seabed. They ride the waves like a ship, extracting energy by using restraints at the bow of the device and along its length. The segments are connected to hydraulic pumps or other converters to generate power as the waves move across. Pelamis wave energy converter is one of the known examples of attenuator devices. 3. Point absorber: It is a floating structure with parts moving relative to each other owing to wave action but it has no orientation in any defined way towards the waves instead absorbs the wave energy coming from any direction. It utilizes the rise and fall of the wave height at a single point for energy conversion. The pressurized water creates up and down bobb in type motion and drives a built-in turbine generator system to generate electricity. Aqua BuOY WEC is an example of point absorber devices. 4. Overtopping devices: These devices have reservoirs like a dam that are filled by incoming waves, causing a slight build-up of water pressure. Gravity causes released water from reservoir to flow back into the ocean through turbine coupled to an electrical generator. Salter Duck WEC is the example of overtopping devices.

a) Float or Buoy Devices

A series of anchored buoys rise and fall with the wave that creates mechanical energy to drive electrical generator for generation of electricity, which is transmitted to ocean shore by underground cables.

b) Oscillating Water Column Devices

An oscillating water column device (OWC device) is shown in Figure 12.5. It is a form of terminator in which water enters through a subsurface opening into a chamber, trapping air above. The wave action causes the captured water column to move up and down like a piston, forcing the air though an opening connected to a turbine to generate power. It is a shoreline-based oscillating water column (OWC) build in UK. Further, it is installed at Islay. It is a concrete structure partially submerged in seawater and encloses a column of air on top of a column of water. The water columns in partially submerged chamber rise and fall, when sea waves impinge on the device. This wave action alternatively compresses and depressurizes the air column, which is allowed to flow to and from the atmosphere via a turbine. The energy can then be extracted from the system and used to generate electricity. Wells' turbines as shown in Figure 12.6 are used to extract energy from the reversing air flow. It has the property of rotating in the same direction regardless of the direction to the airflow.

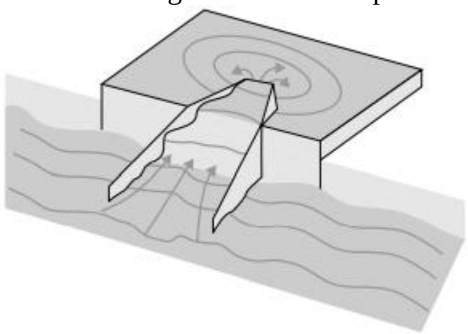


c) Pendulum System

A pendulum flap is hinged over this opening, which swings back and forth by the actions of the waves. The back and forth motion of pendulum is then used to power a hydraulic pump and an electric generator

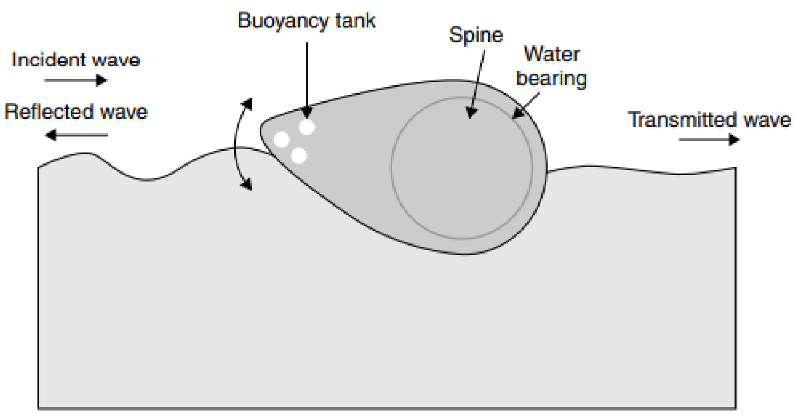
d) TAPCHAN (Tapered Channel)

It has a tapered channel connected to a reservoir constructed above the sea level at a height of 3–5 m. They are relatively low power output devices and suitable for deep-water shore line and low tidal range. It is a very simple device. Waves collect into a channel, which tapers into a large reservoir. The potential energy of water stored in the reservoir is extracted by releasing the reservoir water back to the sea through a low head Kaplan turbine coupled to an electrical generator.



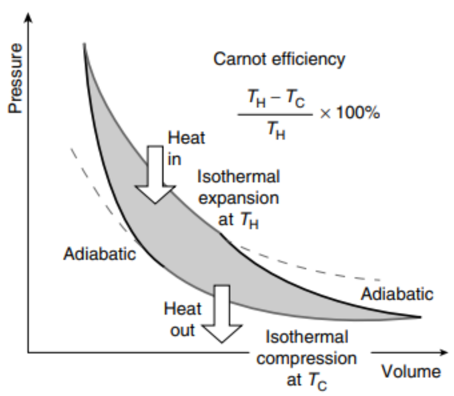
e) Salter's Duck System

It is an egg-shaped device that moves with the motion of the waves. The shape of leading edge of the duck is in such a way that the approaching sea wave pressure is exerted on the duck. It forces the duck to rotate about a central axis and the tip of the cam bobs up and down in the water. As the Salter Duck moves (or bobs or rocks) up and down on the sea waves, pendulum connected to electrical generator swings forward and backward to generate electricity. Two sets of cables are attached to the device, one to a pendulum inside the device and the other to a fixed arm outside the device. The cables attached to the internal pendulum contain hydraulics that pumps as the device moves back and forth with the waves. This movement of the pressurized oil pumped into hydraulic machine that drives electric generators.



7) With a neat sketch, explain the working of a basic Rankine cycle. Explain Carnot efficiency for an OTEC plant with the help of a thermodynamic cycle on a T-S plane. [10 Marks]

The basic Rankine cycle shown in consists of the following:
1. An evaporator
2. A turbine expander
3. A condenser 4. A pump 5. 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 vapourizes. Then, the vapour of boiling fluid enters the turbine expander coupled with an electrical generator to generate electrical power. The vapour released from the turbine enters into condenser where it condenses. The cold deep sea water is pumped through the condenser for heat rejection from vapour 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.
The Carnot cycle is the most efficient thermodynamical cycle by exploiting the warm sea surface water and cold deep sea water
Let W be the work done by the system (energy exiting the system as work), QH be the heat put into the system (heat energy entering the system)
TC be the absolute temperature of the sea surface and TH be the absolute temperature of the deep sea water hot reservoir.
Carnot efficiency (h) is given by the following equation: h = W/QH = 1 − TC/TH



Selection of Working Fluids

The steam Rankine cycle and organic Rankine cycle are the two main types used in OTEC systems, and the choice of working fluids plays an important role in design and performance of OTEC. Water is the only working fluid for steam Rankine cycle, but a large number of working fluid is available for organic Rankine cycle. The working fluid has the following properties: 1. Chemical stability and compatibility: Certain organic fluids are more prone to decompose when subjected to high pressure and temperature which results in material corrosion of different parts of plants, explosion etc. Thus, working fluid should be chemically stable and compatible with materials and structures of OTEC plants. 2. Heat transfer coefficient: Low-thermal resistance of working fluids improves heat transfer . 3. Flash point: A working fluid with a high flash point should be used in order to reduce flammability. 4. Specific heat: A working fluid with a low specific heat should be used to reduce load on the condenser. 5. Latent heat: A working fluid with a high latent heat should be used in order to raise the efficiency of heat recovery. 6. Safety: Working fluid should be non-corrosive, non-toxic, and non-inflammable having maximum allowable concentration and explosion limit for safe and efficient operation of OTEC plants. 7. Environmental acceptability: Low-toxicity working fluid minimizes water contamination. The environmental risk of OTEC plant is low. 8. Cost and availability: The ease of availability and low cost of working fluid is also important.