

UNIT -2

Solar Energy

Solar Energy: Fundamentals; Solar Radiation; Estimation of solar radiation on horizontal and inclined surfaces; Solar radiation Measurements- Pyrheliometers, Pyrometer, Sunshine Recorder. Solar Thermal systems: Flat plate collector; Solar distillation; Solar pond electric power plant.

Solar electric power generation- Principle of Solar cell, Photovoltaic system for electric power generation, advantages, Disadvantages and applications of solar photovoltaic system.

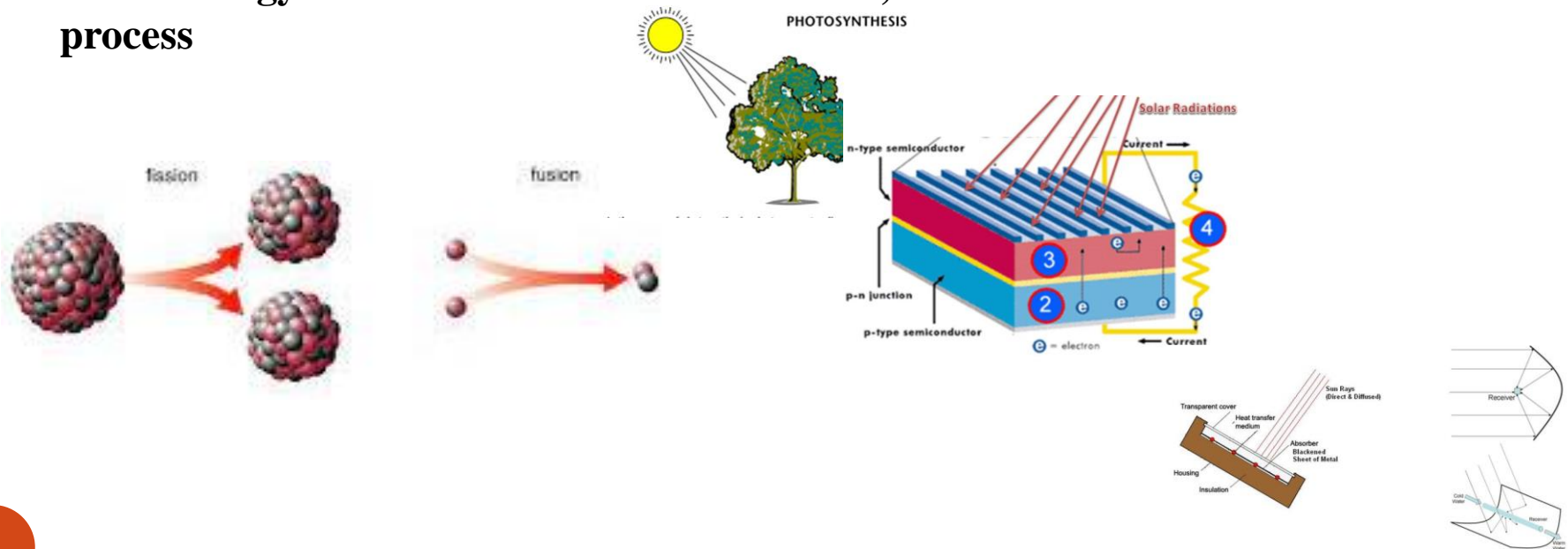
Video Assignment – 10 Marks

- Topic: Renewable Energy
- Duration: 8 minutes
- Use PPT/models/Sketch for presentation
- In presentation you must be present (Audio & Video)
- File name: Roll number – Name
- File format:MP4 Video File (VLC)
- Last Date: 31st December 2022 (Late submission: Reduction in the marks)
- Topic name mention in the watsup group before 26th December 2022
- Marks Distribution

Unique Topic	1 marks
Effective PPT/models/Sketch	4 marks
Effective Explanation (Video, Audio & body language)	4 marks
Your own comment on topic	1 marks
Total	10 marks

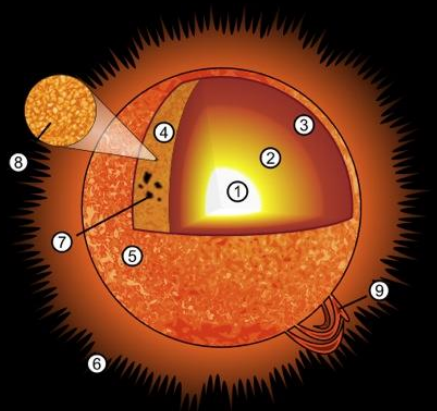
Solar Energy

- Solar energy Originates with the thermonuclear fusion reactions occurring in the sun.
- Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves).
- This energy consists of radiant light and heat energy from the sun.
- Solar energy converted into Helio-chemical, Helio-electrical and Heleio-thermal process



Structure of the Sun

- 1) Core
- 2) Radiative zone
- 3) Convective zone
- 4) Photosphere
- 5) Chromosphere
- 6) Corona
- 7) Sunspots
- 8) Granulation
- 9) Prominence

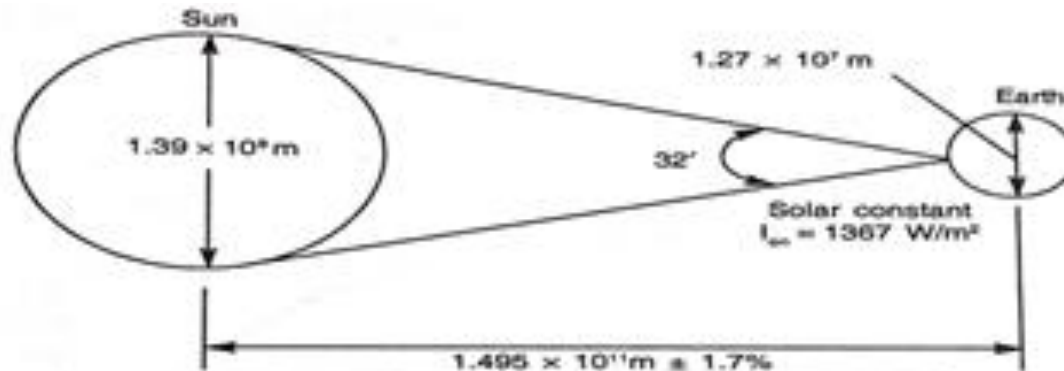


Roughly three-quarters of the Sun's mass consists of hydrogen ($\sim 73\%$); the rest is mostly helium ($\sim 25\%$), with much smaller quantities of heavier elements, including oxygen, carbon, neon, and iron

The Sun

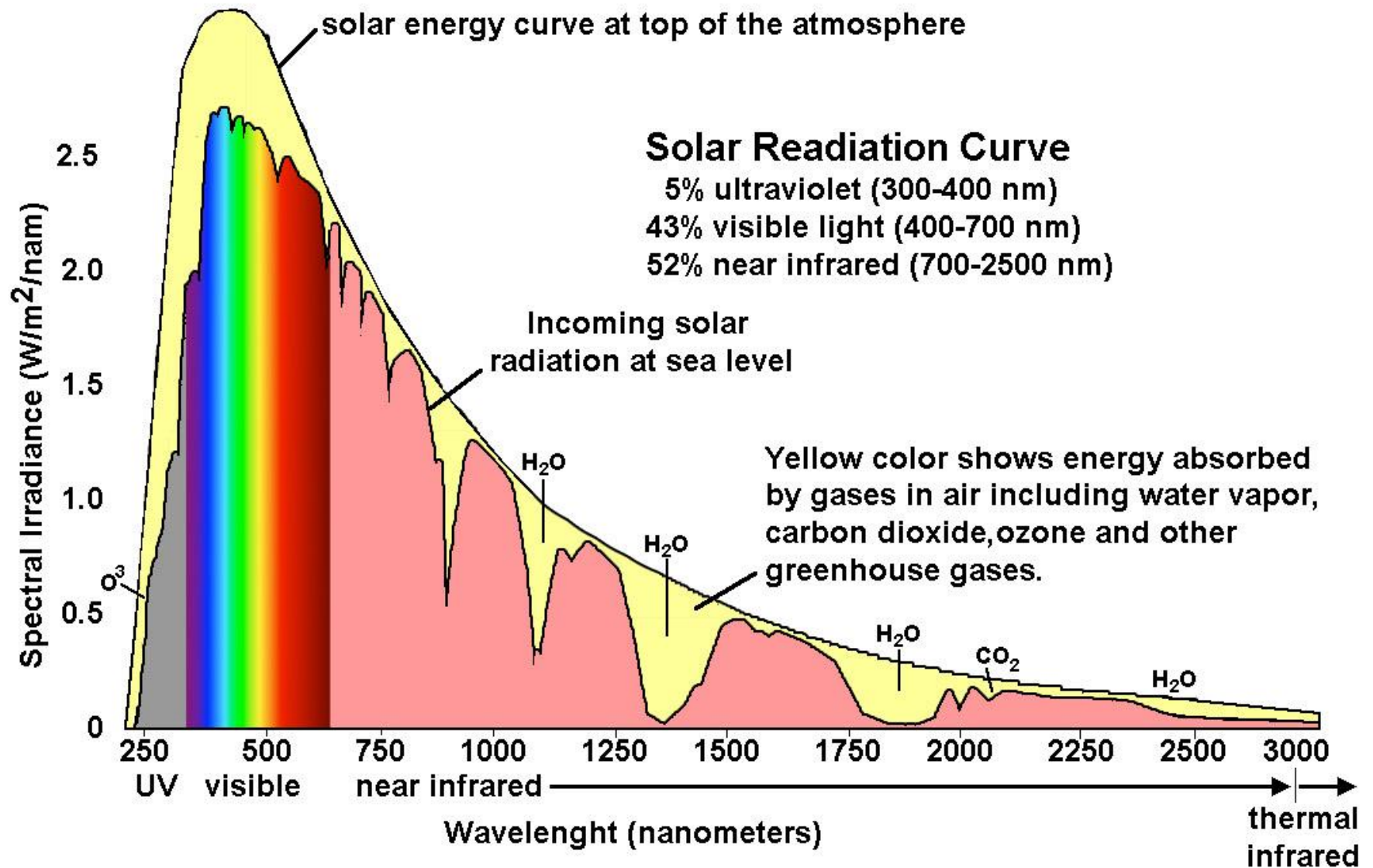


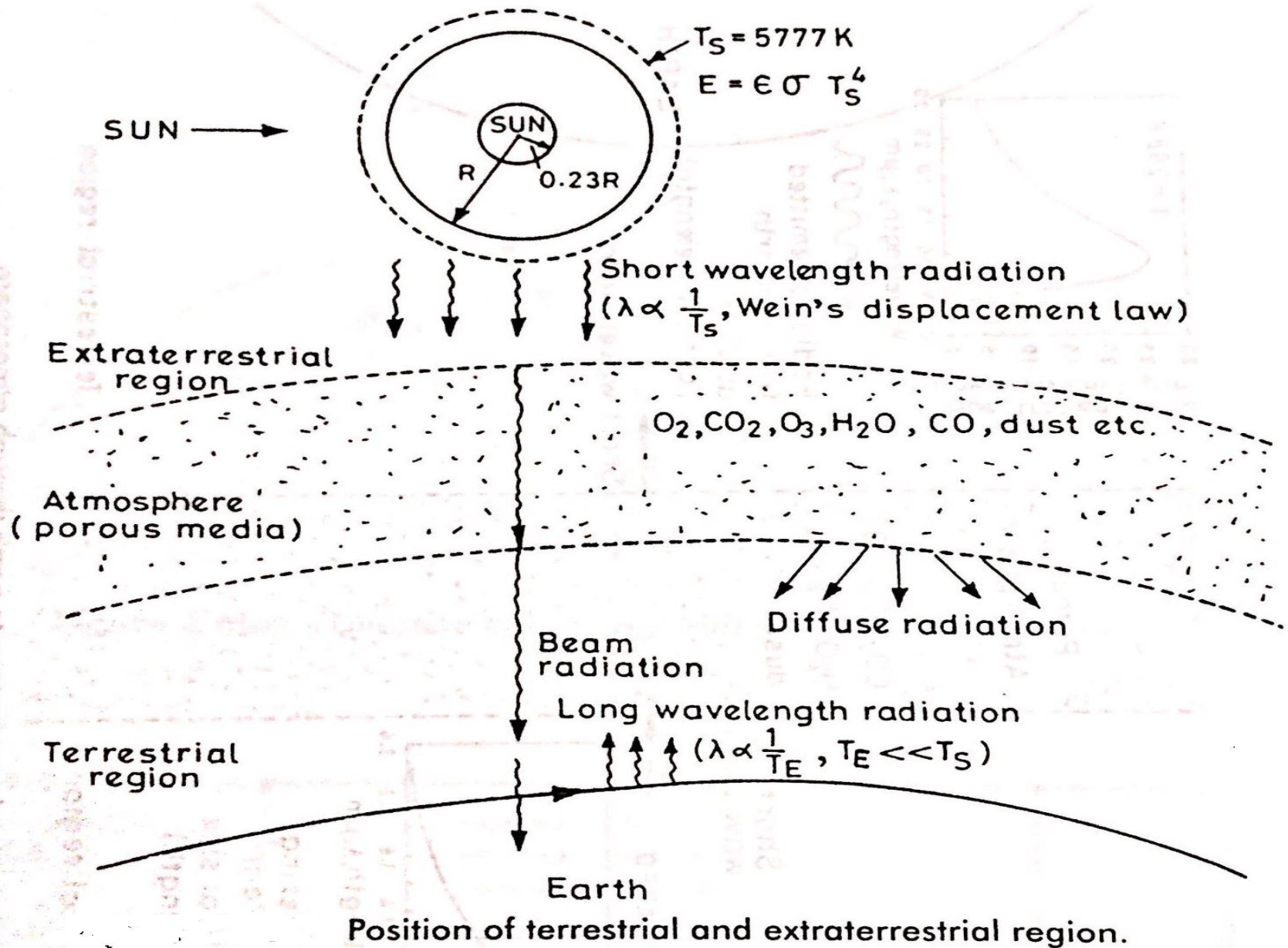
- Diameter: $1.39\text{E}9$ m (120 x greater than earth)
- Distance from earth = $1.495\text{E}11$ m (93 million miles) $\pm 1.7\%$
- Center: Density $\cong 100$ x density of water and $T > 1\text{E}6$ K
- Powered by hydrogen fusion
- Composed of layers. The outer layer is the photosphere
- Effective blackbody temperature of 5777 K



Sun-earth relationships (Duffie & Beckman²)

Solar Energy Distribution





Atmosphere Influence on Solar Radiation

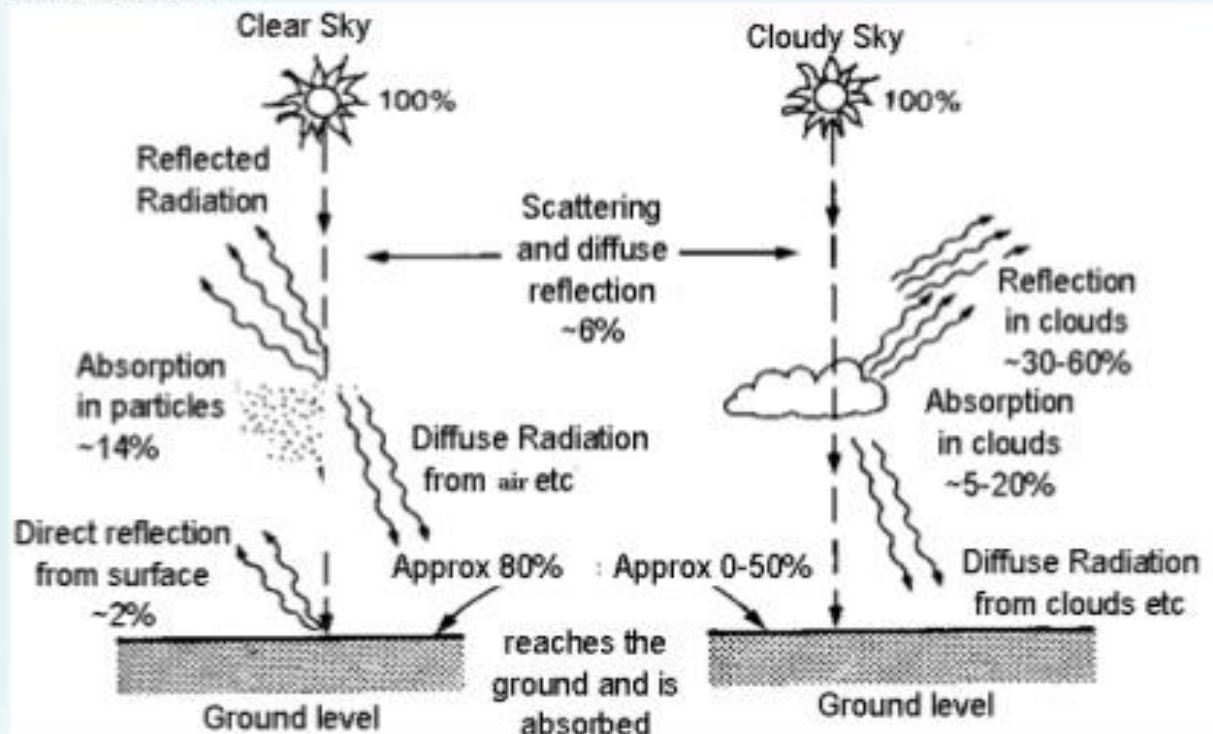
30% is reflected.

17% is absorbed by the atmosphere.

53% reaches the earth surface:

31% direct radiation

22% diffuse radiation .



Insolation

Insolation is the amount of solar radiation reaching the earth & also called **Incident Solar Radiation**.

Components of Solar Radiation:

- Direct radiation
- Diffuse radiation
- Reflect radiation
- Total or Global radiation

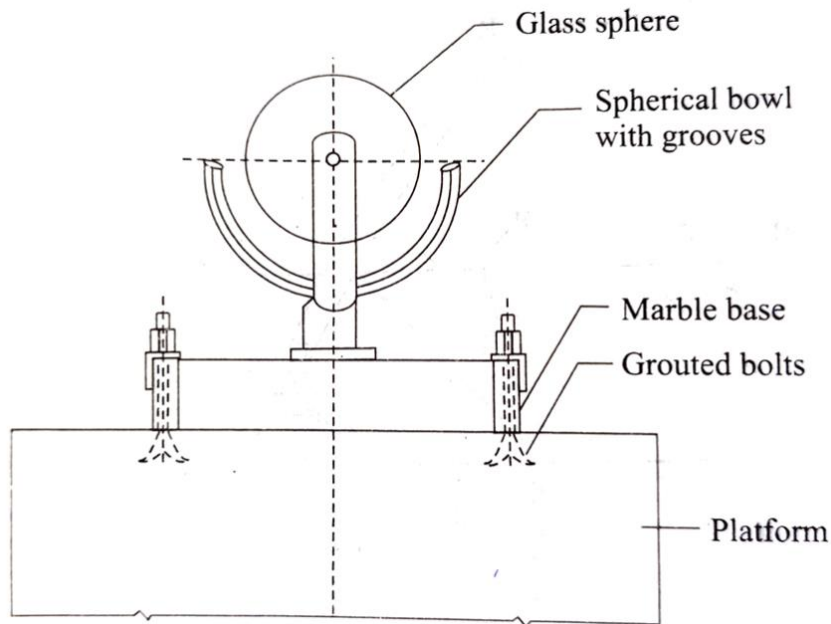
Solar Constant I_{sc} : The amount of energy received from sun in unit time on unit area perpendicular to the sun's direction and at mean distance of the earth from the sun.

$$I_{on} = I_{sc} \left(1 + 0.033 \cos \frac{360 n}{365} \right)$$

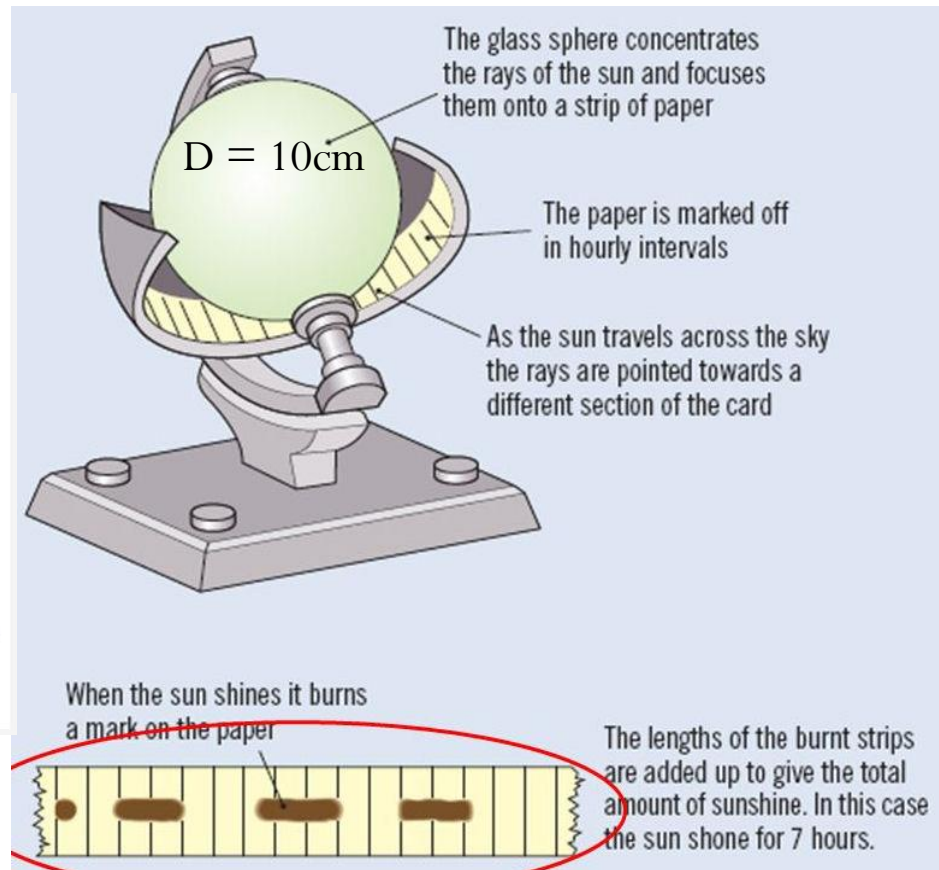
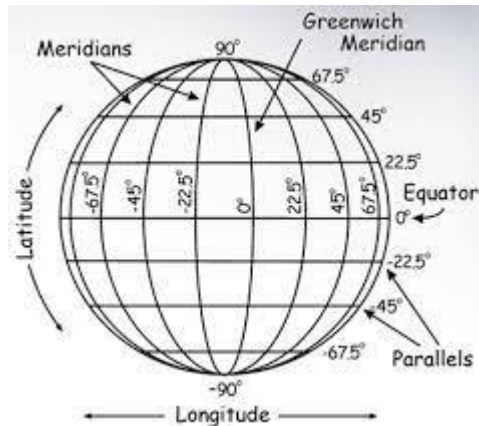
n = day of the year

$I_{sc} = 1.353 \text{ kW}$

Solar radiation measurement- 1. Sunshine recorder



India's location
 20.5937° N, 78.9629° E

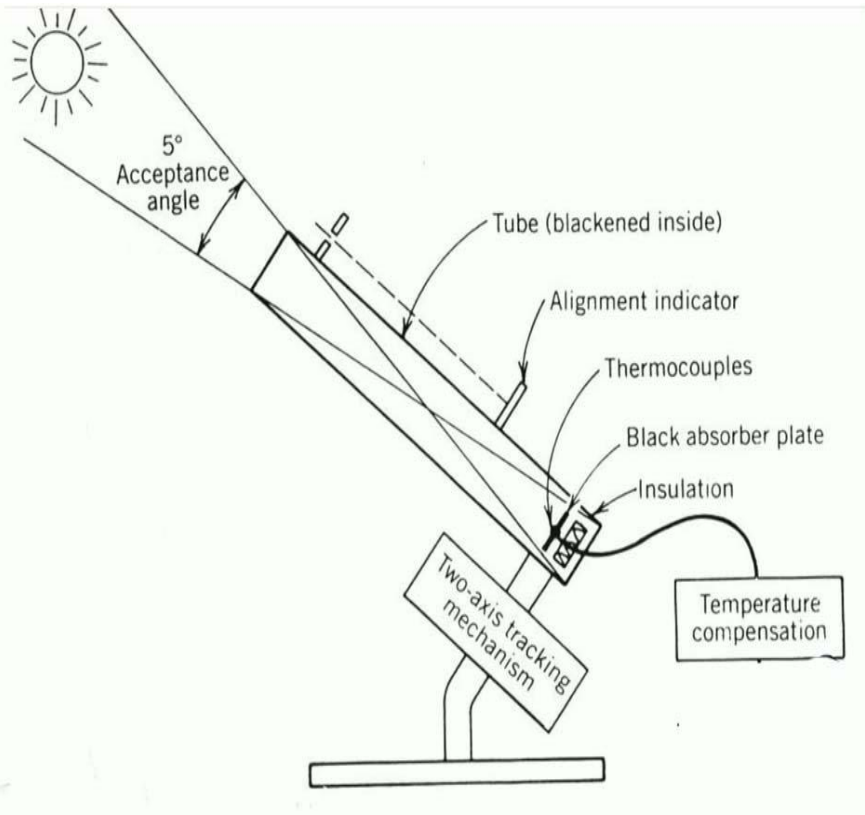


200 W/m^2

Solar radiation measurement: The instrument used for measurement of direct solar radiation and diffuser solar radiation or total solar radiation.

1. Pyrheliometer : An instrument which measures beam radiation

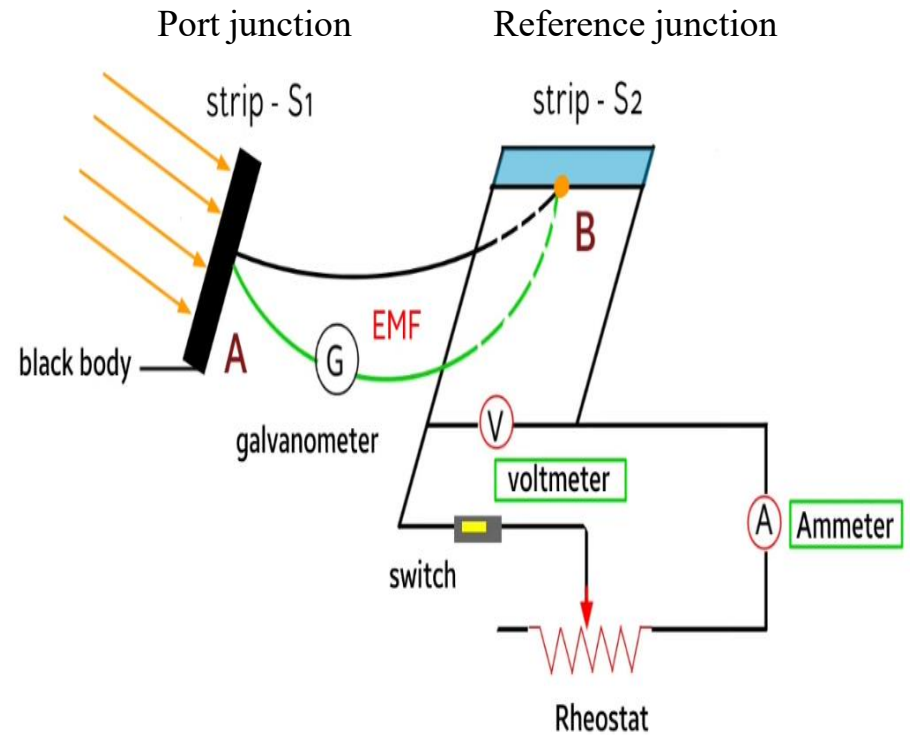
Wavelength: 280nm-3000nm



$$H_D \text{ (Direct radiation on an area)} = Ki^2$$

K = Instrument constant

i = Heating current in amps



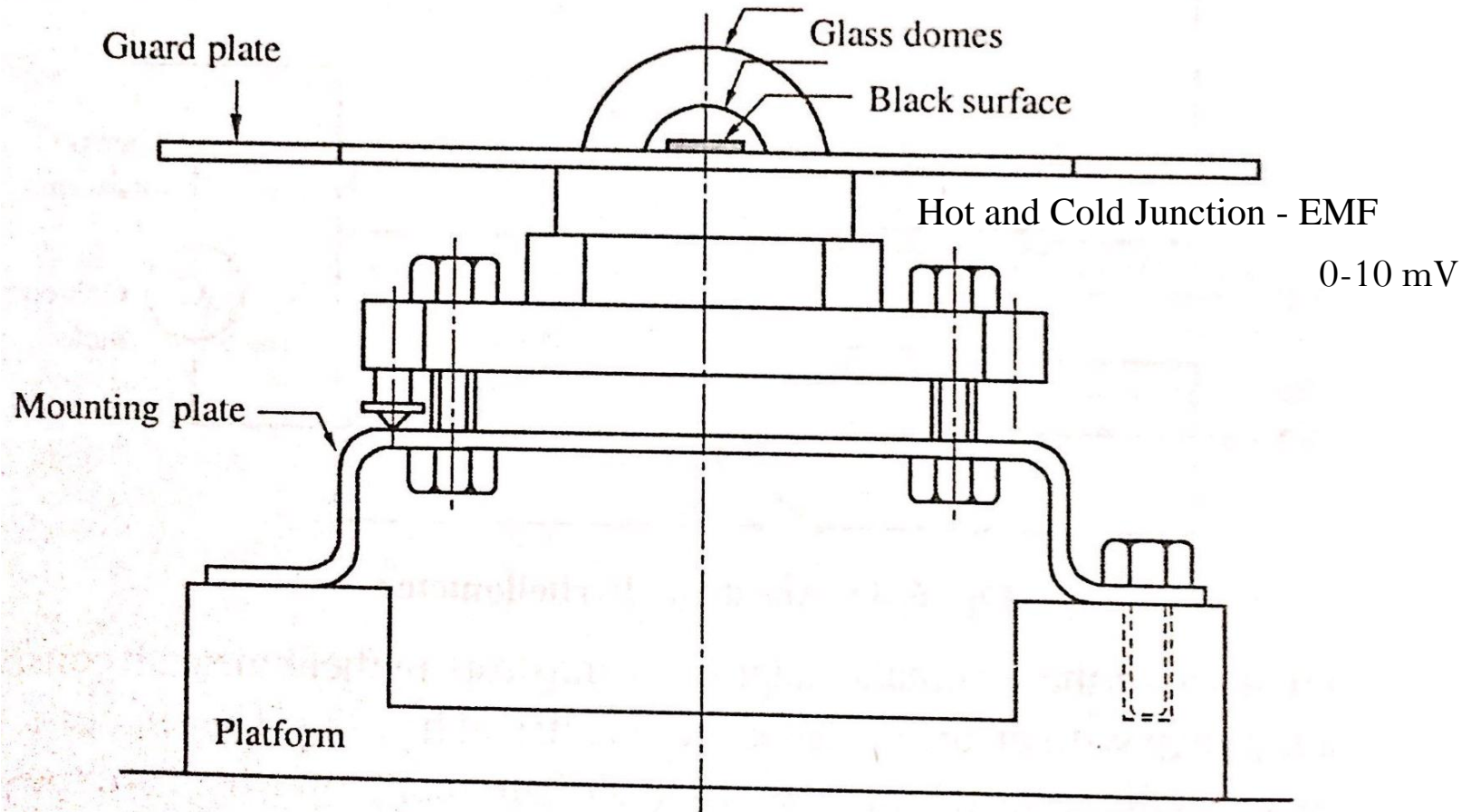
An electrical instrument used to control a current by varying the resistance

Pyrheliometer construction & working

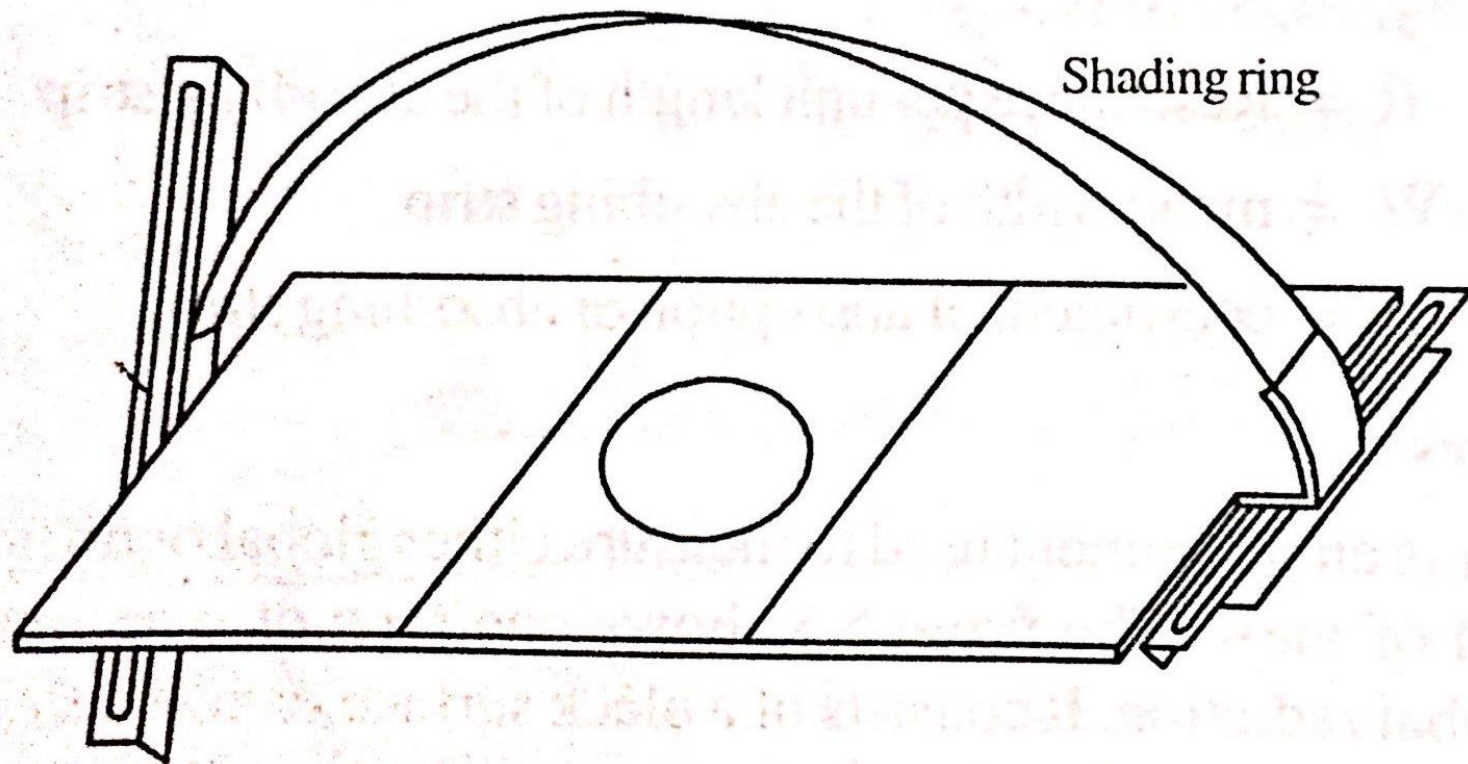
Pyranometer: An instrument which measures total radiation

Acceptance angle 180°

Wavelength: 300nm-2800nm



Pyranometer for global radiation measurement



Pyranometer with shading ring for measuring diffuse radiation

PYRANOMETER

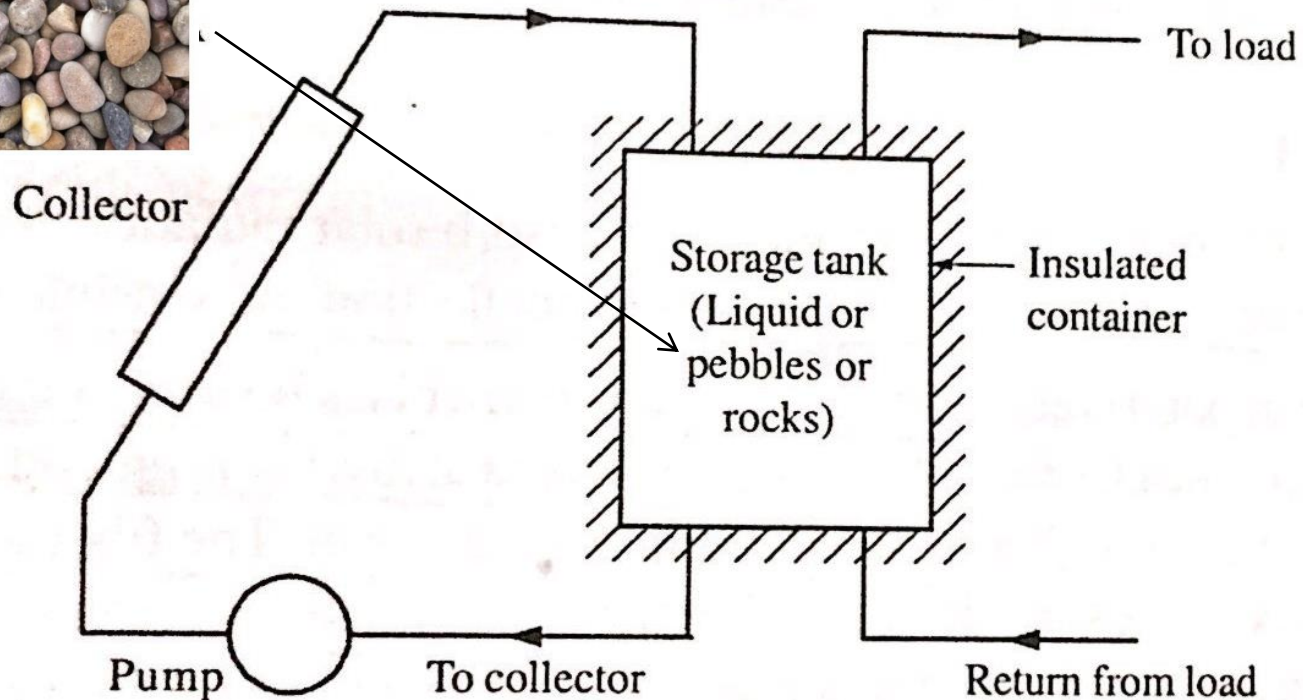
- pyranometer is used to measure direct and diffuse solar radiation
- pyranometer has dome shaped structure
- it do not have requirement of cosine corrector
- pyranometer look up at sky and measure the total solar radiation that is called global solar reform
- pyranometer don't required more maintenance

PYRHeliometer

- pyrhelimeter is used to measure direct solar radiation
- it has tube shaped structures
- pyrhelimeter has requirement of cosine corrector
- pyrhelimeter look up at sun and measure the only direct solar radiation
- pyrhelimeter have requirement of maintenance



Thermal Energy Storage



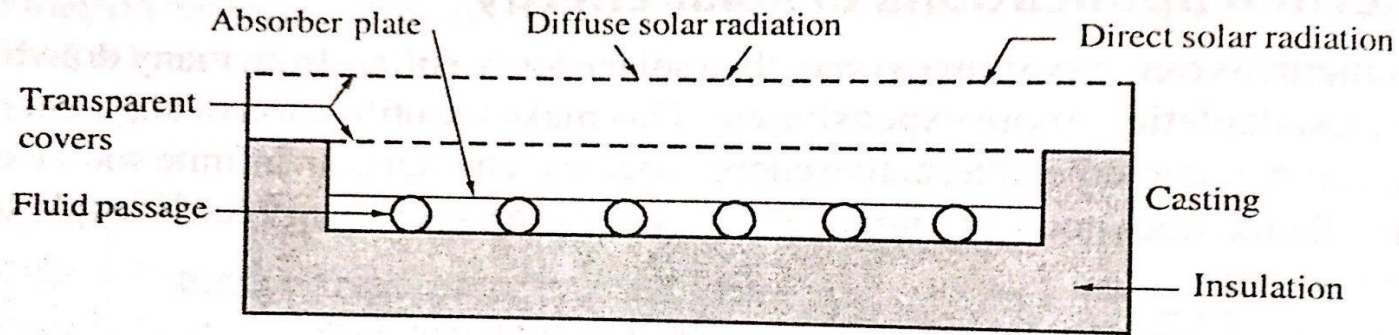
Water tank storage unit

Sensible heat , Latent heat & battery

Flat plate collector

1. Liquid flat plate collector

2. Solar air heater



Liquid flat plate collector

Temperature limited to 100°C

Absorb both direct and diffuse radiations

Area : 1.7 to 2.9 sq. m

Temperature range : 40 to 100°C

Absorber plate : 1 to 2 mm thick & made up of Cu, Al or steel

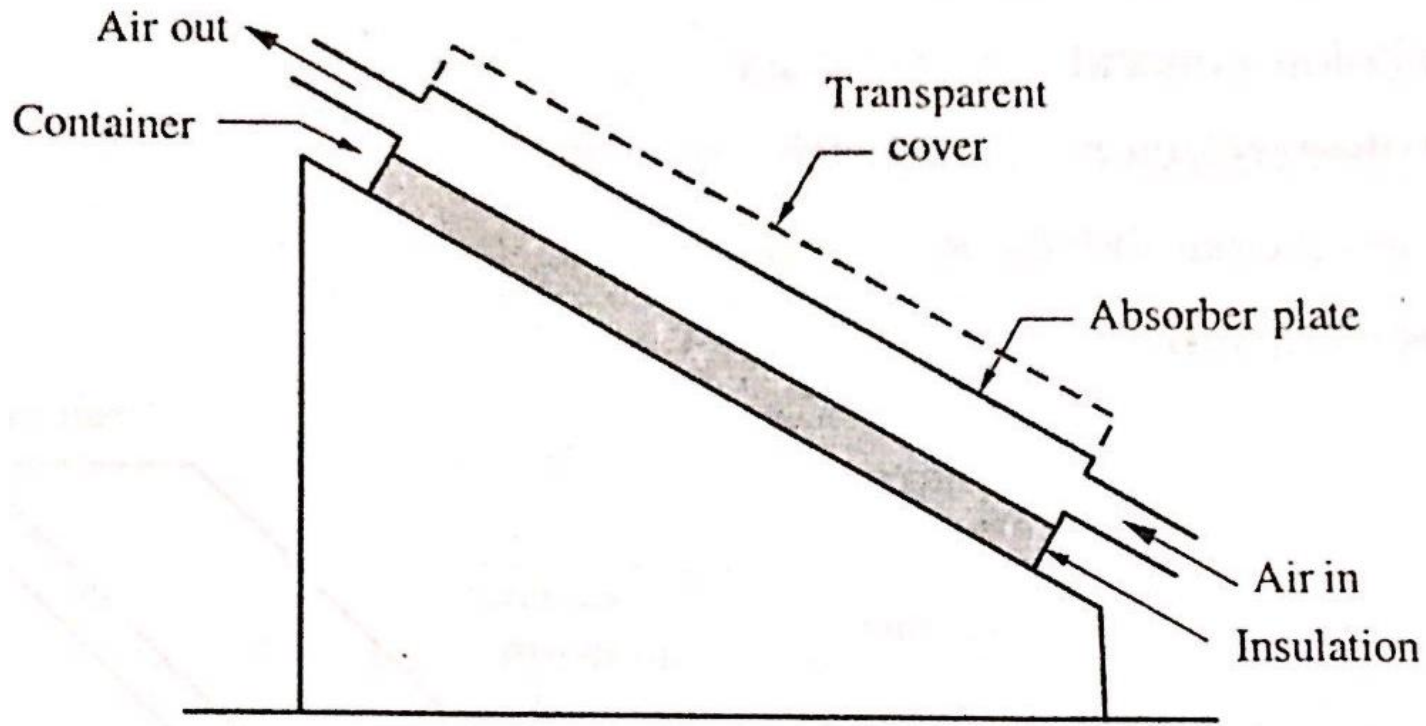
Tube : 1 to 1.5 cm diameter & made up of Cu

Distance between tube : 5 to 15 cm

Insulation : 5 to 10 cm & made up of mineral wool, glass wool or fiber glass

Efficiency: 30 to 50%





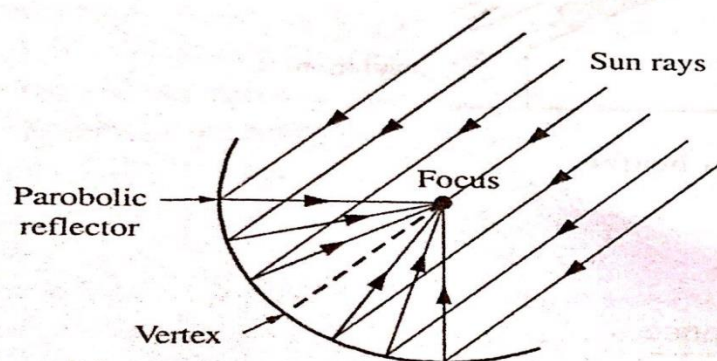
Solar air heater

Advantages of flat plate collector

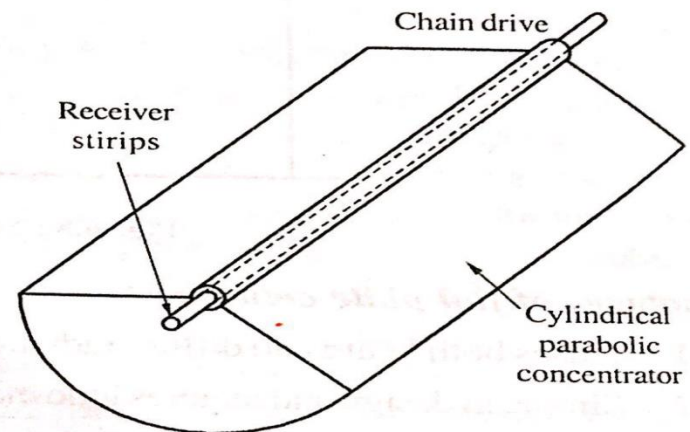
- 1. It uses both beam and diffused radiation**
- 2. Simple in design and less maintenance**
- 3. Orientation of collector towards the sun's direction is not required.**

Concentrating or focusing collector

- For high temperature i.e more than 100°C , concentrated by using focusing or concentrating collector.
- The main type of focusing collectors are
 1. Parabolic trough collector
 2. Paraboloid or dish type concentrating collector
 3. Flat plate collector with adjustable mirrors
 4. Compound parabolic concentrator
 5. Mirror strip reflector



Cross section showing parabolic trough collector



Cylindrical parabolic system

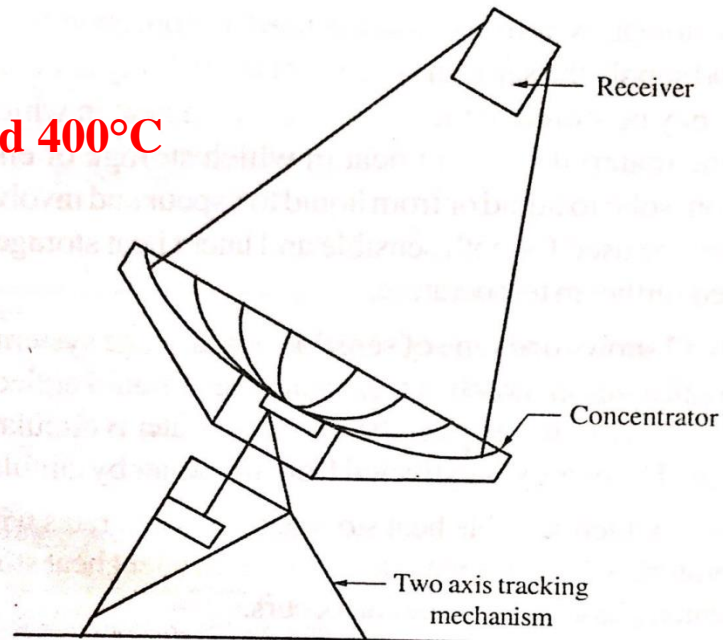
Around 200 to 300°C



More than 500°C



Around 400°C



Paraboloid concentrating collector

Dish type collector



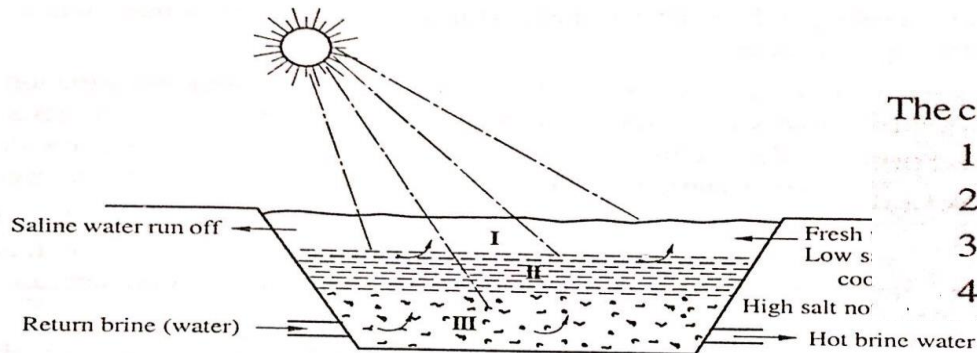
The advantages of using water as the storage medium are,

1. It is cheap and readily available
2. It has high thermal storage capacity
3. Pumping cost is less

The other forms of energy storage which involves some energy conversion process are,

1. Use of large sized fly wheels
2. Energy stored in the form of compressed air
3. In the form of electric batteries ie, lead-acid batteries
4. Solar pond
5. Solar energy can be used for the production of hydrogen which can be stored either in gaseous form or in liquid form.

Solar pond



The collection efficiency of the solar pond depends upon,

1. Salt concentration
2. The amount of suspended dust or other particles
3. Surface impurities like debris, bacteria and algae
4. Type of salt

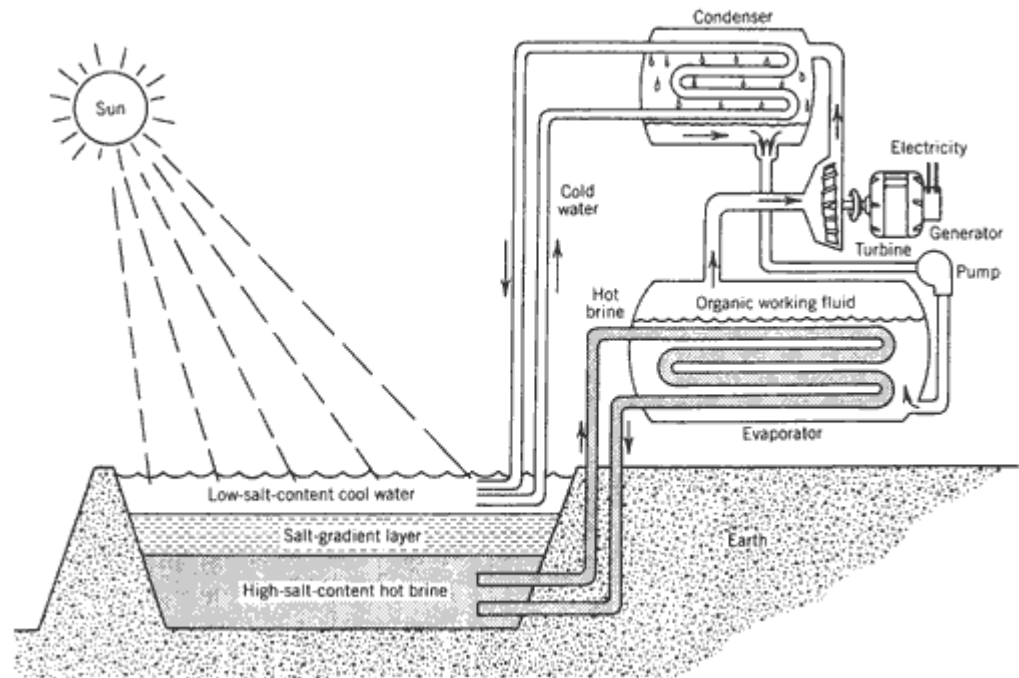
I - Surface or upper convective zone (UCZ)

II - Non convective or Intermediate gradient zone.

III - Storage zone or lower convective zone.

Salt dissolved in water - magnesium chloride, sodium chloride or sodium nitrate.

Principle of solar



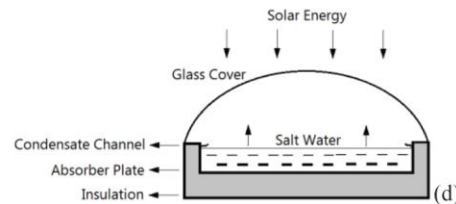
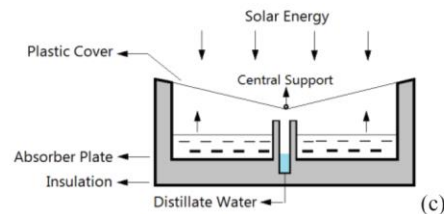
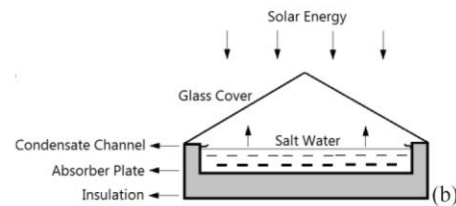
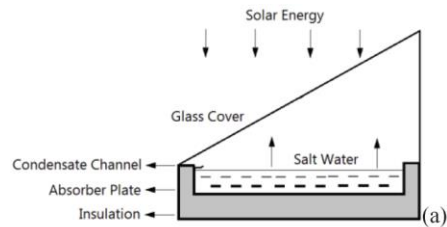
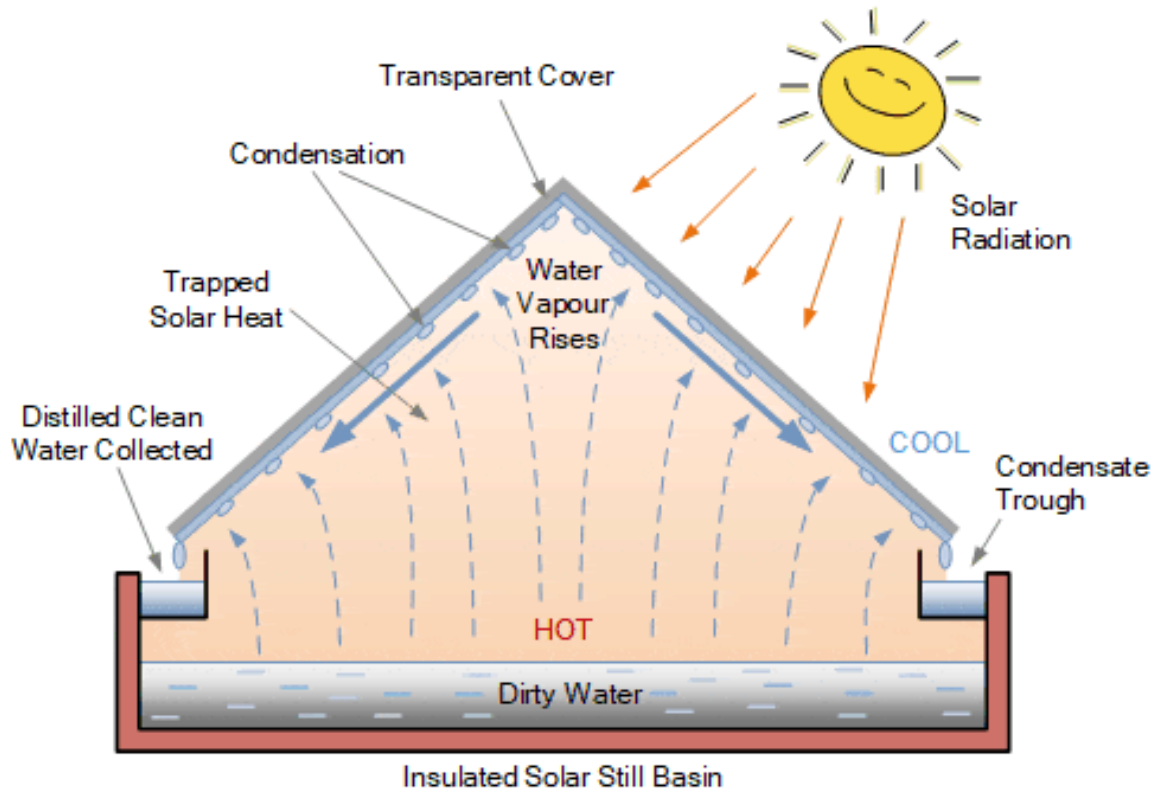
Advantages:

- It is a relatively cheap and low-maintenance system.
- It can be used at the household level and scaled up through programmatic approaches.
- There are climate change adaptation and mitigation benefits.
- There are no energy costs.
- There are no moving parts.

Disadvantages:

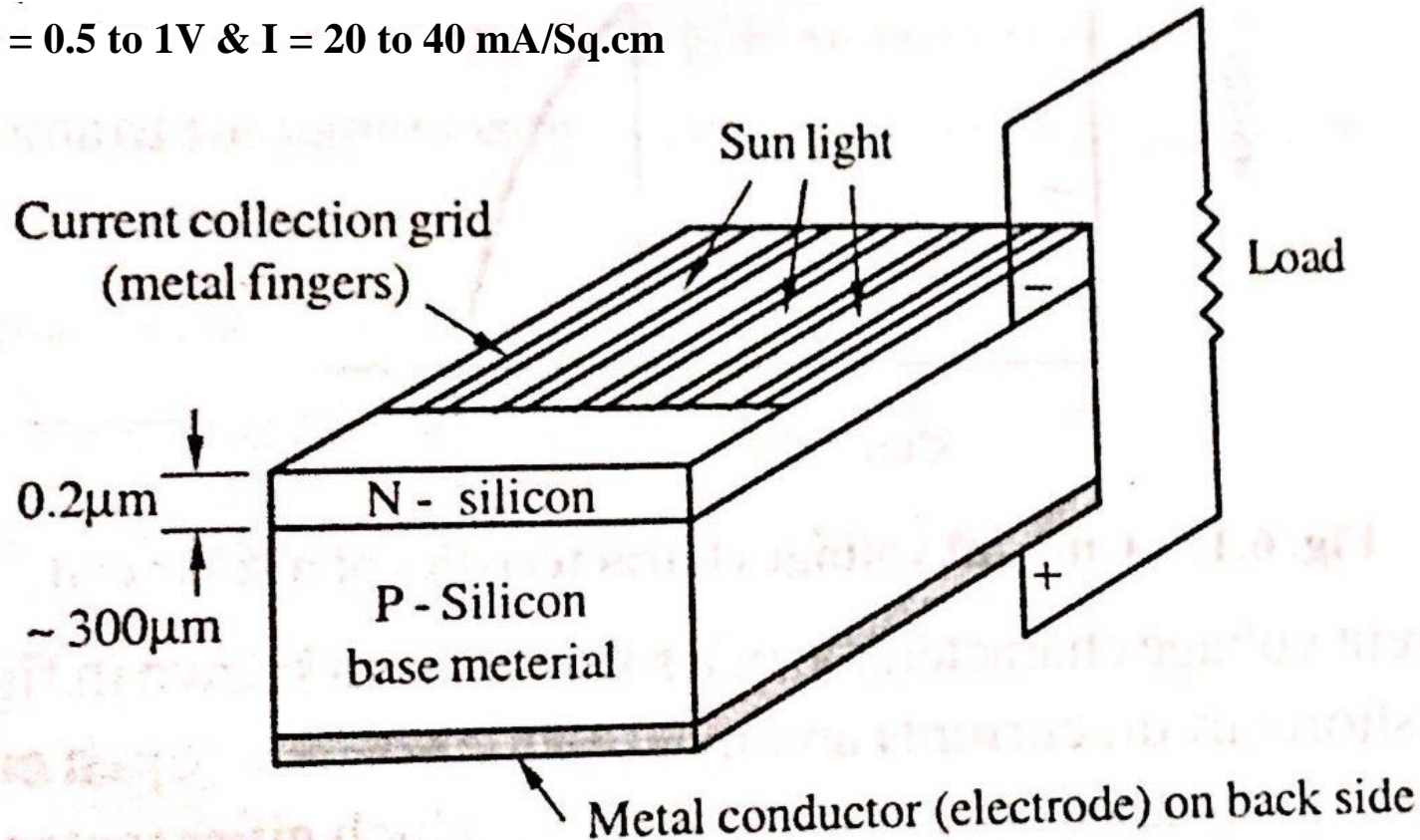
- Rate of distillation is usually very slow (6 litres of water per sunny day).
- It is not suitable for larger consumptive needs.
- The materials required for the distiller may be difficult to obtain in some areas.
- If not correctly disposed of, the distillation process waste stream can be a potential source of environmental pollution (high concentrations of salts and pollutants).

Solar distillation & solar stills



Photovoltaic conversion

$V = 0.5 \text{ to } 1\text{V}$ & $I = 20 \text{ to } 40 \text{ mA/Sq.cm}$



Semiconductor

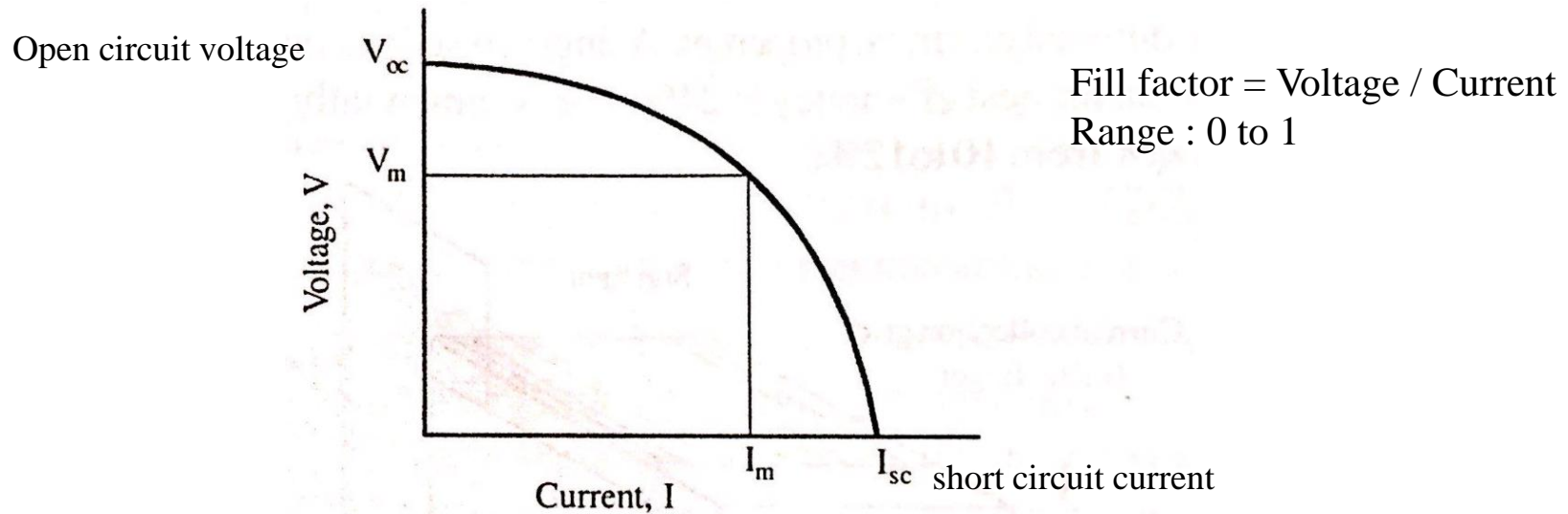
P type: boron, aluminum etc.

N type: arsenic, phosphorus etc.

Efficiency : 15 to 16%

A typical solar cell

Conversion efficiency



Current voltage characteristics of a solar cell

Applications of solar photovoltaic system

1. Used for weather monitoring
2. Used in equipments for railway signalling
3. Water pumping sets to supply drinking water and water for micro irrigation.
4. Street lighting
5. Battery charging

Advantages and disadvantages of photovoltaic solar energy conversion

Advantages

1. No moving parts and no pollution
2. Solar cells have long life and are highly reliable
3. No fuel consumption, as cells operate on solar energy
4. Cells have high power to weight ratio, and hence more suitable for space applications
5. No sun tracking is required, hence it is possible to operate cells in a wide range of applications
6. Solar cells are more suitable for space applications, as they work with less or almost no attention.

Disadvantages

1. The cost is high
2. Because of day night cycle, a necessity becomes to store the energy.