CBCS SCHEME

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BME654B

Sixth Semester B.E./B.Tech. Degree Examination, June/July 2025
Renewable Energy Power Plants

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.

		Module – 1	M	L	C
Q.1	a.	Explain briefly different renewable and non-renewable energy sources.	10	L2	CO1
	b.	Explain environmental benefits and challenges of renewable energy sources.	10	L2	CO1
		OR			
Q.2	a.	Explain extra-terrestrial radiation and special distribution of extra terrestrial radiation.	10	L2	CO1
	b.	Explain solar radiation at the earth's surface.	10	L2	CO1
		Module – 2			
Q.3	a.	Explain pyranometer with neat sketch.	10	L2	CO2
	b.	Explain pyrheliometer with neat sketch.	10	L2	CO2
		OR			
Q.4	a.	Explain PV system components and their functionalities.	10	L2	CO2
	b.	What are the design considerations for solar power plants.	10	L2	CO2
		Module – 3			
Q.5	a.	Explain horizontal wind energy power plant with diagram.	10	L3	CO3
	b.	Explain the parameters effecting the energy extraction through wind.	10	L2	CO1
		OR			
Q.6	a.	Explain with schematic diagram the working of a dry steam geothermal power plant.	10	L3	CO3
	b.	What are the problems associated with geothermal conversion.	10	L2	CO3
		Module – 4			
Q.7	a.	Explain different ways to extract energy through tides with neat diagram.	10	L3	CO4
	b.	Explain different ways to extract energy through waves with neat diagram.	10	L2	CO4
		OR			
Q.8	a.	Describe OTEC and working principle with neat sketch.	10	L2	CO4
	b.	What are the problems associated with OTEC.	10	L2	CO4
		Module – 5			
Q.9	a.	Explain fixed dome biogas power plant with diagram.	10	L2	CO5
	b.	Explain gasification with diagram.	10	L2	CO5
		OR			
Q.10	a.	Explain Hydrogen Production Technology (Electrolysis method).	10	L2	CO5
	b.	Describe advantages of hydrogen energy.	10	L2	CO5

* * * * *

1 @. Different renewable & non renewable energy sources.

sol^{n} :- Renewable energy resources are continuously restored by the nature. They don't run out easily & are generally environmental friendly.

ex :- Solar energy - energy from the sun.

Wind energy - Energy from moving air.

Hydropower - Energy from flowing water.

Biomass energy - Energy from plant & animal waste.

Geothermal energy - Energy from heat inside the earth.

Advantages :-

Sustainable & abundant

Less pollution.

Reduces greenhouse gas emissions.

Non - Renewable Energy sources:

Non - renewable energy comes from resources that are limited & take millions of years to form. Once used, they cannot be quickly replaced.

Examples:-
- coal, oil, natural gas, nuclear energy.

Disadvantages:-
Limited supply.
cause pollution & climate change.
can harm the environment.

1 (b) Environmental benefits of Renewable Energy Source,

1) Low greenhouse gas emissions.
Sources like solar, wind & hydropower produce little to no CO_2 during operation, helping reduce climate change.

2) Reduced Air pollution.
Renewables don't release harmful pollutants such as sulphur dioxide or nitrogen oxides.

3) Sustainable resource use:-
Renewable sources are naturally replenished & do not run out.

4) Less water ~~pollution~~. (pollution)

Generally produce less water contamination compared to coal, oil or nuclear power plants.

5) Lower overall environmental impact

Once installed, many renewable systems operate with minimal environmental disturbance.

Environmental challenges.

1) Land use & habitat disruption.

Large Solar farms & wind farms may disturb wildlife habitats & ecosystems.

2) Impact on wildlife.

Wind turbines can affect birds & bats, hydropower dams can disrupt fish migration.

3) Resource & material use.

manufacturing solar panels, wind turbines & batteries requires mining metals & some material which can harm the environment.

4) Energy storage issues.

Renewable energy is intermittent, requiring batteries or backup systems that have environmental costs.

2 @ Extra terrestrial radiation.

The solar energy recieved above the earths atmosphere around the earth is called the extraterrestrial radiation. The extra terrestrial radiation varies based on the change in sun-earth distance arising from earths elliptical orbit of rotation. The extraterrestrial radiation is not affected by change in atmospheric conditions.

Empirically represented by:

$$I_{ext} = I_{sc}\left(\frac{R_{av}}{R}\right)^2$$

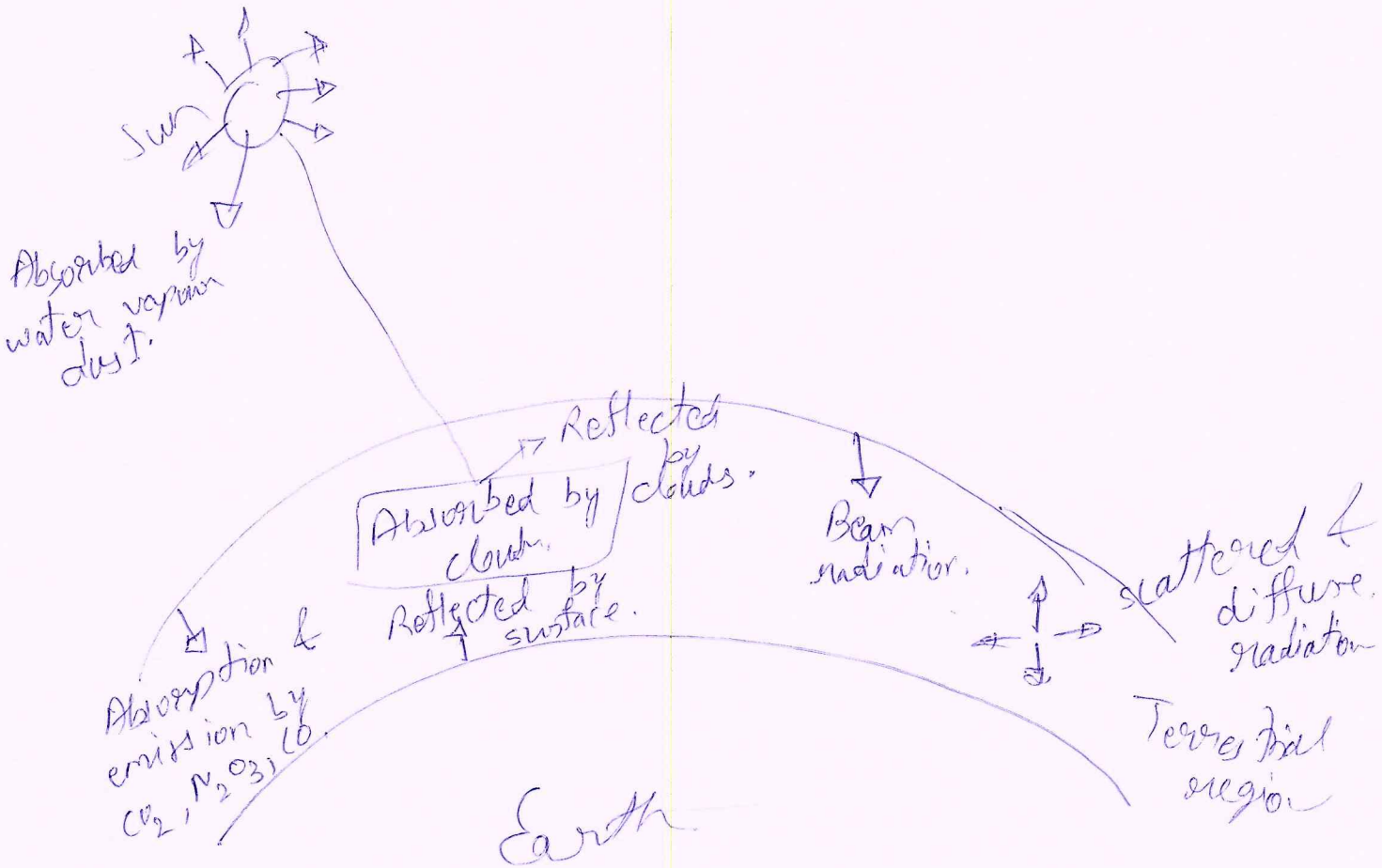
I_{sc} = solar constant = 1367 W/m^2.

R_{av} = Mean sun-earth distance 1.5×10^8 km.

R = Actual sun-earth distance depending on the day of year.

Spectral distribution:

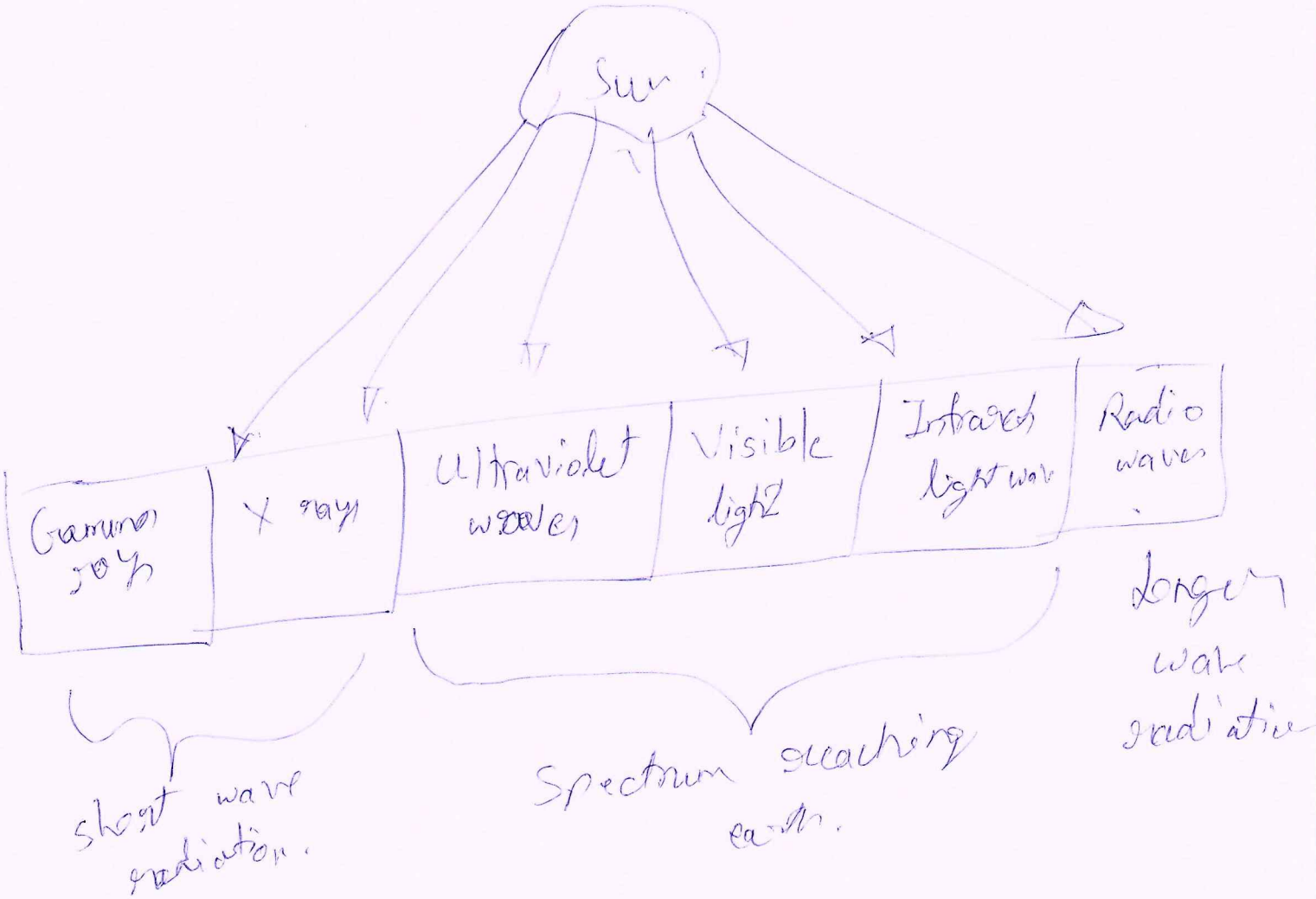
The amount of solar radiation that reaches any given location is dependent on several factors including the geographic location, time of day, season, landscape & local weather.



As the earth is round, the sunrays strikes the surface at different angle ranging from 0° to 90°. When sunrays are vertical the earth surface gets max energy possible. the more slanted the sunrays are the longer they travel through atmosphere.

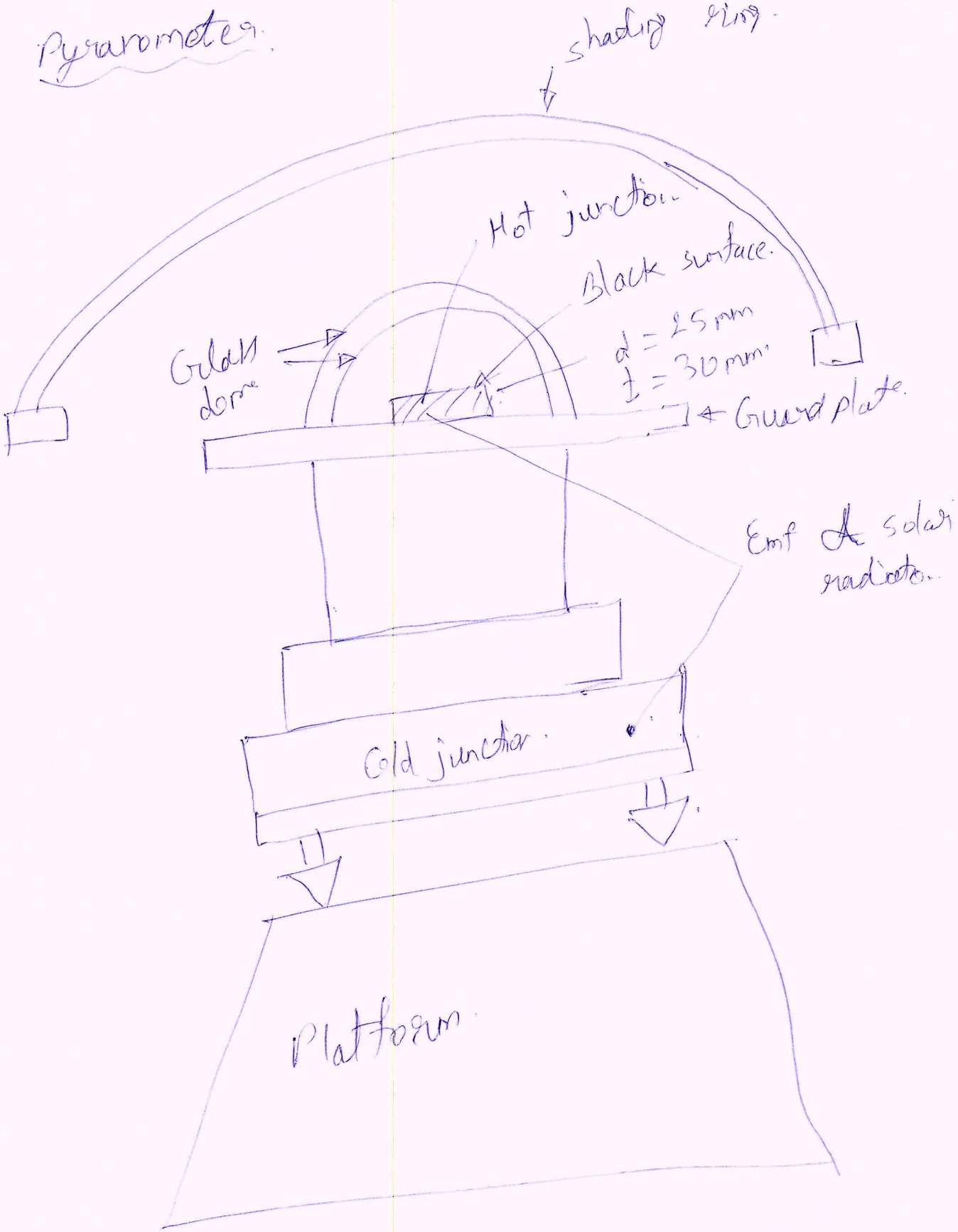
2(b) Solar radiation:

Solar radiation is energy transmitted by the sun by virtue of its temperature. The energy thus emitted travels even in the vacuum in the form of electromagnetic waves or discrete photon. This radiation energy emitted by sun consists of different wavelength spectrum.



Region	Wavelength Range	Description / Importance.
1. UVC.	0.1 μm - 0.28 μm	High energy radiation, completely absorbed by atmosphere.
2. UVB	0.28 μm - 0.315 μm	Partially absorbed, contributes to ozone formation
3. UVA.	0.315 μm - 0.4 μm.	Least absorbed UV, penetrates skin, used in therapy.
4. Visible light	0.38 μm - 0.78 μm	Visible to the human eye, major contributer to solar energy.
5. Infrared (IR).	0.7 μm - 100 μm	Perceived as heat, contributes to Earth's surface heating.

3 @ Pyranometer.

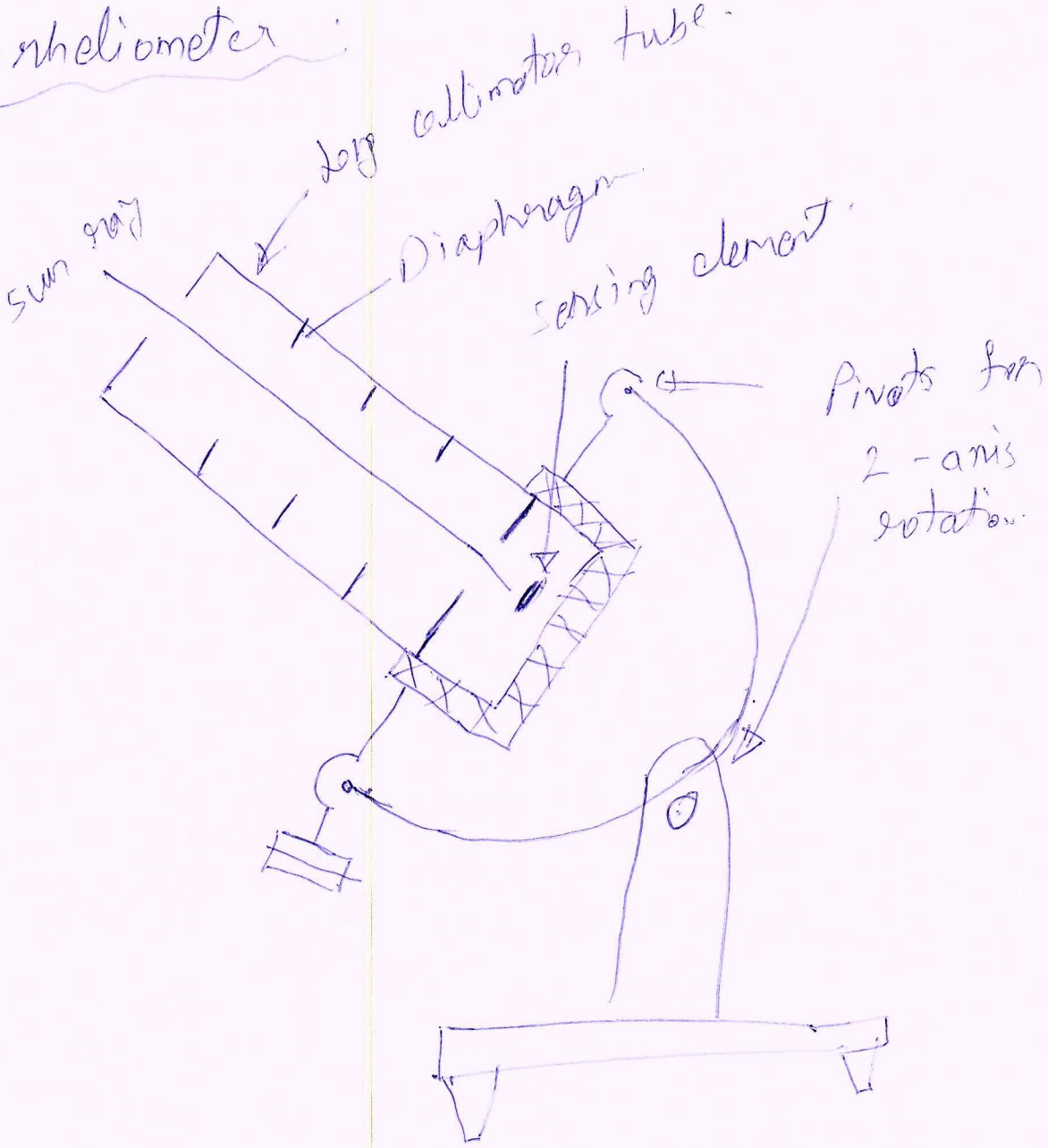


A pyranometer is an instrument which measure either global or diffuse radiation falling on a horizontal surface over a hemispheric field.

Pyranometer consists of a black surface which boost up when exposed to solar radiation Its temp increase until the rate of heat gain by a solar radiation equals to the radiation of heat lost by black surface by convention, conduction & radiation.

The hot junction of a thermocouple is attached to the black surface, while cold junction is located under a ground plate so that they dont receive the radiation directly. As a result an emf is generated. This emf which is usually in the range of 0 to 10 mV can be read, recorded or integrated over a period of time & is a measure of global radiation.

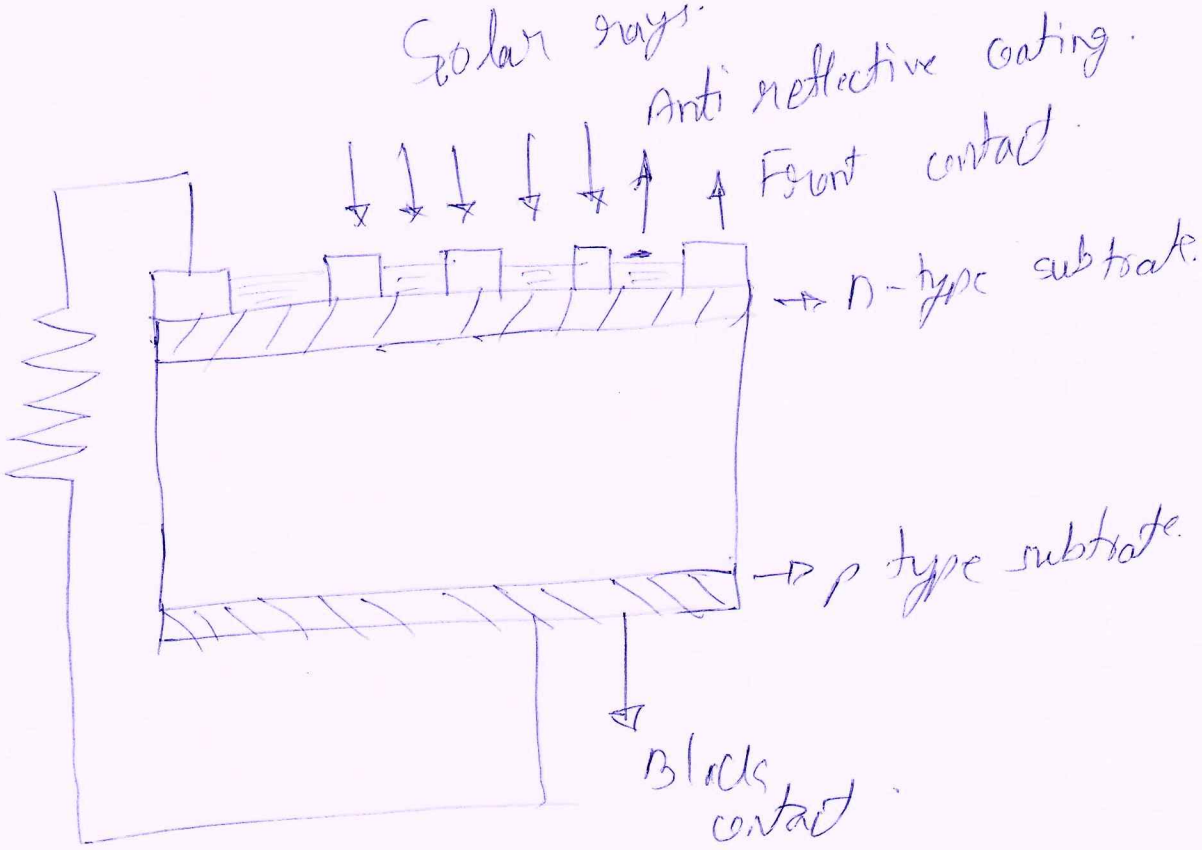
3 (b) Pyrheliometer:



The normal incidence pyranometer uses a long collimator tube to collect beam radiation on whose field of view is limited to a solid angle of 5.5° by appropriate diaphragms inside the tube. The inside of tube is blackened to absorb any radiation ~~who~~ ~~f~~ incident at angles outside the collection solid angle.

At the base of the tube a wire wound thermopile having a sensitivity of approximately 8 μV/w/m² and o/p impedance of approximately 200 Ω is provided. The tube is sealed with dry air to eliminate absorption of beam radiation within the tube by water vapour. A tracker is needed if continuous readings are desired.

4 @.



PV system components.

4@.

Substrate:- It is an unpolished p-type water referred to as p-region base material. parameters to consider are its orientation, resistivity, thickness & doping.

Emitter:- The emitter formation involve the doping of silicon with pentavalent impurities such as phosphorus, arsenic, & antimony. The doping is done by the process of diffusion.

Electrical contacts:-

contacts bridge the connection between the semiconductor material & external electrical load. It includes back contact & front contact.

Anti-reflective coatings:-

Anti reflective coatings are applied to reduce surface reflection & maximize cell efficiency in solar glass & silicon solar cell manufacturing. It helps to reduce the reflection of desirable wavelength from the cell, allowing more light to reach the semiconductor film layer, increasing solar cell efficiency.

4 (b). Design consideration for solar power plants.

When designing a solar power plant, one has to consider the location, the amount of power needed, the materials & safety.

1) Location

- Solar irradiance :- The amount of sunlight available at the location.
- Temperature :- The average temperature of the location.
- Land cover :- The type of land.
- Distance to transmission line :- How close the site is to transmission lines.
- Flood susceptibility

2) Power need :-

- Power consumption :- How much power the plant will need to produce.
- PV modules :- The size & number of PV panels needed.

3> Materials :-

Mounting structure :-

A stable structure that can support the PV panels & withstand the weather condition.

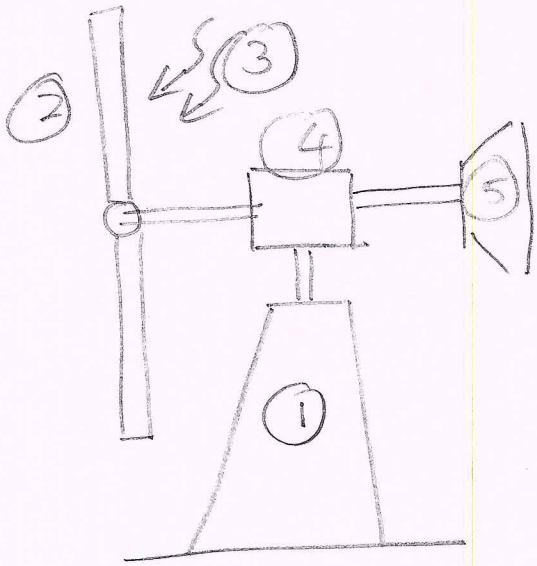
4> Safety and security :-

Ensuring the safety & security to working peoples & surroundings.

(10)

Q5a) Horizontal wind energy power plant-

Block Diagram:



(1) → Support Structure
(2) → Rotor
(3) → wind
(4) → wind mill head
(5) → Tail Vane.

→ Horizontal Wind Energy Power Plant - (HWEPP).
- It uses a wind turbine whose axis of rotation is parallel to the ground

Working:
- Due to the wind power flow, rotor blades rotate
- This in turn rotate the hub and rotor shaft
- The gear box present in the windmill head increases the rotational speed
- Thus Generator mechanism converts mechanical energy to electricity
- The Generated power flows through the cables to a transformer
- Thus electricity is supplied to the grid.

Generated power is $P = \frac{1}{2} \rho A V^3 C_p$.

Module - 3

Q5b Following are the main effects due to a wind turbines.

(i) Electromagnetic interference: It may cause interference with TV and other EM communication system which may weaken the signals, It can be avoided by dispensing with aerials and sending TV signals by cable in areas affected

(ii) Noise: First type of noise is mechanical noise from gearbox and second type is by aerodynamic in nature produced by the movement of the turbine blades.

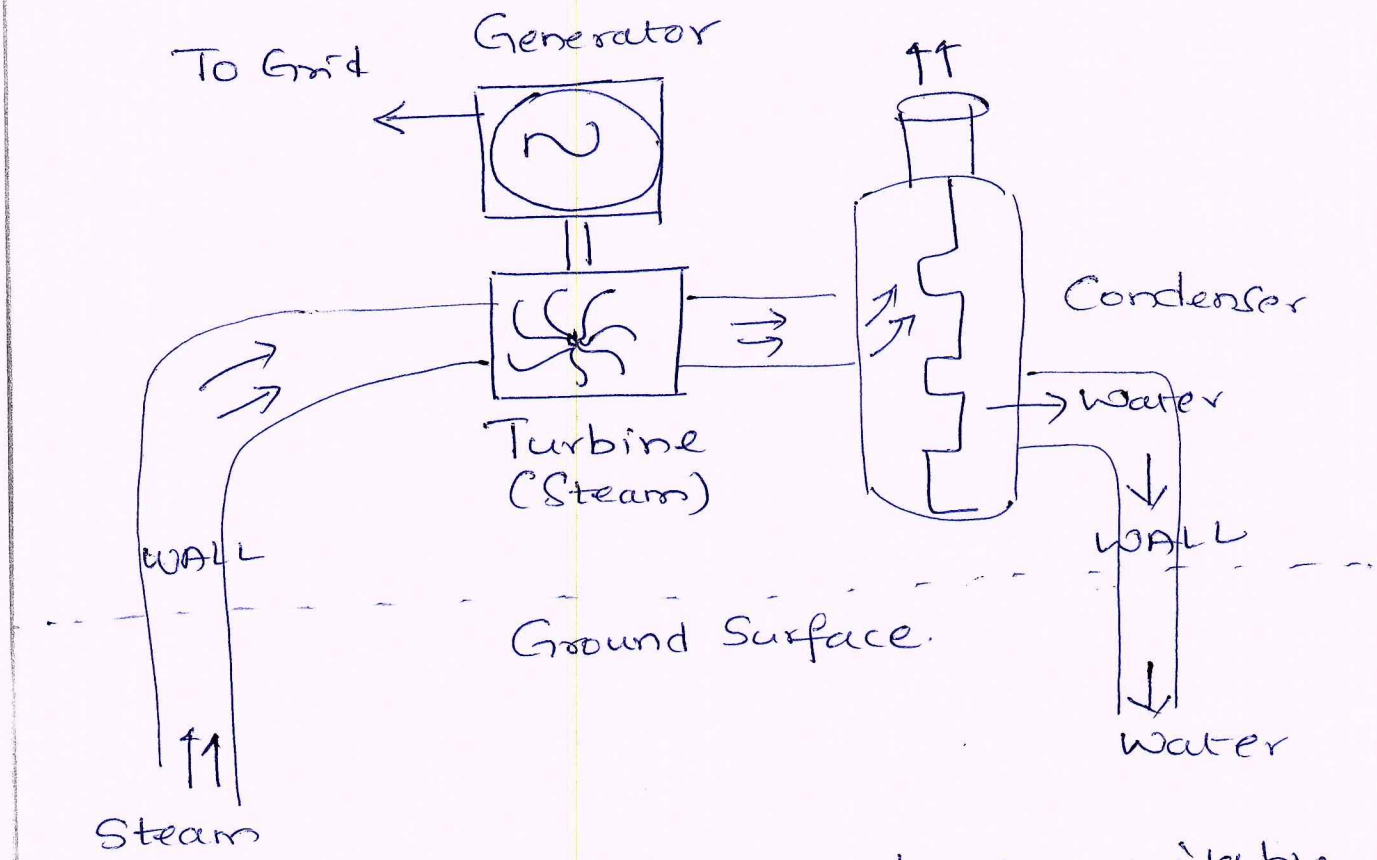
(iii) Visual effects: It is most serious environmental problem associated with the on shore development of wind energy

(iv) Bird life: Depending on the height of the towers, the night flying birds may get effected

(v) Risk: Regular monitoring of tower inclination may avoid falling of tower

Module-3

Q6a) Working of Dry Steam Geothermal power plant-



→ It is the process of using heat available in the water resource near the deep earth core to generate electricity and feeding back the water molecules to earth back.

→ Once the location of the earth is identified where natural steam and heat is available, that heat is passed through steam turbine, which in turn rotates and generates power through Generator and fed to the Grid appropriately.

→ The remaining steam not used is converted back to water molecules through condenser and water is fed back to source.

Module - 3

6b Problems associated with the Geothermal conversion.

1) Solid particles and noncondensable gases. Steam and water from both hydrothermal system contain dissolved solids in the water and non condensable gases. These may affect the system entirely by damaging the instruments due to corrosive effects

2) Land Erosion: Replanting of shrubs and trees can help to solve this problem.

3) Noise: It is another problem, Exhausts blow downs and centrifugal seperation are some of the sources of noise that necessitate the installation of silencers or some equipments.

4) Water borne poisons: The water phase in well-fields some time contain toxic mercury, arsenic, ammonia etc which if discharged could contaminate water downstream

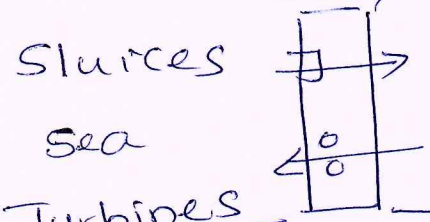
5) Heat-pollution: In well-fields more amount of source of heat wastage can arise from the reinjection of very hot unwanted bore water in to rivers.

6) Silica, Seismicity and Eccaping Steam can also be explained.

7a) Different ways to extract energy through tides.

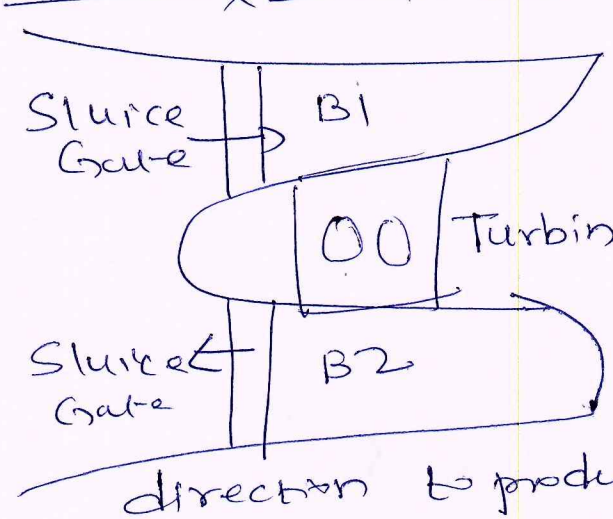
1) Single Basin Arrangement:

- In this case there is only one basin interacting with the sea. The two are seperated by a dam (or barrage) and the flow between them is through sluice ways located along the dam
- The generation of power is obtained by a) Single ebb cycle system
  b) Single tide cycle system
  c) Double cycle system.



In single ebb type water from sea enter the basin and as it fills puts pressure on Turbine due to this change in level power is generated by turbines which is fed to grid

Double basin arrangement:



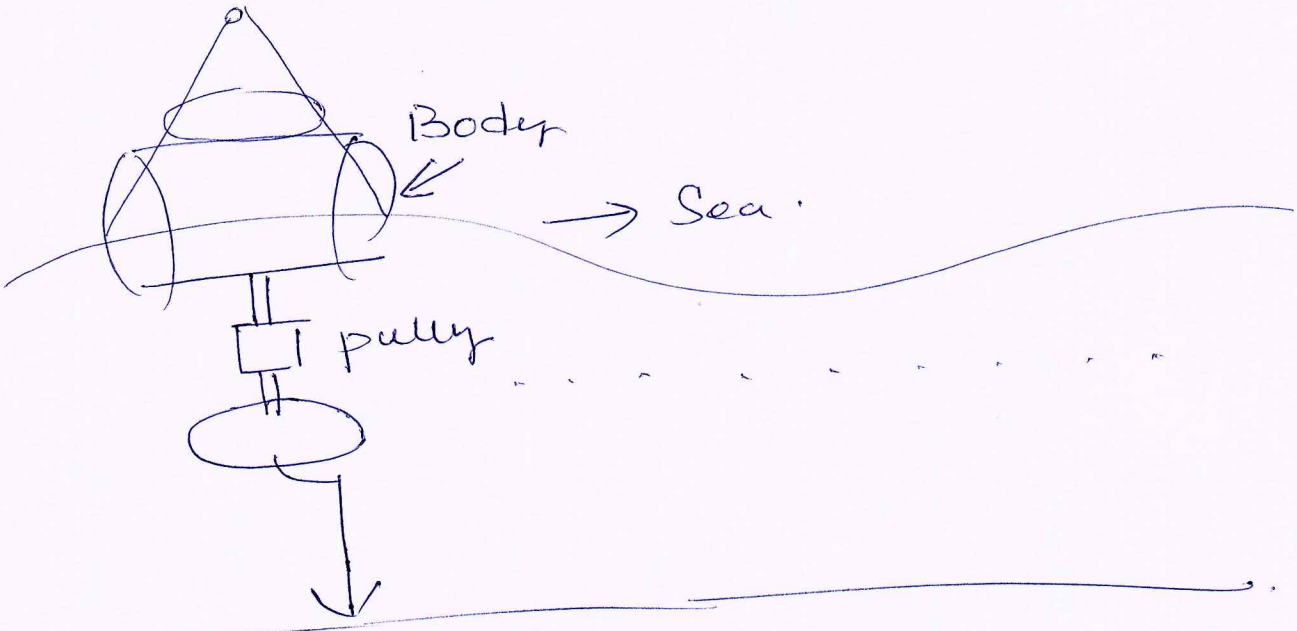
- Here it uses two capacity of basin B1 and B2
- Due to change in flow in B1 and B2 Turbine rotates in clk and Anti clk wise direction to produce current.

Module-4

7b) Different ways to extract energy

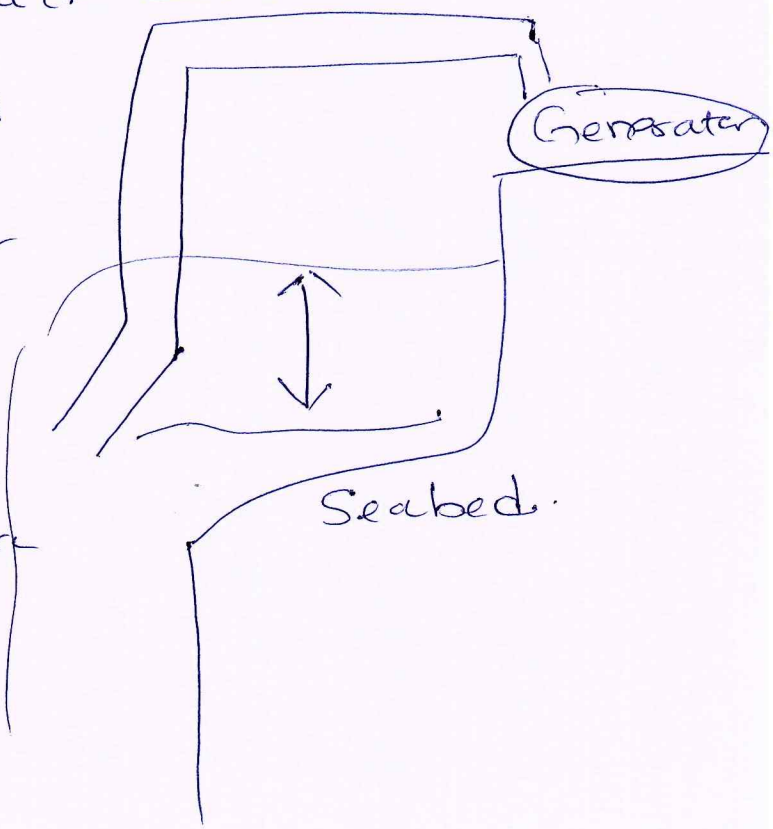
i) Point Absorber

These are the structures that float on water surface and are placed on the seabird. They absorb energy from all directions using vertical heave motion of waves due to which hydraulic piston generates relative energy.



ii) Oscillating water Column:

As waves enter and exit the chamber the enclosed water column acts as piston pushing air up and down. These air turbines convert change in air pressure to electricity.



8a) Describe OTEC & working principle with neat diagram.

* OTEC stands for Ocean Thermal Energy Conversion. Is a renewable energy technology that generates continuous, baseload electricity by utilizing the temperature difference blw warm tropical surface water & cold deep ocean water.

Principle of Working:

*) The operation of the OTEC plant based on thermodynamic principle.

*) If a heat source is available at a higher temperature & a heat sink at a lower temperature, the temperature difference can be utilized in a turbine which convert part of heat into mechanical energy & hence into Electrical Energy.

*) The residual heat is discharged to the sink at the lower temperature.

*) In the OTEC system, the warm ocean surface water is the heat source, & the deep colder water provides the sink.

*) This is called ocean thermal energy conversion.

*) OTEC system has very low efficiency & has very high capital cost, because the temperature difference is small even in tropics

*) The heat contained in the ocean is solar in origin.

*) The surface of the water acts as the collector for solar heat while the upper layer of the sea constitutes infinite heat storage reservior.

*) ~~The surface of the water act~~

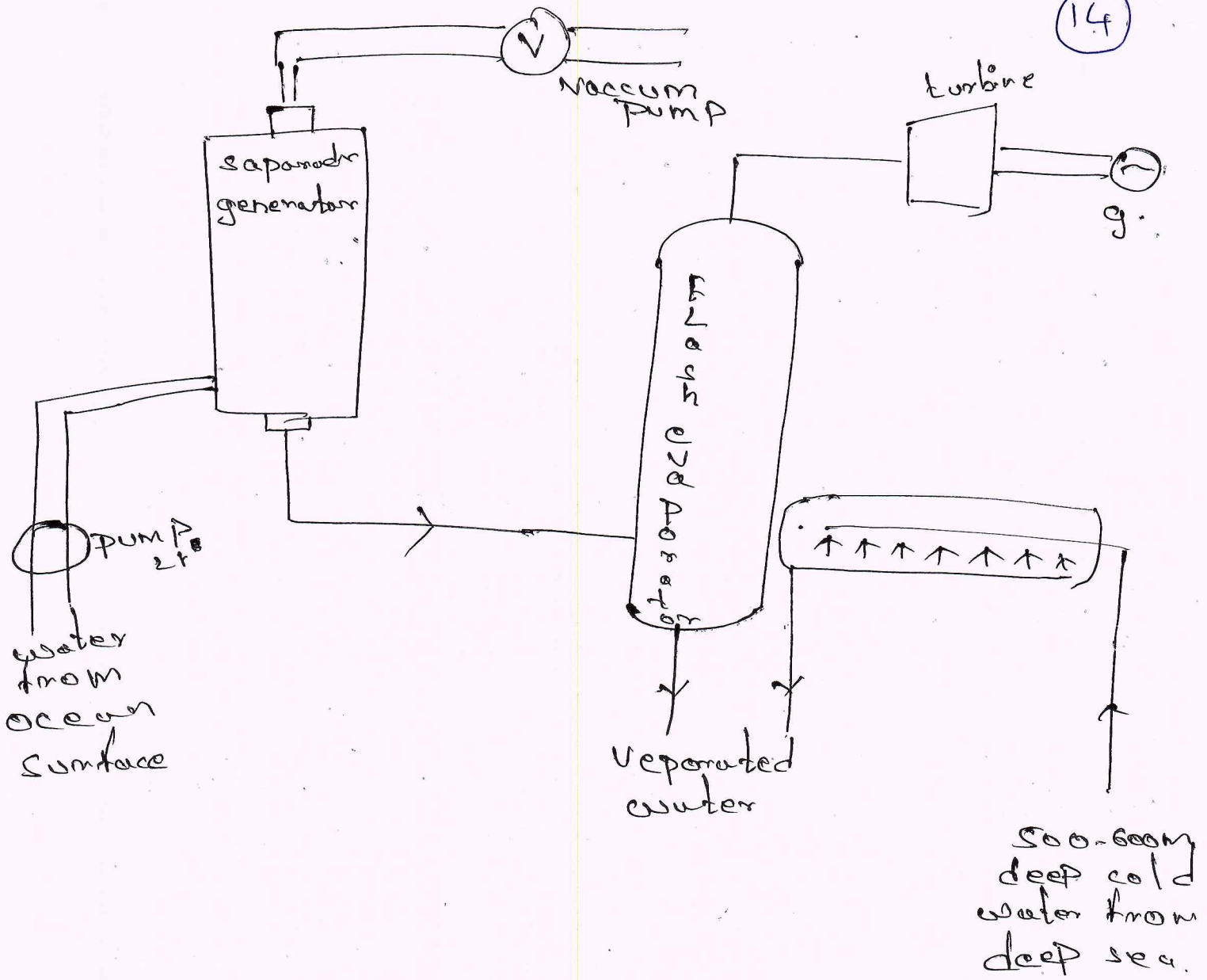
*) Solar energy absorption by the water takes place according to lambert's law of absorption which states that each layer of equal thickness absorbs the same fraction of light that passes through it.

*) Mathematically

$$-\frac{dI_{(x)}}{dx} = kI$$

$$I_x = I_0 e^{-kx}$$

*) Where, I_0 & $I(x)$ are the intensities of radiation at the surface ($x=0$) & at a distance x below the surface


V
Vaccum pump
turbine
G.
saporator generator
Flash evaporator
PUMP
Water from ocean surface
Veporated water
500-600m deep cold water from deep sea.

8b) What are the problems associated with OTEC:

* 1) Heat Exchangers (Evaporators)

* The maximum efficiency for the conversion of heat into mechanical work in a turbine depends on the drop in temperature of the working fluid in its passage through the turbine & the turbine inlet temperature.

2) Biofouling:

*) In an ocean environment, a layer of slime known as "bio fouling" will eventually accumulate on the water side of the heat exchanger.

*) Slime at first stage is composed of microorganisms called as "micro fouling"

3) Site selection:

*) In selecting a site an OTEC plant, the primary consideration is a significant temperature difference b/w surface & deep ocean water.

4) Energy utilization:

*) If OTEC plant is located less than about 20 km from shore, electricity generated can be transmitted inexpensively to land by submarine cable.

Module 5

(15)

9a) Explain fixed dome biogas power plant with Diagram.

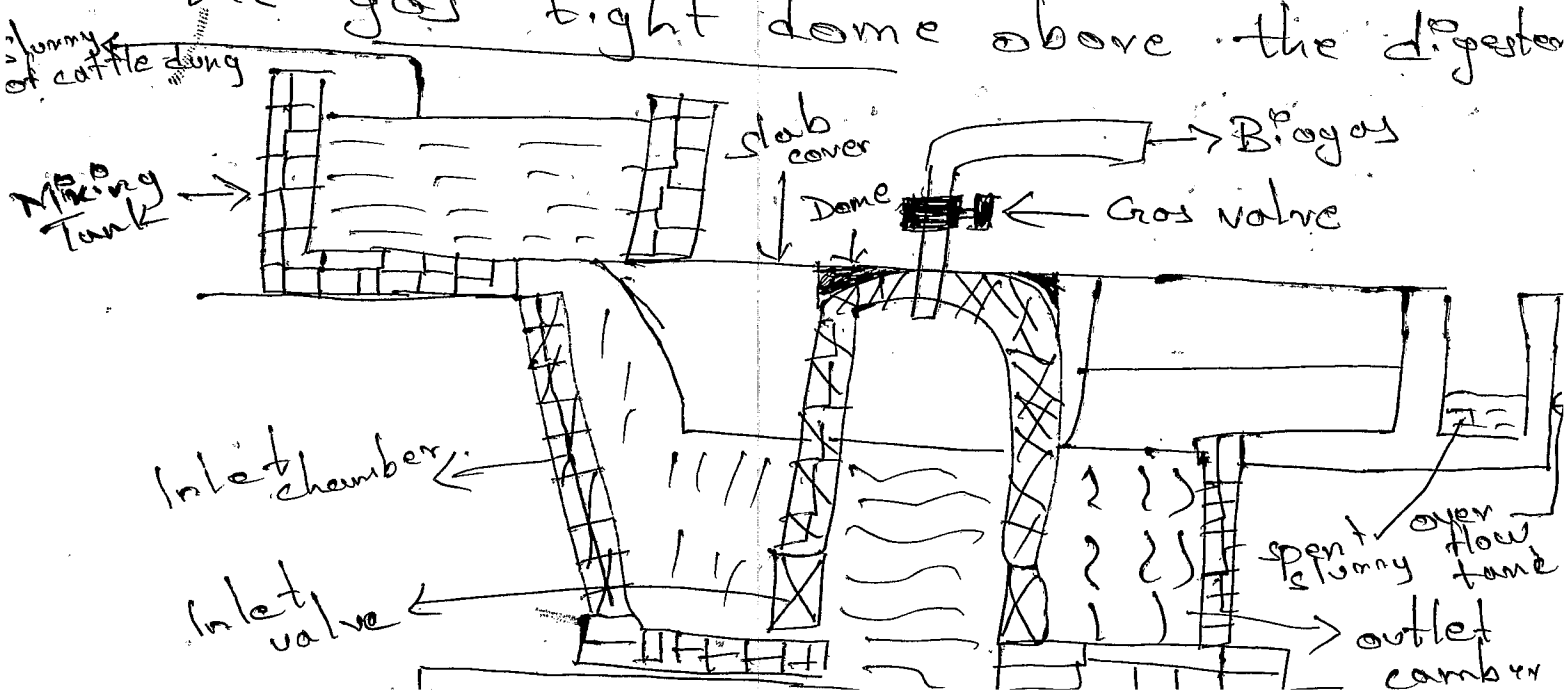
*) Fixed-dome biogas plant, a commonly used system in rural areas for converting organic waste - primarily a mixture of cattle dung & water into biogas & organic fertilizer.

*) The process begins in the mixing tank where cattle dung & water are combined to form a slurry.

*) This slurry flows into the inlet chamber & through inlet valve into the digestion chamber, which lies beneath the dome structure.

*) Within the digester, anaerobic bacteria breaks down the organic matter in the slurry.

*) During this decomposition process, biogas a mixture primarily composed of methane & carbon dioxide is produced & accumulates in the gas tight dome above the digester.



*) As biogas production increases pressure builds up within dome.

*) This pressure pushes the remaining slurry into the outlet chamber & further into overflow tank.

*) This gas is drawn off through a gas valve & pipeline installed at the top of the dome, and can be used for various appln such as cooking, lighting or powering small Engines.

*) The spent slurry now devoid of gas producing materials is still rich in nutrients & is discharged into the overflow tank where it can be collected & used as organic fertilizer in Agriculture

*) Thus the fixed dome biogas plant not only provides clean, renewable energy but also help manage animal waste & enchance soil fertility in sustainable way.

9b) Explain Gasification with diagram. (10)

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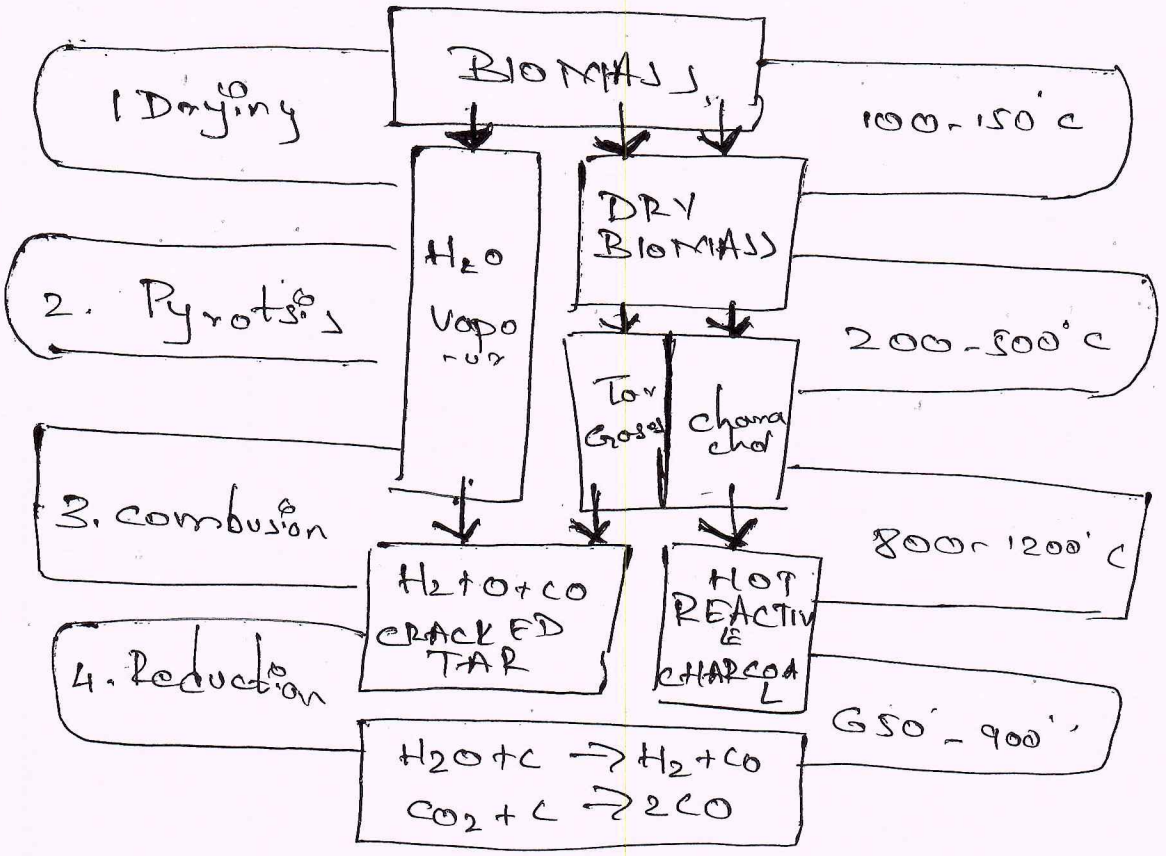


*) Biomass Gasification is a thermal process which converts organic carbonaceous material into a combustible gas comprised of carbon monoxide, hydrogen, carbon dioxide.

*) This is achived by reacting the material at high temperatures, without fully combusting it using a controlled oxygen inlet.

*) The resulting gas mixture is called syn gas. At temperatures of approximately 600 to 1000°C solid biomass undergoes termal decomposition of form gas phase product with typically include CO, H, CH_4, CO_2, & H_2O

The four stage of Gasification process

1) Drying: In the drying zone, moisture in the feedstock is evaporated by the heat from the lower zones at a temperature of blw 150 to 200°C. Vapours move down & mix with vapour originating in the oxidation zone.

2) Pyrolysis: This is the thermal decomposition of biomass in low oxygen condition at temperature ranging from 200 to 600°C

3) Combustion: Oxidation occurs in the presence of reactive gas which affects the calorific value of the gas leaving the gratifier. The use of air as reactive gas is the more common.

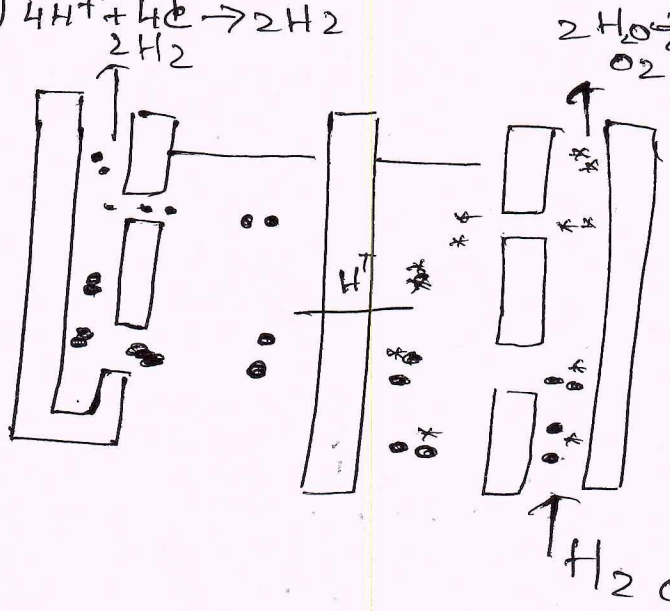
4) Reduction: The products of oxidation zone hot gases & glowing char, move into the reduction zone.

* Since there is insufficient O2 in high temperature zone for continued oxidation a number of reduction reactions take place blw hot gases & char.

10) a Explain Hydrogen Production Technology (Electrolysis)

(17)

-> Hydrogen production by electrolysis Method



*) Electrolysis is a process that uses electrical energy to break down water molecules (H_2O) into their elemental components: hydrogen (H_2) & oxygen (O_2).

*) This process occurs in an electrolytic cell, which consists of two electrodes an anode & a cathode, submerged in water that contains an electrolyte such as sulfuric acid or potassium hydroxide to improve electrical conductivity.

*) When a direct current voltage is applied across the electrodes, water molecules at the cathode gain electrons & form hydrogen gas, while at the anode, water molecules lose electrons & releases water

undergoes reduction to form hydrogen gas & hydroxide ions

$$(2H_2O + 2e^- \rightarrow H_2 + 2OH^-),$$

while at the anode, water molecules are oxidized to form oxygen gas & hydrogen ions

$$(2H_2O \rightarrow O_2 + 4H^+ + 4e^-)$$

The overall Reaction is

$$2H_2O \rightarrow 2H_2 + O_2,$$

meaning for every two molecules of water two molecules of hydrogen gas & one molecule of oxygen gas are produced in 2:1 volume ratio.

The process is significant for hydrogen fuel production, oxygen generation in space or underwater environments & various industrial appln such as chemical synthesis & metal refining

10b) Describe Advantages of hydrogen energy

(18)

1) Clean Energy: Hydrogen is considered a clean energy source as it produce only water when burned.

2) Energy Security: Hydrogen can be produced domestically, reducing depen dence on foreign oil & increasing energy security.

3) Versatility: Hydrogen can be used in a variety of appln including transportation heating, & electricity Generation

4) High Energy Density: Hydrogen has a high energy density making it an efficient energy source for transportation & other application

5) Renewable Energy Source: Hydrogen can be produced from renewable energy source such as wind, solar etc.

6) Storage: Hydrogen can be stored & transported easily making ito flexible energy source.

7) Fuel cell: Hydrogen can be used in fuel cell technology to produce electricity with high efficiency, making it a promising source of clean energy for the future.

8) Safety: Hydrogen is a not toxic & does not pose a risk to human health or the environment.

9) Economic Benefits: The development & production of hydrogen technology can create new jobs & stimulate econ. growth.

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18/2/26

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