Unit 2

1. **Explain in detail the different types of PV cells based on the thickness of the material used for their fabrication.**

A. **Photovoltaic cells** or **PV cells** can be manufactured in many different ways and from a variety of different materials.

- **<u>Monocrystalline silicon PV panels</u>**

  These are made using cells sliced from a single cylindrical crystal of silicon. This is the most efficient photovoltaic technology, typically converting around 15% of the sun's energy into electricity. The manufacturing process required to produce monocrystalline silicon is complicated, resulting in slightly higher costs than other technologies.

- **<u>Polycrystalline silicon PV panels</u>**

  Also sometimes known as multicrystalline cells, polycrystalline silicon cells are made from cells cut from an ingot of melted and recrystallised silicon. The ingots are then saw-cut into very thin wafers and assembled into complete cells. They are generally cheaper to produce than monocrystalline cells, due to the simpler manufacturing process, but they tend to be slightly less efficient, with average efficiencies of around 12%.

- **<u>Thick-film silicon PV panels</u>**

  This is a variant on multicrystalline technology where the silicon is deposited in a continuous process onto a base material giving a fine grained, sparkling appearance. Like all crystalline PV, it is normally encapsulated in a transparent insulating polymer with a tempered glass cover and then bound into a metal framed module.

- **<u>Amorphous silicon PV panels</u>**

  Amorphous silicon cells are made by depositing silicon in a thin homogenous layer onto a substrate rather than creating a rigid crystal structure. As amorphous silicon absorbs light more effectively than crystalline silicon, the cells can be thinner - hence its alternative name of 'thin film' PV. This technology is, however, less efficient than crystalline silicon, with typical efficiencies of around 6%, but it tends to be easier and cheaper to produce.

- **<u>Other thin film PV panels</u>**

  A number of other materials such as cadmium telluride (CdTe) and copper indium diselenide (CIS) are now being used for PV modules.

The attraction of these technologies is that they can be manufactured by relatively inexpensive industrial processes, certainly in comparison to crystalline silicon technologies, yet they typically offer higher module efficiencies than amorphous silicon.

2. Discuss the reasons for low efficiency of solar cells in detail

#1 Hail

The first factor is the presence of hail at a speed of 20-30 m/s, solar panels must remain undamaged.

#2 Snow, ice and dust

The second factor that must be taken into account is snow. Thick layers of snow can directly block the sunlight accessing solar panels, and therefore, reduce solar efficiency values to zero.

It is important to know that most solar panels can work with the presence of a three to four centimeter layer of snow (approx. 1.5 inches). If it is more than that, maintenance procedures must be put into motion to avoid further losses.

Dust and dirt, are also contaminating elements that can influence efficiency values.

Ice is another element that can affect solar panels’ efficiency between 25 to 100 percent, depending on the thickness of the ice layer.

To avoid this problem, during the manufacturing process a silicon coating is applied, and it’s advisable to try to keep the ice off your panels during the winter season

#3 Insulation resistance

Additionally, insulation can also affect solar module efficiency because current leakages can occur along the edges of solar panels.

This factor is especially important for utility-scale projects as higher voltage systems require better insulation properties (linked directly to the selected materials).

#4 Environmental conditions

Higher **temperature** means more heat, which is linked with electrical losses and voltage drops.

It is estimated that an increase per one unit of temperature above the standard test temperature of 25 degrees Celsius (or 77 degrees Fahrenheit) decreases the energy output by 0.25 to 0.5 percent (depending on the module).

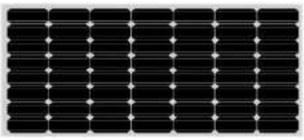
If you think about it: temperature increase of around 60 degrees Celsius (140°F) could reduce the power outcome of your solar panel by 17.5 percent. So, the effect of temperature can be significant in countries with hot climate.

Humidity is also undesirable to solar panels because of corrosion.

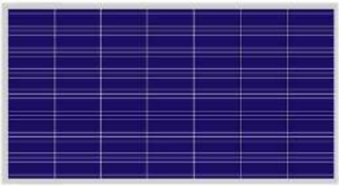
Advanced level of corrosion eventually leads to insulation issues and decreases overall solar panel efficiency.

#5 Selection of a solar panel type

The efficiency of monocrystalline panels varies between 22 to 27 percent.



Polycrystalline panels reach between 15 to 22 percent of efficiency and finally thin film panels between 7 to 13 percent.



The main difference in efficiency values of different panel types lies in the nature of how they have been manufactured. You can see more details about this topic in the recommended reading below.

#6 Design configuration of solar panels

Among other factors associated with the operation of solar panels, the selection of **the orientation towards the sun** and the presence of a solar tracking system has a great importance on the overall efficiency of your solar system.

3. **A solar cell (0.9cm2) receives solar radiation with photons of 1.8eV energy having an intensity of 0.9mW/cm2. Measurements show open circuit voltage of 0.6V/cm2, short circuit current of 10mA/cm2 and the maximum current is 50% of the short circuit current. The efficiency of the cell is 25%. Calculate the maximum voltage that the cell can give and also find the Fill-factor.**

UNIT- 2

Long Answer Questions

3.

$$\eta = \frac{V_{max} I_{max}}{P_{in}}$$

$$V_{max} = \frac{P_{in} \times \eta}{I_{max}}$$

$$= \frac{0.9 \times 10^{-3} \times 0.25}{5 \times 10^{-3}}$$

$$= 0.045\ V/cm^2$$

$$P_{max} = V_{oc} \times I_{sc} \times FF$$

$$FF = \frac{I_{max} \times V_{max}}{V_{oc} \times I_{sc}}$$

$$= \frac{5 \times 10^{-3} \times 0.045}{0.6 \times 10 \times 10^{-3}}$$

$$= 0.0375$$

4. **A photo voltaic cell has $I_0=2x10^{-2}$ amps. Measurements show short circuit current I_{sc} as 30mA per an area of 1cm^2. Find the maximum power output, Fill factor, and the conversion efficiency.**

V	0.5	0.52	0.53	0.54	0.56
I	29.6	29.0	28.6	27.9	25.5

5. **What is the optimum load to be connected for the above PV cell? What is maximum power point tracking?**

A. MPPT or **Maximum Power Point Tracking** is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called maximum power point(or peak power voltage). Maximum power varies with solar radiation, ambient temperature and **solar cell** temperature.

6. **Explain about the tracking control of a solar panel in detail.**

- A typical solar tracking system adjusts the face of the solar panel or reflective surfaces to align with the sun as it moves across the sky. The system moves though one rotation per day.
- Trackers direct solar panels or modules toward the sun. These devices change their orientation throughout the day to follow the sun's path to maximize energy capture.
- In photovoltaic systems, trackers help minimize the angle of incidence (the angle that a ray of light makes with a line perpendicular to the surface) between the incoming light and the panel, which increases the amount of energy the installation produces.
- Concentrated solar photovoltaics and concentrated solar thermal have optics that directly accept sunlight, so solar trackers must be angled correctly to collect energy. All concentrated solar systems have trackers because the systems do not produce energy unless directed correctly toward the sun.
- Trackers generate more electricity than their stationary counterparts due to increased direct exposure to solar rays. This increase can be as much as 10 to 25% depending on the geographic location of the tracking system.
- There are many different kinds of solar trackers, such as single-axis and dual-axis trackers, all of which can be the perfect fit for a unique jobsite. Installation size, local weather, degree of latitude and electrical requirements are all important considerations that can influence the type of solar tracker best suited for a specific solar installation.
- Solar trackers generate more electricity in roughly the same amount of space needed for fixed-tilt systems, making them ideal for optimizing land usage.

SOLAR RADIATION

UNIT - 2

1. Explain terrestrial and Extra-terrestrial solar radiation.

A. <u>Terrestrial solar radiation:</u>

→ It is a Electromagnetic radiation which originates from Earth and it's atmosphere.

→ Terrestrial radiation is a longer wavelength which is totally infrared.

→ When the terrestrial solar radiation reaches the Earth's surface, it is broken into two components i.e diffuse radiation and beam radiation.

<u>Extra-terrestrial solar radiation:</u>

→ The Extra-terrestrial solar radiation is the radiation which is incident outside the earth's surface.

→ The Extra-terrestrial radiation is 1367 Watts/m^2

→ Due to the change in distance between earth and sun, there is a seasonal Variation in the Extra terrestrial rate.

2. Write a short note on concentrating collectors?

A. A concentrating collector comprises a receiver, where the radiation is absorbed and converted to some other Energy form, and a concentrator, which is the optical system that directs beam radiation onto the receiver.

→ concentrating collectors provide energy at temperatures higher than those of FPCs and ETCs.

→ They redirect solar radiation passing through an aperture(A_a) into an ~~ab~~ absorber and usually require tracking of the sun

→ In concentrating collectors, solar energy is optically concentrated before being transferred into heat.

→ concentration can be obtained by reflection of solar radiation by the use of mirrors or lense.

3. Explain solar thermal conversion.

A. solar thermal technologies are designed to convert the incident solar radiation into usable heat.

→ The process of solar thermal conversion implies using energy collectors - the specially designed mirrors, lenses, heat exchangers, which ~~could b~~ would concentrate the radiant energy from the sun and transfer it to a carrier fluid.

→ In all the thermal conversion processes, solar radiation is absorbed at the surface of a receiver, which contains or is in contact with flow passages through which a working fluid passes.

→ The upper temperature that can be achieved in solar thermal conversion depends on the isolation, the degree to which the sunlight is concentrated, and the measures taken to reduce heat losses from the working fluid.

4. What is Fresnel lens?

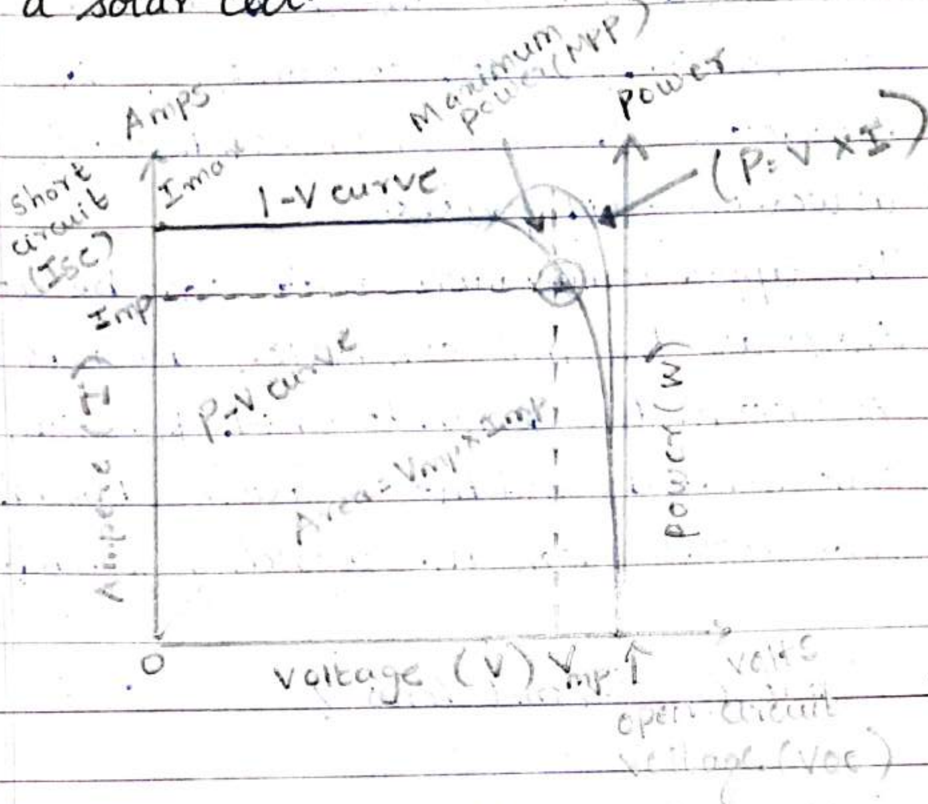
A. A Fresnel lens is a type of composite compact lens originally developed by French physicist Augustin-Jean Fresnel (1788-1827) for light houses.

→ It is a thin piece of plastic, used as magnifier. Fresnel lenses were first used the 1880s as the lens that focuses the beam in lighthouse lamps.

→ The quality of the image is not nearly as good as that from a continuous glass lens, but in lots of applications (like RV), perfect image quality is not necessary

5. Explain current - voltage characteristics of a solar cell.

A.



→ Solar cell I-V characteristic curves shows the current and voltage (I-V) characteristics of a particular photovoltaic (PV) cell, module or array giving a detailed description of it's solar Energy conversion ability and efficiency.

→ Knowning the Electrical I-V characteristics (more Imp Pmax) of a solar cell, or panel is critical in determining the device's o/p performance and solar efficiency.

→ The main Electrical characteristics of a PV cell or module are summarized in the relationship between current and voltage produced on a typical solar cell

I-V characteristics curve:

→ The intensity of the solar radiation (insolation) that hits the cell controls the current (I), while the increases in the temperature of the solar cell reduces it's voltage (V).

→ The power delivered by a solar cell is the product of current and voltage (I × V).

→ With the solar cell open-circuited, that is not connected to any load, the current will be at it's minimum (zero) and the voltage across the cell is as it's maximum, known as the solar cells open circuit voltage.

→ At the other Extreme, when the solar cell is short circuited; that is the +ve & -ve leads connected together, the voltage across the cell is at it's minimum (zero) but current flowing out of the cell reaches it's maximum, known as the solar cells short circuit current; or ISC.

→ The maximum power point (MPP) of a solar cell is positioned near the bend in the I-V characteristic curve.

→ However, there is one particular combination of current & voltage for which the power reaches it's maximum value at Imp and Vmp.

6. Explain Water heating and air heating using solar energy.

A. Water heating:

→ Solar water heating system is a device that use solar energy to heat water for domestic, commercial, and Industrial needs.

→ Heating of water is the most common application of solar energy in the world.

→ A typical solar system water heating system can save up to 1500 units of electricity every year, for every 100 litres per day of solar water heating capacity.

→ Parts of the solar Water heating System:

- A solar water heating system consists of a flat plate solar collectors, a storage tank kept at a height behind the collector, and connecting pipes.
- The collector usually ~~use~~ comprises copper tubes welded to copper sheets with a toughened glass sheet on top and insulating material at the back. The entire assembly is placed in a flat box.
- In certain models, evacuated glass tubes are used instead of copper, a separate cover sheet and insulating box are not required in this case.

→ Working of a solar ~~Heater~~ Water Heater
- The system is generally installed on the roof or open ground, with the collector facing the sun and connected to a continuous water supply.
- Water flows through the tubes, absorbs solar heat and becomes hot.
- The heated water is stored in a tank for further use.
- The water stored in the tank remains hot overnight as the storage ~~sink~~ tank is insulated and heate losses are small.

Air heating:

→ Solar air heating is a solar thermal technology in which the energy from the sun, insolation, is captured by an absorbing medium and used to heat air.

→ Solar air heating is a renewable energy heating technology used to heat or condition air for buildings or process heat applications.

→ It is typically the most cost-effective out of all the solar technologies, especially in commercial & industrial applications, and it addresses the largest usage of building energy in heating climates, which is space heating and industrial process heating.

→ Solar ~~bo~~ air collectors can be divided into two categories.

- Unglazed air collectors or Transpired solar collectors.
- Glazed solar collectors.

7. What are the reasons for low efficiency of Solar cells.

A. i) Hail : The first factor is the presence of Hail at a speed of 20-30 m/s, solar panels must remain undamaged.

ii) Snow, ice and dust : The second factor that must be taken into account is snow. Thick layers of snow can directly block the sunlight accessing solar panels, and therefore reduce solar efficiency value to zero

iii) Insulation resistance : Insulation can also affect solar module efficiency because current leakages can occur ~~due~~ along the edges of solar panels.

iv) Environmental conditions:

Higher temperature means more heat, which is linked with electrical losses & voltages drops.

Humidity: is also undesirable to solar panels because of corrosion.

v) Selection of a solar panel type
vi) Design configuration of solar panels.

8. Distinguish between North-south orientation and East-West orientation of solar panel.

A.

North-South orientation	East-West orientation
• North orientation panels that face north will produce the most electricity overall. • North facing solar panels ~~have produce the~~ have the greatest environmental benefit. • South facing panels only produce about 15% less electricity overall than north facing panels, but as the northern territory still has a high feed-in tariff the most cost effective direction to face solar modules in north.	• placing some solar panels facing east and some facing west will result in the total amount of electricity being produced is 12% less than if all the modules ~~we~~ were placed facing north. • This arrangement is often called and East/west split and has the advantage of producing a more constant o/p of electricity during the day which can help to increase self consumption. • The steeper the roof, the smoother the o/p of the system will be.

9. Short notes on Flat plate collectors

A. A Flat plate collector is a heat Exchanger that converts the radiant solar Energy from the sun into heat energy using the well Known greenhouse effect.

→ It ~~is~~ collects, or captures, solar energy and uses that energy to heat water in the home for bathing, washing & heating, and can even be used to heat outdoor swimming pools and hot tubs.

→ A solar flat plate collector typically consists of a large heat absorbing plate, usually a large sheet of copper or aluminium as they are both good conductors of heat, which is painted or chemically etched black to absorb as much solar radiation as possible for maximum efficiency.

~~→ As the plate gets hotter this heat is conducted through the~~

→ This blackened heat absorbing surface has several parallel copper pipes or tubes called risers, running length ways across the plate which contain the heat transfer fluid, typically water.

10. Explain the Effects of Emission of greenhouse gases in detail.

A. i) Thawing of glacial masses –
Glaciers retreat also has it's own consequences: reduced albedo – the percentage of Solar radiation that the earth's Surface reflects or returns to the atmosphere.
ii) Flooding of islands and costal cities
According to Intergovernmental panel on climate change (IPCC, 2014) during the period 1901 – 2010 the global average sea level rose 19 centimeters.
iii) Hurricanes will be more devasting
iv) Migration of Species
v) Desertification of fertile areas.
vi) Impact on agriculture and livestock.
→ The greenhouse Effect on human health
i) Food Shortage
ii) The spread of diseases and pandemics.

11. What is the maximum power point (MPP) tracking?

A. MPPT (or) maximum power point tracking is algorithm that include in charge controllers used ~~to~~ for Extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called maximum power point (or peak power voltage).

power (W) = volts (V) x Amps (A)

or $P = V \times I$.

12. What is 'Fill Factor'? Explain.

A. The Fill Factor is the ratio of actual maximum obtainable power to the product of the open circuit voltage and short circuit current.

→ This is a key parameter in evaluating performance.

→ The "fill factor", more commonly known by its abbreviation "FF", is a parameter which, in conjuction with V_{oc} and I_{sc}, determines the maximum power from a solar cell.

→ The FF is defined as the ratio of the maximum power from the solar cell to the product of V_{oc} & I_{sc} so that:

$$FF = \frac{P_{MP}}{V_{oc} \times I_{sc}}$$

13. Define
i) Solar constant
ii) Incident angle
iii) Latitude angle.

A. i) Solar constant:
The total radiation energy received from the sun per unit of time per unit of area on a theoritical surface perpendicular to the sun's rays and at Earth's mean distance from the sun.

ii) Incident angle:
The angle formed by a ray or a wave incident on a surface and a line perpendicular to the surface at the point of incidence.

iii) Latitude angle:
Latitude is an angle which ranges from 0° at the equator to 90° (North or South) at the poles. Briefly, geodetic latitude at a point is the angle formed by the vector perpendicular (or normal) to the ellipsoidal surface from that point, and the equatorial plane.

14. Differentiate flat plate collectors and concentrating collectors.

	Flat-plate collectors	concentrating collectors
1.	Flat-plate collectors require more area for absorber than focusing collectors.	1. concentrating collectors requires less area for absorber than flat-plate collectors
2.	An additional anti-freeze is used for Protection	2. No additional requirements are needed.
3.	This can reach only to a low-temperature range	3. This can ~~range~~ reach to a high-temperature range.
4.	Due to low temperature, it does not use to produce power	4. Due to high temperature, it can be used for power generation.
5.	Design is Easy	5. complex design.
6.	It has low insulation intensity.	6. It has high insulation intensity
7.	concentration ratio is 1.	7. concentration ratio is high.
8.	Required low maintenance.	8. Require more maintenance than flat-plate collectors.
9.	Flat-plate collector absorber has uniform flux	9. concentrating collectors have non-uniform flux.
10.	This is comparatively low cost.	10. This is costly.

15. What is Winston's profile?

A. Roland Winston is a leading figure in the field of non-imaging optics and it's applications to solar energy, and is sometimes termed the "father of non-imaging optics". He is the inventor of the compound parabolic concentrator (CPC), a breakthrough technology in Solar Energy.

→ They have the capability of reflecting to the absorber all of the incident radiation within wide limits.

16. Why do we need tracking system?

A. Solar tracking is a technology for orienting a solar collector, reflector, or photovoltaic panel towards the sun.
As the angles of sunlight change with different seasons and times of the day, a solar tracking system can adjust the angle of photovoltaic panels to gain the highest utilization efficiency by maximizing the Exposure to the rays of the sun that beat down vertically on the Earth.

17. Explain about the tracking control of the solar panel.

A: A typical solar tracking system adjust the face of solar panel or reflective surfaces to align with the sun as it moves across the sky.

→ In technical terms, a solar tracking system is meant to move pv modules for ensuring maximum exposure to sun that eventually leads to optimum irradiation.

→ This basically means that the solar tracker is an extremely useful device that can orient a payload towards the sun.

18. What are two power electronic converters used to ~~ste~~ step up or step down the voltage level of solar panel?

A: A DC-to-DC convertors are used to step up or step down the voltage level of solar panel.

19. 'Sea is the god given Solar pond'. Which technology is exploited in generating power through the solar pond as sea?

A. A solar pond is a pool of salt water which collects and stores solar thermal energy. The salt water naturally forms a vertical salinity gradient also known as a "haloc-line", in which low-salinity water floats on top of high-salinity water

(or)

the solar-pond with thermal desalination system can be made by the use of the concentrate from desalination plants and the waste energy coming from the power plant.

20. In PV module electromagnetic fields are generated when sun rays fall - To which theory it is related to?

A. In pv module Electromagnetic fields are generated when sun rays fall - This theory is related to 'Solar panel'.