USN

18ME651

Sixth Semester B.E. Degree Examination, June/July 2023
Non-Conventional Energy Sources

Time: 3 hrs. Max. Marks: 100

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

Module-1

1 a. Enlist and explain the merits and demerits of any three non-conventional Energy Sources. **(10 Marks)**

b. Explain Tar Sands and Oil shale as energy sources and mention their limitations. **(10 Marks)**

OR

2 a. With schematic representation, explain mechanism of absorption, scattering beam and diffuse radiation received at earth's surface. **(10 Marks)**

b. Explain with a neat sketch, explain the working of pyrenometer. **(05 Marks)**

c. Explain briefly the need for alternate energy sources. **(05 Marks)**

Module-2

3 a. Define the following term with respect to solar radiation:
i) Hour angle ii) Declination angle iii) Zenith angle iv) Latitude angle
v) Solar Azimath angle. **(10 Marks)**

b. Calculate the day length of location (latitude 22° 00′ W, 73° 10′ E) during the month of March 1. **(05 Marks)**

c. With the usual expression for flux explain beam and diffuse radiation on a tilted surface. **(05 Marks)**

OR

4 a. With a neat sketch explain working of liquid flat-plate collector. **(08 Marks)**

b. Describe solar pond for solar energy collection and storage. **(07 Marks)**

c. Explain how solar energy can be used for drying with a neat sketch. **(05 Marks)**

Module-3

5 a. List and discuss the various parameters that affect the performance of collector. **(10 Marks)**

b. Explain the heat transfer process in LFPc with neat sketch and write the energy balance equation, explaining each terminal. **(10 Marks)**

OR

6 a. Explain the working principle and I-V characteristics of a solar PV cell. **(10 Marks)**

b. Define : i) Collector efficiency factor ii) Collector heat removal factor of LPFc write the expression for the above. **(05 Marks)**

c. What are the applications of solar PV cell? **(05 Marks)**

Module-4

7 a. Describe the main consideration in selecting the site for wind generators. **(10 Marks)**

b. Wind blows with a velocity of 15 m/s at 15°C and 1 std. atm. pressure. The turbine diameter is 120m with operating speed of 40 rpm at maximum efficiency. Propeller type wind turbine is considered. Calculate the following :
i) Total power density in the wind stream
ii) Maximum obtainable power density
iii) Obtainable power density
iv) Total power
v) Torque at max η
vi) Maximum axial thrust
Assume R = 0.287 kJ/kgK , η = 35%. **(10 Marks)**

OR

8 a. Explain with a sketch, the closed Rankine cycle OTEC system. **(10 Marks)**
b. Explain briefly the harnessing of Tidal energy. **(05 Marks)**
c. Explain the advantages and disadvantages of Tidal energy. **(05 Marks)**

Module-5

9 a. State the environmental problem associated with geothermal energy conversion. **(05 Marks)**
b. List the factors affecting biogas generation. **(05 Marks)**
c. Sketch and explain the working of a fixed dome type biogas plant used in India. **(10 Marks)**

OR

10 a. What are the different methods of hydrogen production? Describe electrolytic method of hydrogen production. **(10 Marks)**
b. Briefly explain the safe utilization of hydrogen energy. **(05 Marks)**
c. Describe various methods of storage of hydrogen. **(05 Marks)**

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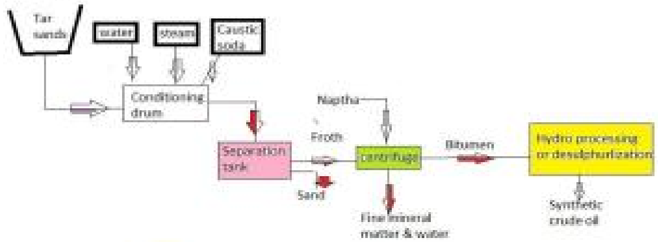
1a	**SALIENT FEATURES OF CONVENTIONAL ENERGY RESOURCES** **ADVANTAGES** • Coal: as present is cheap. • Security: by storing certain quantity, the energy availability can beensured for a certain period. • Convenience: it is very convenient to use. **DISADVANTAGES** 1) Fossil fuels generate pollutants: CO, CO2, NOX, SOX. Particulate matter & heat. The pollutants degrade the environment, pose health hazards & cause various other problems. 2) Coal: it is also valuable petro-chemical & used as source of raw material for chemical, pharmaceuticals & paints, industries, etc. From long term point of view, it is desirable to conserve coal for future needs. 3) Safety of nuclear plants: it is a controversial subject. 4) Hydro electrical plants are cleanest but large hydro reservoirscause the following problems 5) As large land area submerges into water, which leads todeforestation. 6) Causes ecological disturbances such as earthquakes 7) Causes dislocation of large population & consequently their rehabilitation problems
b	TAR SANDS: • Tar sand or oil sands is an expression used to describe porous sandstone deposits impregnated with heavy viscous oils calledbitumen or simply deposits of heavy oils. • The above schematic diagram indicating the processes involved in producing synthetic crude oil from tar sands made up of sand stone deposits containing bitumen. • The sands obtained from surface mining are first passed througha conditioning drum where water, steam & caustic soda are added & slurry is formed. The slurry passes into a separation tank where the coarse sand settles at the bottom & a froth of bitumen, water &fine mineral matter forms on the top

- The froth is diluted with *naptha* & subjected to *centrifugal action*. As a result, fine mineral matter & water is removed. After this, the naptha is recovered & recycled, & the bitumen obtained is subjected to hydro processing & desulphurization to producesynthetic crude oil.



OIL SHALE:

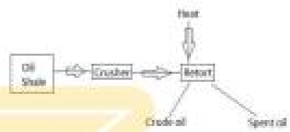


Fig Oil shale **Production of crude oil from oil shale**

Oil shale [a sedimentary rock] refers to a finely textured rock mixedwith a *solid organic material* called *kerogen*. When crushed, it can be burnt directly [like coal] & has a heating value ranging from 2000 to 17,000 KJ/Kg. It is used in this manner for generating electricity & supplying heat.

Alternatively, the oil shale can be converted to oil. This is done by heating crushed oil shale to about 500 °c in the absence of air. Under theconditions, *pyrolysis* occurs & the kerogen is converted to oil.

2a

Absorption occurs primarily because of the presence of ozone and water vapour in the atmosphere and lesser extent due to other gases (lik e CO_2,NO_2, CO,O_2 and CH_4) and particulate matter. It results in an increase in the internal energy of the atmosphere. On the other hand, scattering occurs dueto all gaseous molecules as well as particulate matter in the atmosphere. The scattered radiation is redistributed in all directions, some going back to the space and some reaching the earth's surface.

Solar radiation received at the earth's surface without change of direction i.e.,in line with the sun is called *direct radiation* or *beam radiation*. The radiation received at the earth's surface from all parts of sky's hemisphere (after being subjected to scattering in the atmosphere) is called *diffuse radiation*. The sum of beam radiation and diffuse radiation is called as *total* or *global radiation*.

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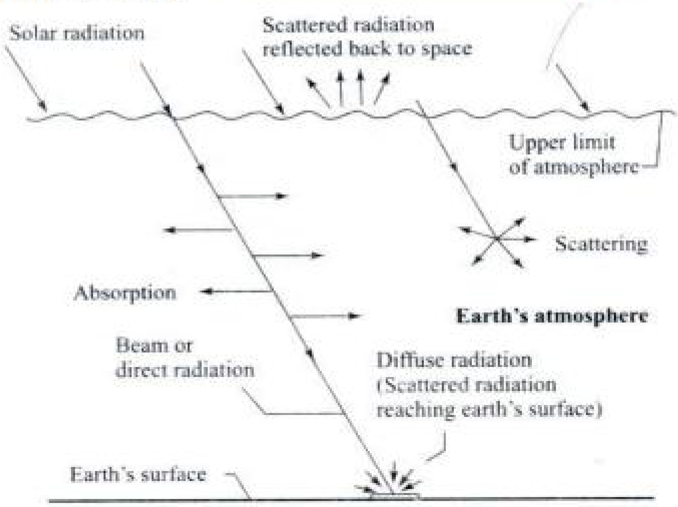
Solar Radiation Received at the Earth's surface:

Solar radiation received at the earth's surface is in the attenuated form because it is subjected to the mechanisms of absorption and scattering as it passes through the earth's atmosphere (Figure below).



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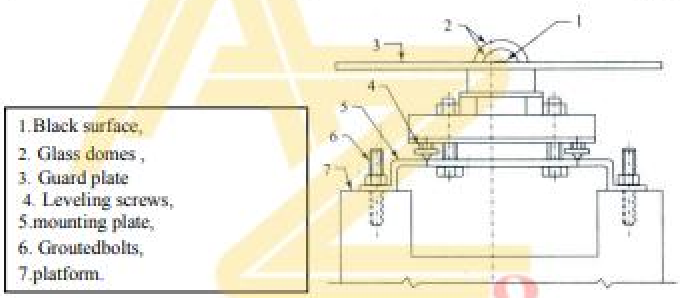
Pyrometer

A pyrometer is an instrument which measure's either global or diffuse radiation falling on a horizontal surface over a hemispherical field of view. Asketch of one type of pyrometer as installed for measuring global radiationis shown in the following figure.



Pyrometer consists of a black surface which heats up when exposed to solar radiation. It's temperature increases until the rate of heat gain by solar radiation equals the rate of heat loss by convection, conduction and radiation. The hot junctions of thermopile are attached to the black surface, while the cold junctions are located under a guard plate so that they do not receive the radiation directly. As a result an elf is generated. This emf which is usually in the range of 0 t0 10mv can be read, recorded or integrated over a period of time and is a measure of global radiation.

The pyrometer can also be used for measurement of diffuse radiation. Thisis done by mounting it at the center of a semi- circular shading ring. The shading ring is fixed in such a way that it's plane is parallel to the plane of path of sun's daily movement across the sky and it shades the thermopile element and two galss domes of pyranometer at all the times from direct sun shine. Consequently the pyranometer measures only the diffuse radiation received from the sky.

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here is a growing need for alternative energy sources for several reasons:

1. **Environmental Concerns:** Traditional energy sources like fossil fuels (coal, oil, and natural gas) release greenhouse gases into the atmosphere when burned, leading to global

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	warming and climate change. Alternative energy sources, such as renewables, have a significantly lower carbon footprint and can help mitigate these environmental concerns. 2. **Resource Depletion:** Fossil fuels are finite resources, and their extraction can be environmentally damaging. As these resources become scarcer, the cost of extraction and the potential for supply disruptions increase. Alternative energy sources like solar, wind, and geothermal power are renewable and do not deplete natural resources. 3. **Energy Security:** Many countries rely on imported fossil fuels, which can lead to energy security concerns. Shifting to domestic sources of alternative energy can reduce dependence on foreign energy supplies and enhance national security. 4. **Economic Benefits:** The renewable energy sector has been a source of job creation and economic growth in many regions. As technology advances and economies of scale are realized, renewable energy sources can become more cost-competitive with fossil fuels. 5. **Energy Access:** Alternative energy sources can be harnessed in remote or off-grid areas where it is impractical or expensive to extend traditional power infrastructure. This can improve energy access and promote economic development in underserved regions. 6. **Reduced Air Pollution:** Fossil fuel combustion contributes to air pollution, which has adverse health effects. Alternative energy sources produce little to no air pollution, improving air quality and public health. 7. **Technological Advancements:** Advances in alternative energy technologies have made them more efficient and cost-effective. Solar panels, wind turbines, and battery storage systems have seen significant improvements in recent years. 8. **Energy Independence:** Utilizing alternative energy sources can reduce a nation's dependence on energy imports, providing more control over its energy supply and reducing vulnerability to international energy market fluctuations. 9. **Mitigating Natural Disasters:** Traditional power grids are susceptible to damage during natural disasters. Decentralized alternative energy systems, like microgrids and rooftop solar, can provide resilience and power continuity during emergencies. 10. **Long-Term Sustainability:** Alternative energy sources, such as solar, wind, and hydroelectric power, are sustainable over the long term and can provide energy for future generations without depleting finite resources. In light of these reasons, many governments, businesses, and individuals are increasingly investing in and adopting alternative energy sources to address environmental, economic, and energy security challenges. This transition is a critical step in building a more sustainable and resilient energy future.
3a	Definitions: (a) Solar altitude angle(α): Altitude Angle is the angle between the Sun's rays and projection of the Sun's rays on the horizontal plane (b) Zenith angle(θ_z): It is Complementary angle of Sun's Altitude angle It is a vertical angle between Sun's rays and line perpendicular to the horizontal plane through the point i.e. angle between the beam and the vertical $\Theta_z=\pi/2-\alpha$ (c) Solar Azimuth Angle(γ_s): It is the solar angle in degrees along the horizon east or west ofnorth or It is the horizontal angle measured from north to the horizontalprojection of sun's rays.

	(d) Declination(δ): It is the angle between a line extending from the centre of the Sun and center of the earth and projection of this on earth's equatorial plane. ➢ Declination is the direct consequence of earth's tilt and Itwould vary between 23.5^{o} on June 22 to – 23.5^{o} on December 22. On equinoxes of March21 & Sept22 declination is zero. ➢ The declination is given by the formula $\delta = 23.45\ Sin\left\{\frac{360}{365}(284+n)\right\}$ Where n is the day of the year **(e) Meridian:** Meridian is the immaginery line passing through a point orplace on earth and north and south poles of the earth'. **(f) hour angle(ω):** Hour angle is the angle through which the earth must turn tobring meridian of the point directly in line with the sun's rays. Hour angle is equal to 15° per hour. **(g) slope(β):** Angle between the collector surface with the horizantal plane iscalled slope(β). **(h) surface azimuth angle(γ):** Angle between the normal to the collector and south direction iscalled surface azimuth angle(γ) **(i) Solar Incident angle(θ):** It is the angle between an incident beam radiation falling on thecollector and normal to the plane surface
B	
c	**Beam Radiation:** **Tilt factor (R_b):** The ratio of beam radiation flux falling on the tiltedsurface to that of horizontal surface is called the TILT FACTOR for beam radiation. For case of tilted surface facing due south γ=0 $\cos\theta = \sin\delta\sin(\phi-\beta) + \cos\delta\cos\omega\cos(\phi-\beta)$ while for a horizontal surface $\cos\theta_z = \sin\phi\sin\delta + \cos\phi\cos\delta\cos\omega$ Hence $r_b = \frac{\cos\theta}{\cos\theta_z} = \frac{\sin\delta\sin(\phi-\beta)+\cos\delta\cos\omega\cos(\phi-\beta)}{\sin\phi\sin\delta+\cos\phi\cos\delta\cos\omega}$

Tilt factor (rd): The ratio of diffuse radiation flux falling on the tilted surface to that of horizontal surface is called the tilt factor for diffuse radiation.

Its value depends on the distribution of diffuse radiation over the sky and the portion of the sky dome seen by the tilted surface.

Assuming that the sky is an isotropic source of diffuse radiation, for a tilted surface with slope β, we have

$$r_d = \frac{1 + \cos\beta}{2}$$

(1+ cosβ)/2 is the shape factor for a tilted surface w.r.t. sky

For Total radiation, let H_b=Hourly beam radiation and H_d=Hourly diffuse radiation.

Thus the total beam radiation incident on a tilted surface is given as,

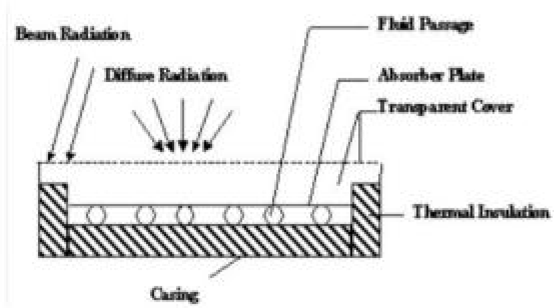
$$\mathbf{H_T = H_bR_b} + \frac{(11+cosS)}{22} + \frac{(Hb+Hd)\ (11-cosS)}{22}\rho$$

ρ = diffuse reflectance which is used to account for the reradiated

4a

Liquid flat plate collector

- In operation cold water from the over head tank is made to flow through water tubes.
- When solar radiation passes through transparent glass cover & falls on the absorber plate it absorbs heat energy.
- This heat energy transferred to the cold water flowing through the tube and gets heated up.
- Heated water being lighter in density than cold water hence it raises up and collects in the solar water heater tank.



b

SOLAR POND

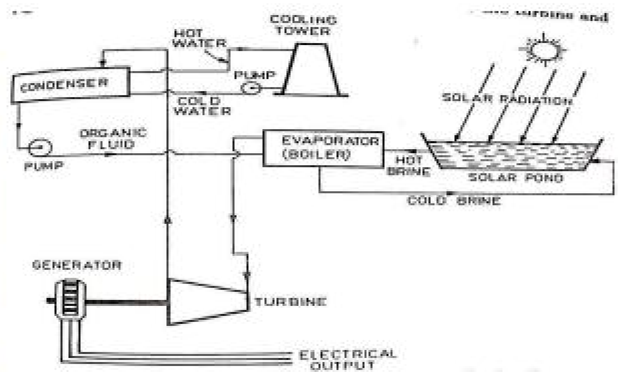


Fig. 4.3.3. Solar pond electric power plant with cooling tower.

A solar pond is a mass of shallow water about 1 or 2 meters deep with a large collection area, which acts as a heat trap. It contains dissolved salts to generate a stable density gradient. Part of the incident solar radiation entering the pond surface is absorbed throughout the depth and the remainder which penetrates the pond is absorbed at the black bottom. If the pond were initially filled with fresh water, the lower layers would heat up, expand and rise to the surface. Because of the convective mixing and heat loss at the surface, only a small temperature rise in the pond could be realized. On the other hand, convection can be eliminated by initially creating a sufficiently strong salt concentration gradient. In this case, thermal expansion in the hotter lower layers is insufficient to destabilize the pond. With convection suppressed, the heat is lost from the lower layers only by conduction. Because of the relatively low conductivity, the water acts as an insulator and permits high temperature (over 90oC) to develop in the bottom layers. At the bottom of the pond, a thick durable plastic liner is laid. Materials used for the liner include butyl rubber, black polyethylene and hyperon reinforced with nylon mesh. Salts like magnesium chloride, sodium chloride or sodium nitrate are dissolved in the water, the concentration varying from 20 to 30 percent at the bottom to almost zero at the top.

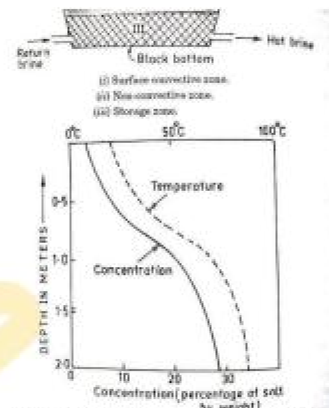


Fig. 4.3.2 Temperature and concentration profile for a typical pond.

c

Roof storage of solar heat:

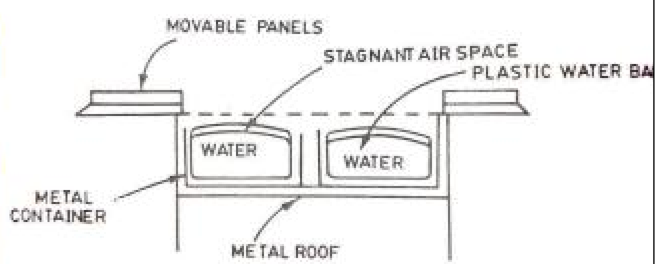


Fig. 5.3.2. Roof storage of Solar heat.

A passive solar system, trade named sky therm, was designed for house having a flat roof located in a mild climate. The heat is absorbed and stored in water about 0.25 m deep contained in plastic bags held in blackened steel boxes on the house roof. In a later design, a layer of clear plastic sealed to the top of the bag provides a stagnant airspace to reduce heat losses to the atmosphere. Heat is transferred from the heated water to the rooms below by conduction through a metal ceiling. Air circulation may be aided by means of electric fans, but this is not essential. To prevent loss of heat during the night, thermal insulator panels are moved, either manually or by a time controlled electric motor, to cover the water bags. In the day time, the panels, which are in sections, are removed and stacked one above the other.

5a

- It is seen from the above table that with a non-selective absorber plate, the top loss coefficient is 7.26 W/m -K and the efficiency is 31.5 per cent.
- The top loss coefficient increases by 3.14 W/m -K, while the efficiency decreases by 12.1%.
- Thus, significant differences are observed.
- With the other selective surface, in which the value of α is marginally higher and that of ε_p is less, it is observed that the value of U_t decreases and the efficiency increases a little compared to the first selective surface.

Number of Covers

- The effect of the number of covers on the performance of a collector can be studied considering a sample collector with a selective surface having with α = 0.94 and ε = 0.14 and a non-selective surface with $\alpha = \varepsilon$ = 0.94.
- Calculations are carried out for 1, 2 and 3 covers

Number of covers (Effect of selective Surface)

	1	2	3
$(\tau\alpha)_b$	0.8041	0.6892	0.5932
$(\tau\alpha)_d$	0.7284	0.6008	0.5114
$U_t (W/m^2 - K)$	4.12	2.68	1.99
$\eta_i(\%)$	43.6(highest efficiency)	41.0	36.6

Number of covers (Effect of non-selective surface)

	1	2	3
$(\tau\alpha)_b$	0.8041	0.6892	0.5932
$(\tau\alpha)_d$	0.7284	0.6008	0.5114
$U_t (W/m^2 - K)$	**7.26**	**4.04**	**2.75**
$\eta_i(\%)$	**31.5**	**35.3**	**33.4**

- It can be observed from the above tables that, when the absorber plate is **SELECTIVE:**
  - the **highest value of efficiency** is obtained with **one cover.** As the number of covers keep increasing, the efficiency keeps decreasing.
- When the absorber plate is **NON-SELECTIVE:**
  - the **efficiency increases when the number of plates is increased from 1 to 2 but then starts to decrease with further addition of plates.**
- It can hence be concluded that, it is optimum to use **only one cover if the absorber plate is selective** and **two covers if the absorber plate is non-selective**.

Fluid Inlet Temperature

- The fluid inlet temperature is an operational parameter which strongly influences the performance of a flat-plate collector. The effect is best illustrated by again carrying out calculations for the case similar to the other factors.

EFFECT OF VARIOUS PARAMETERS ON THE COLLECTOR PERFORMANCE

- A large number of parameters influence the performance of a liquid flat-plate collector.
- These parameters could be classified as **design parameters, Operational parameters, meteorological parameters and environmental parameters.**

Collector Orientation

- Flat-plate collectors are normally fixed in one position and do not track the sun.
- Because of this factor, the amount of tilt or the orientation of the plate is an important factor.
- Assuming that extra-terrestrial insolation was falling on the collector plate, calculations were made.
- They calculated the annual insolation per unit area by integrating the expression for the flux on a tilted surface first over the day length and then summing up over the days of the year.
- Taking $\gamma\gamma = 0°$, so that the daily insolation is maximized, the following expression is obtained:

$$Q_{opt} = \text{ttttt}^{-11} \sum_{ii=11}^{1122} \ldots \pm \ldots \text{tttt}|\emptyset - \delta\delta_{ii}| \ldots \sum_{ii=11}^{1122} \ldots$$

Sele[ctive Surface]

- The effect of a selective surface on the performance of a collector can be best illustrated by taking specific situations.
- A collector's performance without a selective surface (α = ε = 0.94) and with a selective surface (α = 0.95, ε = 0.085) is calculated.
- The calculations are carried out in a manner similar to that adopted earlier and the results obtained are indicated in the table below:

	Selective Surface α = 0.94, ε_p = 0.14 (Selected Sample)	Non - selective Surface α = ε_p = 0.94	Selective Surface α = 0.95, ε_p = 0.085
$T_{pm}(K)$	351.2	346.2	351.9

b

- Each of the terms in the above equation is multiplied by a term called the **transmissivity-absorptivity product ($\tau\alpha$)** in order to determine the flux S absorbed in the absorber plate.
- Thus,

$$I_T = I_b r_b (\tau\alpha)_b + \{I_d r_d + (I_b + I_d) r_r\}(\tau\alpha)_d$$

Where,

τ = transmissivity of the glass cover system, the ratio of the solar radiation coming through after reflection at the glass-air interfaces and absorption in the glass to the radiation incident on the glass cover system,

α = absorptivity of the absorber plate,

$(\tau\alpha)_b$ = transmissivity-absorptivity product for beam radiation falling on the collector

$(\tau\alpha)_d$ = transmissivity-absorptivity product for diffuse radiation falling on the collector.

- The **instantaneous collection efficiency** is given by

$$\eta = \frac{Useful\ heat\ gain}{Radiation\ incident\ on\ the\ collector} = \frac{q_u}{A_c I_T}$$

Where,

Ac = is the collector gross area (the area of the topmost cover including the frame). **A_c is usually 15 to 20 per cent more than A_p.**

BASIC ENERGY – BALANCE EQUATION

- Energy balance is simply the relationship between energy input and energy output.
- In thermal systems, this is defined as: "A fundamental concept for thermal analysis of any thermal system is the conservation of energy, which can be analysed through energy balance calculation under steady state conditions. In steady state, the useful energy output of the collector is the difference between the absorbed solar radiation and the total thermal losses from the collector."

Useful energy = Absorbed solar energy - Thermal losses

- An energy balance on the absorber plate yields the following equation;

$$q_u = A_p S - q_l$$

Where,

q_u = useful heat gain, i.e., the rate of heat transfer to the working fluid,

S = incident solar flux absorbed in the absorber plate,

A_p = area of the absorber plate,

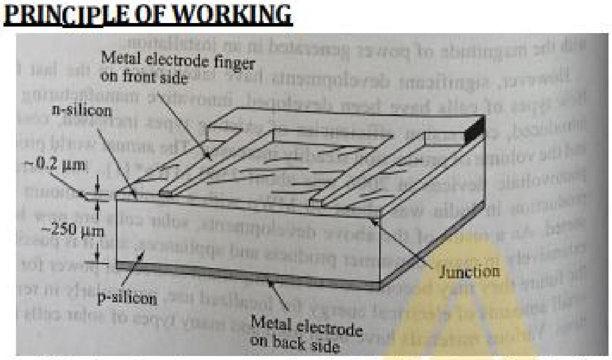
q_l = rate at which heat is lost by convection and re-radiation from the top, and by conduction and convection from the bottom and sides.

- The flux incident on the top cover plate is given by:

$$I_T = I_b r_b + I_d r_d + (I_b + I_d) r_r$$

6a

PRINCIPLE OF WORKING

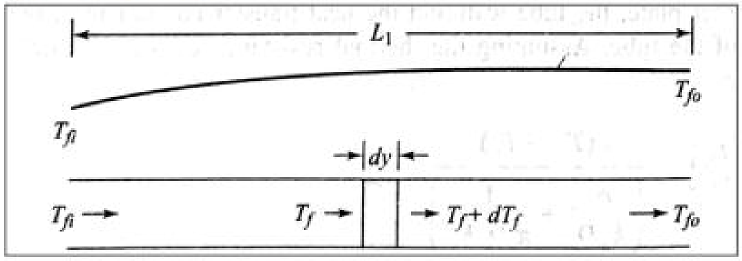


- The first solar cells were made in the fifties fro single crystal silicon.
- Even today silicon is the material generally use for making most cells.
- Single crystal silicon cells are thin wafers abou 250 in thickness, sliced from a single crystal of type doped silicon.
- A shallow junction is formed at one end b diffusion of the n-type impurity.
- Metal contacts are attached to the front and back side of the cell.
- On the front side, the contact is in the form of a metal grid with fingers which permits the sunlight to g through, while on the back side, the contact completely covers the surface.
- Generally, for the front contacts, screen printing of a paste consisting of 70% silver, an organic binder an sintered glass is done.
- For the back contact, a paste containing aluminium is screen printed.
- The cell is placed in a furnace at a temperature of about 600^0 to 700^0C so that the metals in the past diffuse both at the front as well as on the back to make contact with the silicon.
- An anti-reflection coating of silicon nitride or titanium dioxide, having a thickness of about 0.1 gm i applied on the top surface to complete the cell.
- The cells are encapsulated in a thin transparent material in order to protect them from the environme

B

COLLECTOR HEAT-REMOVAL FACTOR

- The final one-dimensional analysis will be performed along the direction of fluid flow with the of determining the variation of fluid temperature.
- This analysis will help in linking the useful heat gain rate with the fluid inlet temperature.
- Consider a length dy as a control volume of one tube.
- Applying first law of thermodynamics.



$$\frac{dT_f}{dy} = \frac{WF'U_l}{(\dot{m}/N)C_p}\left[\left(\frac{S}{U_l} + T_a\right) - T_f\right]$$

- The **instantaneous collection efficiency** is given by

$$\eta = \frac{Useful\ heat\ gain}{Radiation\ incident\ on\ the\ collector} = \frac{q_u}{A_c I_T}$$

Where,

Ac = is the collector gross area (the area of the topmost cover including the frame). **A_c is usually 15 to 20 per cent more than A_p.**

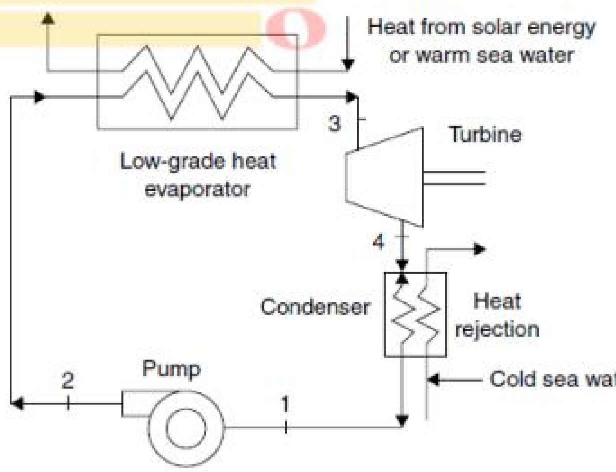
c

APPLICATIONS

1. **Solar Farms** - Many acres of PV panels can provide utility-scale power—from tens of megawatts more than a gigawatt of electricity.
2. **Remote Locations** - It is not always cost-effective, convenient, or even possible to extend power lin to locations where electricity is needed.
3. **Stand-Alone Power** - In urban or remote areas, PV can power stand-alone devices, tools, a meters.
4. **Power in Space** - From the beginning, PV has been a primary power source for Earth-orbiti satellites.
5. **Building-Related Needs** - In buildings, PV panels mounted on roofs or ground can supply electrici
6. **Military Uses** - Lightweight, flexible thin-film PV can serve applications in which portability ruggedness are critical.
7. **Transportation** - PV can provide auxiliary power for vehicles such as cars and boats.

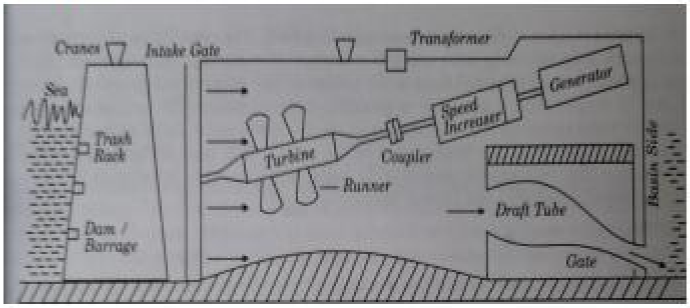
7a

MAJOR PROBLEMS ASSOCIATED WITH WIND POWER Wind energy can have adverse environmental impacts, including the potential to reduce, fragment, or degrade habitat for wildlife, fish, and plants. • Wind power must still compete with conventional generation sources on a cost basis i.e. wind projects must be able to compete economically with the lowest-cost source of electricity, and some locations may not be windy enough to be cost competitive. NON-CONVENTIONAL ENERGY SOURCES (18ME651) Department of ME CMRIT Page 62 • Good land-based wind sites are often located in remote locations, far from cities where the electricity is

	needed. Transmission lines must be built to bring the electricity from the wind farm to the city. • Wind resource development might not be the most profitable use of the land. Land suitable for windturbine installation must compete with alternative uses for the land, which might be more highly valued than electricity generation. • Turbines might cause noise and aesthetic pollution. • Wind plants can impact local wildlife. Birds have been killed by flying into spinning turbine blades.
b	A three-bladed wind rotor with blade length of 52 m is operating in a wind stream having wind velocity of 12 m/s. Air density is 1.23 kg/m^3 and power coefficient may be taken as 0.4. Calculate the extractable power from the wind. Solution: Given data are as follows: Blade length, L = 52 m; wind speed, v = 12 m/s; air density, ρ = 1.23 kg/m^3; power coefficient, C_p = 0.4. Thus, A = swept area = $\Pi r^2 = \Pi (52)^2 = 8495\ m^2$ P Available = $C_p (1/2 \rho A v^3) = 0.4 \times ½ \times 1.23 \times 8495 \times (12)^3$ = 3.6 MW
8a	**PRINCIPLE OF WORKING** The basic principle of ocean thermal energy conversion (OTEC) is explained as follows: **Closed cycle OTEC** • The warm water from the ocean surface is collected and pumped through the heat exchanger to hea and vaporize a working fluid, and it develops pressure in a secondary cycle. • Then, the vaporized working fluid expands through a heat engine (similar to a turbine) coupled to ar electric generator that generates electrical power. • Working fluid vapor coming out of heat engine is condensed back into liquid by a condenser. • Cold deep ocean water is pumped through condenser where the vapor is cooled and returns to liqui state. • The liquid (working fluid) is pumped again through heat exchanger and cycle repeats. It is known a closed-cycle OTEC. **RANKINE CYCLE** 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.  **Fig 4.7: OTEC Rankine Cycle**

b

power output.



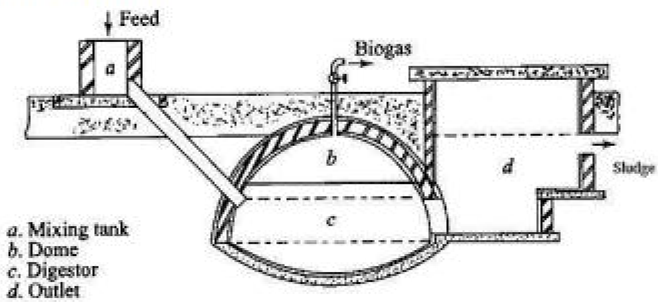
HARNESSING TIDAL ENERGY

- **Tidal stream generator**: Tidal stream generators make use of the kinetic energy of moving water to power turbines, in a similar way to wind turbines that use the wind to power turbines. Some tidal generators can be built into the structures of existing bridges or are entirely submersed, thus avoiding concerns over the impact on the natural landscape.
- **Tidal barrage**: Tidal barrages make use of the potential energy in the difference in height (or hydraulic head) between high and low tides. When using tidal barrages to generate power, the potential energy from a tide is seized through the strategic placement of specialized dams. When the sea level rises and the tide begins to come in, the temporary increase in tidal power is channeled into a large basin behind the dam, holding a large amount of potential energy. With the receding tide, this energy is then converted into mechanical energy as the water is released through large turbines that create electrical power through the use of generators
- **Dynamic tidal power:** Dynamic tidal power (or DTP) is a theoretical technology that would exploit an interaction between potential and kinetic energies in tidal flows. It proposes that very long dams (for example: 30–50 km length) be built from coasts straight out into the sea or ocean, without enclosing an area
- **Tidal lagoon**: A new tidal energy design option is to construct circular retaining walls embedded with turbines that can capture the potential energy of tides. The created reservoirs are similar to those of tidal barrages, except that the location is artificial and does not contain a pre-existing ecosystem. The lagoons can also be in double (or triple) format without pumping or with pumping that will flatten out the power output.

C	**LIMITATIONS** • Economic recovery of energy from tides is feasible only at those sites where energy is concentrat in the form of tidal range of about 5 m or more and geography provide favorable site for econon construction of a tidal plant, thus it is site specific • Due to mismatch of lunar driven period of 12.5 hours and human (solar) period of 24 hours, t optimum tidal power generation is not in phase with demand • Changing tidal range in two weeks period produces changing power • The turbines are required to operate at variable heads • Requirement of large water volume flow at low head necessitates parallel operation of many turbin • Tidal plant disrupts marine life at the location and can cause potential harm to ecology • It requires very large capital cost at most potential installations • The location of sites may be distant from the demand centers
9a	What are the Disadvantages of Geothermal Energy? 1. Location Restricted The largest single disadvantage of geothermal energy is that it is location specific. Geothermal plants need to be built in places where the energy is accessible, which means that some areas are not able to exploit this resource. Of course, this is not a problem if you live in a place where geothermal energy is readily accessible, such as Iceland.. Environmental Side Effects Although geothermal energy does not typically release greenhouse gases, there are many of these gases stored under the Earth's surface which are released into the atmosphere during digging. While these gases are also released into the atmosphere naturally, the rate increases near geothermal plants. However, these gas emissions are still far lower than those associated with fossil fuels. 3. Earthquakes Geothermal energy also runs the risk of triggering earthquakes. This is due to alterations in the Earth's structure as a result of digging. This problem is more prevalent with enhanced geothermal power plants, which force water into the Earth's crust to open up fissures to greater exploitation of the resource. However, since most geothermal plants are away from population centres, the implications of these earthquakes are relatively minor. 4. High Costs Geothermal energy is an expensive resource to tap into, with price tags ranging from around \$2-\$7 million for a plant with a 1 megawatt capacity. However, where the upfront costs are high, the outlay can be recouped as part of a long-term investment. 5. Sustainability In order to maintain the sustainability of geothermal energy fluid needs to be pumped back into the underground reservoirs faster than it is depleted. This means that geothermal energy needs to be properly managed to maintain its sustainability. It is important for industry to assess the geothermal energy pros and cons in order to take account of the advantages while militating against any potential problems.
b	Factors affecting Biogas generation: 1) PH value 2) Temperature 3) Total solid content 4) Load rating 5) Seeding 6) Uniform feeding 7) Dia to depth ratio 8) Carbon to nitrogen ratio 9) Nutrient 10) Mixing 11) Retention time 12) Type of feedstock Page 93 13) Toxicity 14) Pressure

c

Deenbandhu biogas plant:



Deenbandhu model was developed in 1984, by Action for Food Production (AFPRO), a voluntary organization based in New Delhi. Schematic diagramof a Deenabandhu biogas plant entire biogas programme of India as it reduced the cost of the plant half of that of KVIC model and brought biogas technology within the reach of even the poorer sections of the population. The cost reduction has been achieved by minimizing the surface area through joining the segments of two spheres of different diameters at their bases. The cost of a Deenbandhu plant having a capacity of 2 m3/day is about Rs.8000/. The Deenbandhu biogas plant has a hemispherical fixed- dome type of gas holder, unlike the floating dome of the KVIC-design is shown. The dome is made from pre-fabricated Ferro cement or reinforced concrete and attached to the digester, which has a curved bottom. Theslurry is fed from a mixing tank through an inlet pipe connected to the digester. After fermentation, the biogas collects in the space under the dome. It is taken out for use through a pipe connected to the top of the dome, while the sludge, which is a by-product, comes out through anopening in the side of the digester. About 90% of the biogas plants in India are of the Deenbandhutype.

10 a	Production:

Although hydrogen is the third most abundant element on the earth, it does not exist in Free State, except for small quantities in the upper atmosphere. It is, therefore, not a primary energy source. It can therefore, be produced through two routes:

a) Fossil fuels, such as natural gas, coal, methanol, gasoline etc., and biomass are decomposed by thermo-chemical (steam reforming or partial oxidation) methods to obtain hydrogen. The CO produced in the process is eliminated by water gas shift reaction. This route of hydrogen production causes CO2 emission. The energy

content of the produced hydrogen is less than the energy content of the original fuel, some of it being lost as excessive heat during production.

b) Hydrogen can also be produced by splitting water into hydrogen and oxygen by using energy from nuclear or renewable sources such as solar, wind, geothermal, etc., through electrical or thermal means (i.e. electrolysis and thermolysis respectively). Water splitting is also possible through biophotolysis process using solar radiation.

1. Electrolysis of Water:

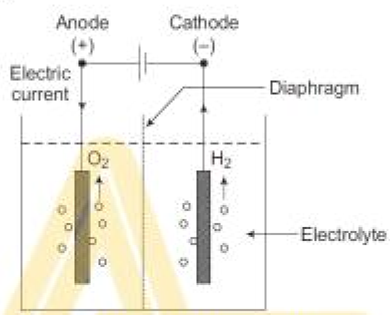


Fig: Electrolytic cell

Electrolysis is the simplest method of hydrogen production. Currently, this method is not as efficient or cost effective as thermo-chemical method using fossil fuels or biomass. But it would allow for more distributed hydrogen generation and open the possibilities for use of electricity generated from renewable and nuclear resources for hydrogen production.

An electrolysis cell essentially consists of two electrodes, commonly flat metal or carbon plates, immersed in an aqueous conducting solution called electrolyte, as shown in Fig. A direct current decomposes water into H2 and O2, which are released at cathode (–ve electrode) and anode (+ve electrode) respectively. As water itself is poor conductor of electricity, an electrolyte, commonly aqueous KOH is used.

Ideally, a decomposition voltage of 1.23 V per cell should be sufficient at normal temperature and pressure; however, due to various reasons a voltage of about 2 V per cell is applied in practice. The energy required is 3.9–4.6 kWh per m3 of hydrogen produced. About 60–70 per cent of this energy is actually utilized in electrolysis.

Therefore, the efficiency of electrolysis process is about 60–70 per cent, which can be improved up to 80 per cent by using catalyst such as porous platinum or nickel. A diaphragm (usually woven asbestos) prevents electronic contact between the electrodes and passage of gas or gas bubbles. Electrolysis method is most suitable when primary energy is available as electrical energy, e.g. solar photovoltaic energy. It is also suitable where cheap electricity is available from other sources such as wind, geothermal, etc.

b	Hydrogen is a versatile and clean energy carrier that has the potential to play a significant role in a sustainable energy future. However, ensuring the safe utilization of hydrogen energy is of paramount importance, as hydrogen is highly flammable and presents certain challenges. Here are some key considerations for the safe utilization of hydrogen energy: 1. **Hydrogen Production Safety:** • Hydrogen production methods should be chosen with safety in mind. Common methods include electrolysis of water, natural gas reforming, and biomass gasification. Each method has its own safety considerations. 2. **Storage Safety:** • Hydrogen must be stored in a safe manner to prevent leaks and explosions. High-pressure gas storage tanks and cryogenic storage systems are commonly used. Adequate safety measures must be in place to prevent over-pressurization or leaks from storage systems. 3. **Transport Safety:** • Hydrogen transportation can involve pipelines, trucks, or ships. Proper safety measures are essential to prevent accidents during transportation. Leak detection systems and safety valves are critical components of hydrogen transportation infrastructure. 4. **Distribution Safety:** • When distributing hydrogen to end-users, safety measures are essential. Hydrogen pipelines must be designed and maintained to prevent leaks. Safety regulations and protocols must be followed during distribution. 5. **Hydrogen Fueling Stations:** • Hydrogen fueling stations for fuel cell vehicles need to adhere to strict safety standards. These stations should be equipped with safety systems, including sensors for leak detection and emergency shut-off mechanisms. 6. **Leak Detection and Ventilation:** • Hydrogen is odorless and colorless, making leaks difficult to detect without specialized equipment. Leak detection systems should be installed in areas where hydrogen is used or stored. Adequate ventilation systems can help disperse hydrogen in case of leaks. 7. **Hydrogen Compatibility:** • Hydrogen can embrittle certain metals and materials. Ensure that equipment and materials used in hydrogen-related applications are compatible with hydrogen and meet safety standards. 8. **Training and Education:** • Proper training and education are essential for those working with or around hydrogen. Individuals should be aware of the properties and risks associated with hydrogen and how to respond in case of emergencies. 9. **Regulations and Standards:** • Adherence to safety regulations and standards, such as those developed by organizations like the International Code Council (ICC) and the National Fire Protection Association (NFPA), is crucial for safe hydrogen utilization. 10. **Emergency Response Plans:** • Have well-defined emergency response plans in place in case of hydrogen-related incidents. First responders should be trained in handling hydrogen emergencies. 11. **Public Awareness:** • Public awareness campaigns can help educate people about the safe use of

	hydrogen, especially as it becomes more widely used in transportation and energy systems. Safety is a critical aspect of harnessing the benefits of hydrogen as a clean energy source. By implementing strict safety measures and adhering to established standards and guidelines, the risks associated with hydrogen can be effectively managed to enable its safe utilization in various applications.
c	Hydrogen energy can be stored using various methods, each with its advantages and disadvantages. The choice of storage method depends on factors like the intended use, efficiency, safety, and cost considerations. Here are some common methods of storing hydrogen energy: 1. **Compressed Hydrogen Gas (CH2):** • **Description:** In this method, hydrogen is compressed at high pressures (typically 350-700 bar or 5,000-10,000 psi) and stored in high-strength tanks made of materials like carbon fiber-reinforced composites or metal alloys. • **Advantages:** Simple technology, well-established, and suitable for gaseous hydrogen storage. It can be used for various applications, including fuel cell vehicles. • **Challenges:** Requires high-pressure tanks, which can be heavy and expensive. Energy can be lost during compression and decompression. 2. **Liquid Hydrogen (LH2):** • **Description:** Hydrogen is cooled to extremely low temperatures (around -253°C or -423°F) to become a cryogenic liquid and stored in well-insulated tanks. • **Advantages:** High energy density, especially for large-scale applications. Well-suited for long-term storage and transportation. • **Challenges:** Requires energy for liquefaction and insulation. Boil-off losses can occur over time. Cryogenic tanks can be heavy and costly. 3. **Hydrogen Chemical Storage:** • **Description:** Hydrogen can be chemically bound to a carrier material, such as metal hydrides (e.g., magnesium hydride) or chemical compounds (e.g., ammonia), and released when needed through chemical reactions. • **Advantages:** Can offer safe and compact storage options, suitable for stationary applications and hydrogen refueling stations. • **Challenges:** May have lower energy density compared to other methods. Efficiency can vary based on the specific chemical reactions involved. Regeneration of the carrier material may require high temperatures. 4. **Hydrogen Underground Storage:** • **Description:** Hydrogen can be stored in natural geological formations, similar to natural gas storage. It is injected into underground salt caverns, depleted gas reservoirs, or aquifers. • **Advantages:** Large storage capacity, suitable for seasonal or long-term energy storage. Minimal energy loss during storage. • **Challenges:** Requires appropriate geological formations. Initial infrastructure investment can be substantial. 5. **Metal Hydride Storage:** • **Description:** Hydrogen is absorbed by certain metals, forming metal hydrides. The hydrogen is released when the metal hydride is heated. • **Advantages:** Safe and compact storage, particularly for small-scale applications. Can operate at lower pressures.

- **Challenges:** Typically lower hydrogen storage capacity compared to compressed gas or liquid storage. The release process requires energy input.

6. **Carbon Nanotube and Nanostructured Materials:**
    - **Description:** Carbon nanotubes and other nanostructured materials can adsorb hydrogen molecules on their surfaces. This is a developing area of research for hydrogen storage.
    - **Advantages:** High surface area and potential for efficient hydrogen storage.
    - **Challenges:** Research is ongoing, and commercial viability is still being explored.
7. **Pumped Hydrogen Storage:**
    - **Description:** This method involves using surplus electricity to electrolyze water, producing hydrogen, which is then stored in tanks. When electricity is needed, the stored hydrogen is converted back to electricity using fuel cells.
    - **Advantages:** Enables energy storage and grid balancing. Can store large amounts of energy.
    - **Challenges:** Efficiency losses during the energy conversion processes. Infrastructure and equipment costs.

The choice of hydrogen storage method depends on the specific application, whether it's for transportation, grid energy storage, or industrial processes. Additionally, ongoing research and development are exploring innovative methods to improve the efficiency, safety, and practicality of hydrogen storage technologies.

Regenerate