Solar and Wind Systems (EL0422)

UNIT-I

Solar Energy

- Solar energy is the radiant light and heat from the sun that is harnessed using a range of ever evolving technologies (electro magnetic radiation).
- It is an important source of renewable energy and its technologies are broadly characterized as either **passive solar** or **active solar** depending on how they capture and distribute solar energy or convert it into solar power.

Solar Energy

- **Passive solar energy**: Direct use for heating, lighting, drying, ventilation purposes etc.
- **Active solar energy**: Conversion to electricity with the aid of special instruments.

Solar Energy

- The energy radiation from the sun is electro-megnetic waves reaching the planet earth in three spectral reagions:

i) Ultraviolet: 6.4% ($\lambda \leq 0.38$ μm)

ii) Visible: 48 % (0.38 μm $\leq \lambda \leq 0.78$ μm)

iii) Infrared: 45.6 % ($\lambda \geq 0.78$ μm) of total energy

- Due to large diatance between the sun and the earth the bean of radiation received from the sun on the earth is almost parallel.

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- **Direct radiation**: Solar radiation that reaches to the surface of the earth with out being diffused is called direct beam radiation.
- **Diffused radiation**: As sunlight passes through the atmosphere, some of it is abosrbed, scattered, and reflected by the air molecules, water vapour, cloud, dust and pollutants from the power plants, forest fires etc. This is called diffusion radiation.
- **Global solar radiation**: The sun of diffuse and direct solar radiation is called global solar radiation.

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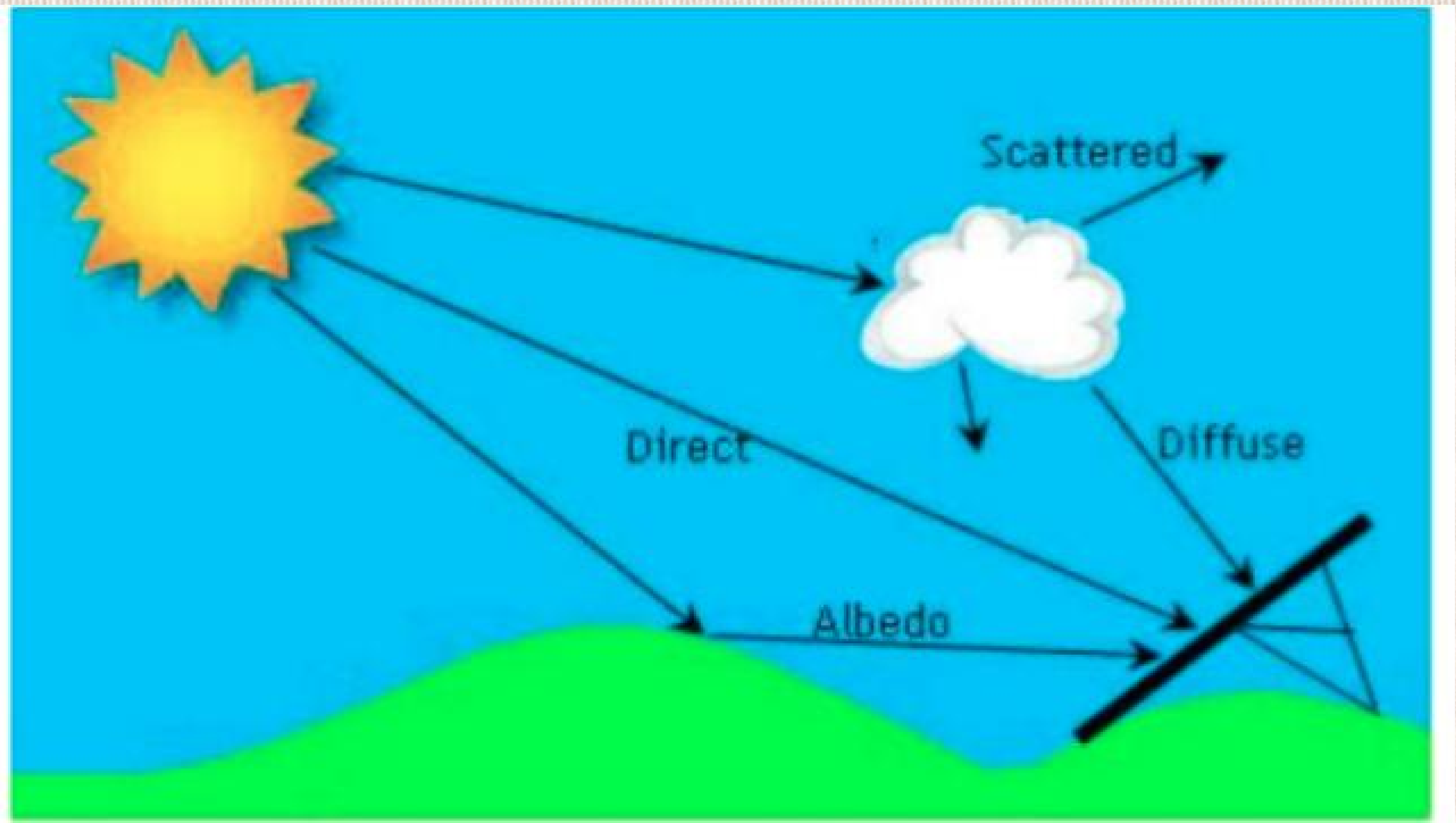

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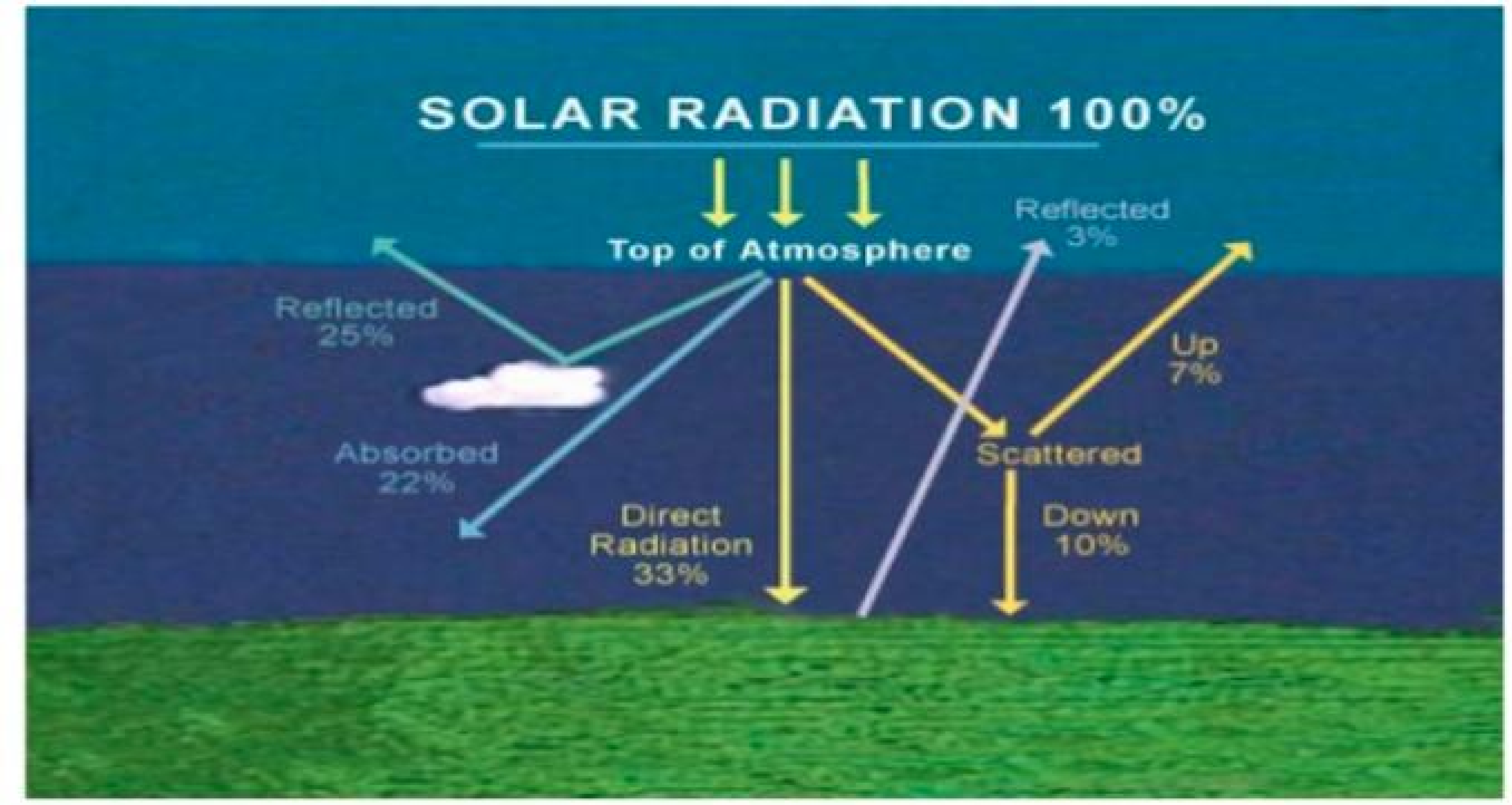

Solar Energy

Measurement of solar radiation

- Some of the instruments that are used for the measurement of solar radiations are

  i) Pyranometer

  ii) Pyrheliometer

  iii) Sunshine Recorder

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Pyranometer

- A type of actinometer used to measure irradiance of solar energy within the preferred location as well as flux density of solar radiation.
- The range of solar radiation extends between 300 & 2800 nm.
- The SI units of irradiance are W/m^2 (watts /square meter).

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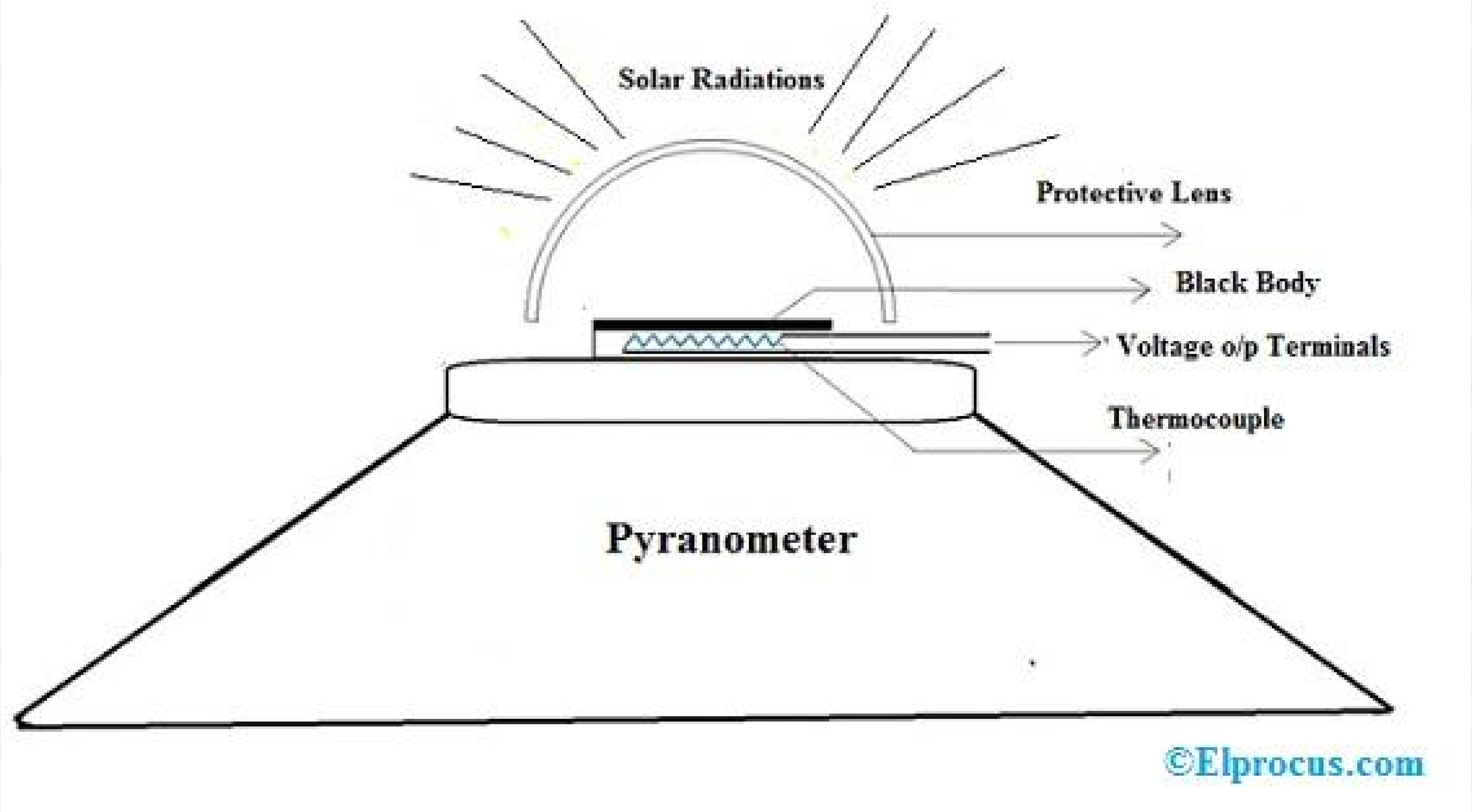
Pyranometer Design / Construction



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Pyranometer Design / Construction

The pyrometer design or construction can be done using the following three components.

i) Thermopile

ii) Glass Dome

iii) Occultation Disc

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Pyranometer Design / Construction

i) Thermopile

As the name implies, it uses a thermocouple used to notice dissimilarity in temperature between two surfaces. These are hot (labeled active) and cold (reference) accordingly. The labeled active surface is a black surface in flat shape and it is exposed to the atmosphere. The reference surface depends on the difficulty of the pyranometer because it changes from a second control thermopile to the covering of the pyranometer itself.

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Pyranometer Design / Construction

ii) Glass Dome

Glass dome in the pyrometer limits the response of spectral from 300 nm to 2800 nm from 180 degrees of view. It also protects the thermopile sensor from rain, wind, etc. This construction of the second dome gives extra radiation protection among the inner dome & sensor compared to a single dome because a second dome will reduce the instrument offset.

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Pyranometer Design / Construction

iii) Occultation Disc

The occultation disc is mainly used to measure the radiation of blocking beam & diffuse radiation from the panel surface.

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Pyranometer Working

The working principle of the pyranometer mainly depends on the difference in temperature measurement between two surfaces like dark and clear. The solar radiation can be absorbed by the black surface on the thermopile whereas the clear surface reproduces it, so less heat can be absorbed.

The thermopile plays a key role in measuring the difference in temperature. The potential difference formed within the thermopile is due to the gradient of temperature between the two surfaces. These are used to measure the sum of solar radiation.

But, the voltage which is generated from the thermopile is calculated with the help of a potentiometer. The information of radiation needs to be included through planimetry or an electronic integrator.

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Pyranometer Types

Pyrometers are classified into two types

i) Thermopile pyranometer,

ii) Photodiode-based pyranometer.

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Pyranometer Types

i) **Thermopile pyranometer**

This type of pyranometer is used to measure the flux density of the solar radiation from a 180° angle. Usually, it measures 300nm to 2800 nm with a largely level spectral sensitivity. The first generation of this pyranometer includes the sensor that works as an active part by dividing black & white sectors equally. Irradiation was measured from the two sectors like white & black within the temperature. Here, the black sector is exposed to the sun whereas the white sector doesn’t expose to the sun.

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Pyranometer Types

i) **Thermopile pyranometer**

These pyranometers are normally used in climatology, meteorology, building engineering physics, photovoltaic systems & climate change research.

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Pyranometer Types

ii) Photodiode–based pyranometer.

Photodiode based pyrometer is also known as a silicon pyrometer. This is used to detect the segment of the solar spectrum between 400 nm & 900 nm. This photodiode changes the frequencies of the solar spectrum to current at high speed. This change will be influenced through the temperature with the raise in current, generated by the temperature rise.

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Pyranometer Types

ii) Photodiode-based pyranometer.

These types of pyranometers are executed wherever the amount of irradiation of the noticeable solar spectrum needs to be measured and it can be done by using diodes with exact spectral responses.

These are used in cinema, lighting technique & photography; sometimes these are connected closely to photovoltaic system modules.

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Pyranometer Applications

Some of the the applications are

- The solar intensity data can be measured.
- Climatological & Meteorological studies
- PV systems design
- Locations of the greenhouse can be established.
- Expecting the requirements of insulation for building structures

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Pyranometer Advantages and Disadvantages

The pyranometer advantages and disadvantages are

- The temperature coefficient is extremely small
- Standardized to ISO standards
- Measurements of performance ration & performance index are accurate.
- Response time is longer compare to PV cell
- The disadvantage of the pyranometer is, its spectral sensitivity is imperfect, so it does not observe the complete spectrum of the sun. So errors in measurements can occur.

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Pyrheliometer

The pyrheliometer is one type of instrument, used to measure the direct beam of solar radiation at the regular occurrence. This instrument is used with a tracking mechanism to follow the sun continuously. It is responsive to wavelengths bands that range from 280 nm to 3000 nm. The units of irradiance are W/m^2. These instruments are specially used for weather monitoring & climatological research purposes.

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Pyrheliometer

Solar Energy

Pyrheliometer Construction & Working Principle

The external structure of the Pyrheliometer instrument looks like a telescope because it is a lengthy tube. By using this tube, we can spot the lens toward the sun to calculate the radiance. The Pyrheliometer basic structure is shown below. Here the lens can be pointed in the direction of the sun & the solar radiation will flow throughout the lens, after that tube & finally at the last part where the last apart includes a black object at the bottom.

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Pyrheliometer Construction & Working Principle

The irradiance of solar enters into this device through a crystal quartz window and directly reaches onto a thermopile. So this energy can be changed from heat to an electrical signal that can be recorded.

A calibration factor can be applied once changing the mV signal to a corresponding radiant energy flux, and it is calculated in W/m^2 (watts per square meter).

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Pyrheliometer Construction & Working Principle

This kind of information can be used to increase Insolation maps. It a solar energy measurement, that is received on a specified surface region in a specified time to change around the Globe. The isolation factor for a specific area is very useful once setting up solar panels.

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Pyrheliometer Circuit Diagram

The circuit diagram of the pyrheliometer is shown below. It includes two equal strips specified with two strips S1 & S2 with area ‘A’. Here, a thermocouple is used where its one junction can be connected to S1 whereas the other is connected to S2. A responsive galvanometer can be connected to the thermocouple.

The S2 Strip is connected to an exterior electrical circuit.

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Pyrheliometer Circuit Diagram

The S_2 Strip is connected to an exterior electrical circuit.

Once both the strips are protected from the radiation of solar, then the galvanometer illustrates there is no deflection because both the junctions are at equal temperature. Now 'S_1' strip is exposed to the solar radiation & S_2 is protected with a cover like M. When S_1 strip gets heat radiations from the sun, then strip temperature will be increased, thus the galvanometer illustrates deflection.

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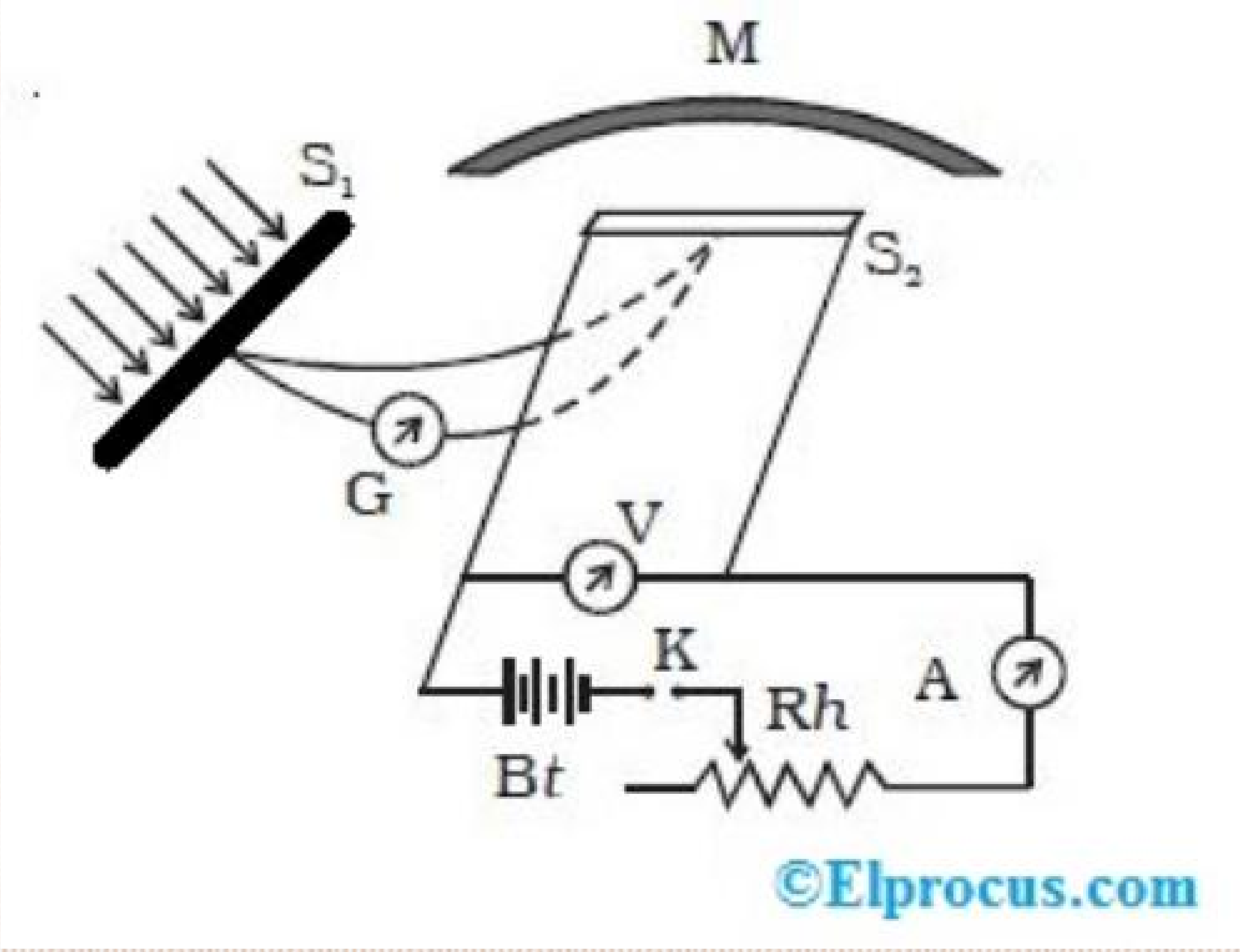
Pyrheliometer Circuit Diagram



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Pyrheliometer Circuit Diagram

When current is supplied throughout the S_2 strip, then it is adjusted and the galvanometer illustrates there is no deflection. Now, again both the strips are at equal temperature.

If the heat radiation amount occurred over the unit area within the unit time on S_1 strip is 'Q' & its absorption co-efficient, so the heat radiation amount which is absorbed through the S_1 strip S_1 within unit time is 'QAa'. In addition, the heat generated in unit time within the S_2 strip can be given through VI. Here, 'V' is the potential difference & 'I' is the flow of current through it.

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Pyrheliometer Circuit Diagram

When heat absorbed is equivalent to the heat generated, so

$QAa = VI$

$Q=VI/Aa$

By substituting the values of V, I, A and a, the value of ‘Q’ can be calculated.

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Pyrheliometer Types

There are two types of Pyrheliometers like **SHP1** and **CHP1**

SHP1

The SHP1 type is a better version compare with CHP1 type, as it is designed with an interface including both improved analog o/p & digital RS-485 Modbus. The response time of this kind of meter has below 2 seconds & independently calculated temperature correction will range from -40°C to +70°C.

Solar Energy

Pyrheliometer Types

There are two types of Pyrheliometers like **SHP1** and **CHP1**

CHP1

The CHP1 type is the most frequently used radiometer used to measure solar radiation directly. This meter includes one thermopile detector as well as two temperature sensors. It generates an utmost o/p like 25mV beneath usual atmospheric situations. This type of device totally obeys the most recent standards which are set by ISO and WMO about the criteria of the Pyrheliometer.

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Difference between Pyrheliometer and Pyranometer

Pyranometer	Pyrheliometer
It is one kind of acidometer mainly used to measure the solar irradiance over a planar surface.	This instrument is used to measure direct ray solar irradiance.
It uses thermoelectric detection principle	In this, the thermoelectric detection principle is used
In this, the measurement of increasing temperature can be done through thermocouples which are linked in series otherwise series-parallel to build a thermopile.	In this, the increasing temperature can be calculated through thermocouples that are allied in series/series-parallel to create a thermopile.
This is frequently used in meteorological research stations	This is also used in meteorological research stations
This instrument calculates global solar radiation.	This instrument calculates direct solar radiation.

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Pyrheliometer Applications

The applications of this instrument include the following.

- Scientific meteorological
- Observations of Climate
- Testing research of Material
- Estimation of the solar collector’s efficiency
- PV devices

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Pyrheliometer Advantages

The advantages of the Pyrheliometer include the following.

- Very low power consumption
- Operates from a wide range of voltage supplies
- Ruggedness
- Stability

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Sunshine Recorder

A sunshine recoder is a device that records the amount of sunshine at a given location. The results provide information about the weather and climate as well as the temperature of the geographical area.

There are two types of sunshine recorder

i) Compbell–Stokes Recorder

ii) Blake– Larsen Recorder

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Campbell–Stokes Sunshine Recorders

A Campbell–Stokes sunshine recorder concentrates sunlight through a glass sphere onto a recording card

placed at its focal point. The length of the burn trace left on the card represents the sunshine duration.

The device’s structure is shown in Figure (a)

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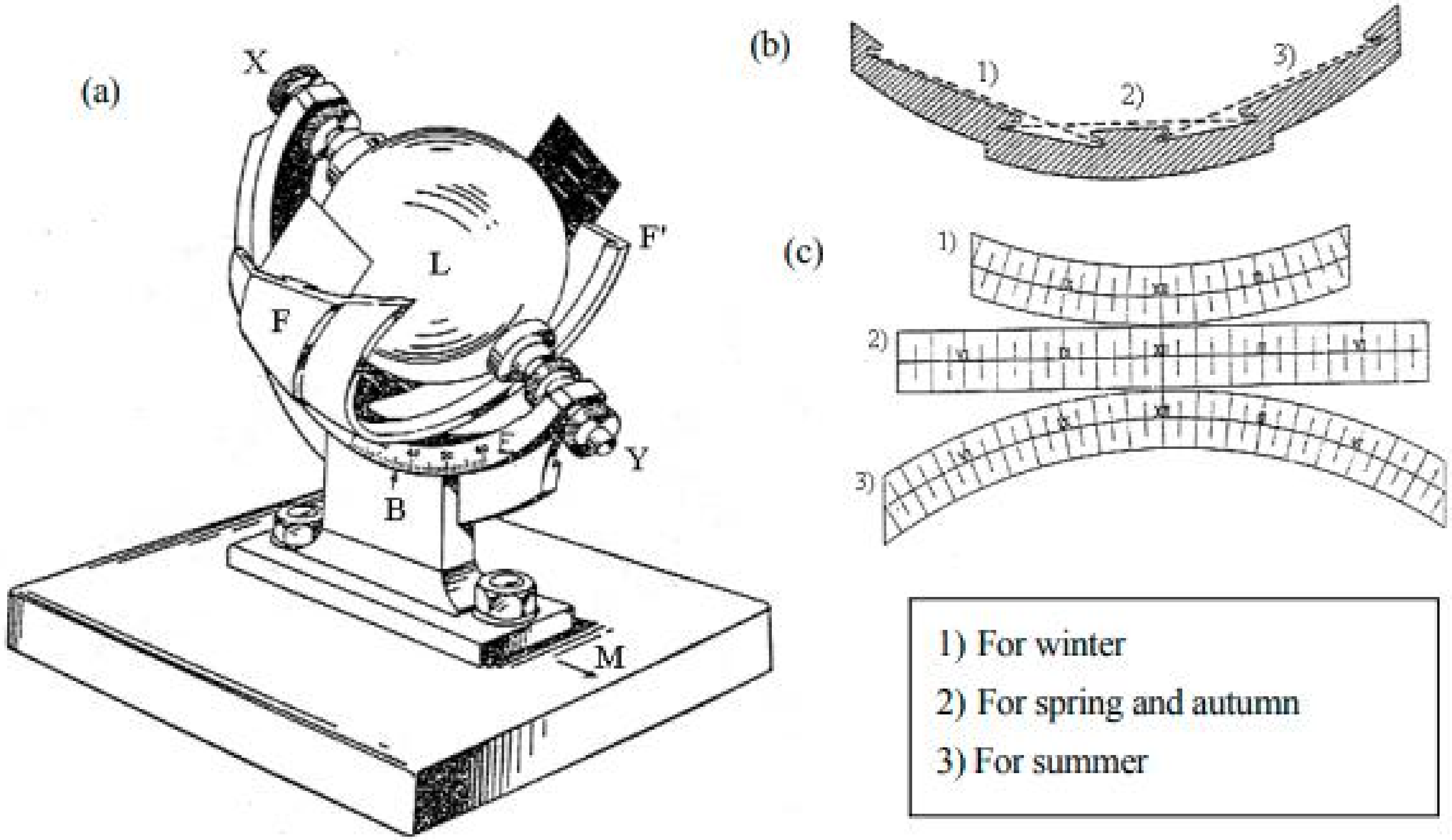

Figure 7.1 Campbell-Stokes sunshine recorder

(a) Structure

(b) Cross section of bowl and grooves

(c) Recording cards

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Campbell–Stokes Sunshine Recorders

A homogeneous transparent glass sphere L is supported on an arc XY, and is focused so that an image of the sun is formed on recording paper placed in a metal bowl FF' attached to the arc. The glass sphere is concentric to this bowl, which has three partially overlapping grooves into which recording cards for use in the summer, winter or spring and autumn are set (Figure b).

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Campbell–Stokes Sunshine Recorders

Three different recording cards (Figure c) are used depending on the season. The focus shifts as the sun moves, and a burn trace is left on the recording card at the focal point. A burn trace at a particular point indicates the presence of sunshine at that time, and the recording card is scaled with our marks so that the exact time of sunshine occurrence can be ascertained. Measuring the overall length of burn traces reveals the sunshine duration for that day. For exact measurement, the sunshine recorder must be accurately adjusted for planar leveling, meridional direction and latitude.

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Campbell–Stokes Sunshine Recorders

Reading of Recording Paper

To obtain uniform results for observation of sunshine duration with a Campbell–Stokes sunshine recorder, the following points should be noted when reading records:

(a) If the burn trace is distinct and rounded at the ends, subtract half of the curvature radius of the trace's ends from the trace length at both ends. Usually, this is equivalent to subtracting 0.1 hours from the length of each burn trace.

Solar Energy

Campbell–Stokes Sunshine Recorders

(b) If the burn trace has a circular form, take the radius as its length. If there are multiple circular burns, count two or three as a sunshine duration of 0.1 hours, and four, five or six as 0.2 hours. Count sunshine duration this way in increments of 0.1 hours.

Solar Energy

Campbell–Stokes Sunshine Recorders

(c) If the burn trace is narrow, or if the recording card is only slightly discolored, measure its entire length.

(d) If a distinct burn trace diminishes in width by a third or more, subtract 0.1 hours from the entire length or each place of diminishing width. However, the subtraction should not exceed half the total length of the burn trace.

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Blake– Larsen Recorder

Designed few years ago, the Blake Larsen sunshine recorder is a more sophisticated sunshine recorder that uses sensors to detect solar radiation and record them.

The recorder unit and PC software produce a fully automated system to measure the duration of bright sunlight from dawn to dusk.

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Blake– Larsen Recorder

The system can be easily integrated into WEB based weather recording systems.

Solar Energy

Blake– Larsen Recorder

The main advantages of this are:

The system can produce results which are far more accurate than, the Campbell Stokes recorder which requires manual intervention and skilled interpretation.

Solar Energy

Solar Collector

Solar collectors transform solar radiation into heat and transfer that heat to a medium (water, solar fluid, or air). Then solar heat can be used for heating water, to heating or cooling systems, or for heating swimming pools. Solar cooling technologies demand high temperatures and not all the type of solar collectors are capable of producing them. The collectors needed are based on technologies, which can supply hot water at relatively high temperature (90–150 C).

Solar Energy

Solar Collector (**Types**)

1. Non concentrating of flat plate type solar collector

- **Flat Plate Collector**:
    - Liquid based,
    - Air based and
    - Evacuated tube

2. Concentrating type solar collector

- **Line focusing type**
- **Point focusing type**

Solar Energy

Solar Collector

- Flat plate collectors may be used for water heating and most space heating applications
- Concentrating collectors uses mirror or lenses to focus the collected solar energy on smallet areas to obtain high working temperature.

Solar Energy

Solar Collector

Flat-plate collectors are the most widely used kind of collectors in the world for domestic water-heating systems and solar space heating/cooling. The first accurate model of flat plate solar collectors was developed by Hottel and Whillier in the 1950's.

A typical flat-plate collector consists of an absorber, transparent cover sheets, an insulated box and fluid passage tubes

Solar Energy

Solar Collector

The transparent cover of glass or plastic allows short wave solar radiation (Beam, diffuse radiation) to enter the box and fall on the black plate but it prevents the long wave (Thermal) radiation emitted by the black plate from being lost.

The radiation is absorbed by absorber plate which is coated with black abosrber paint. The fluid tubes which are connected to absorber plate abosrb the hrat and transferred to the water passing through the tube and gets heated.

Solar Energy

Solar Collector

The hot water collected from all the tubes flow into a storage tank.

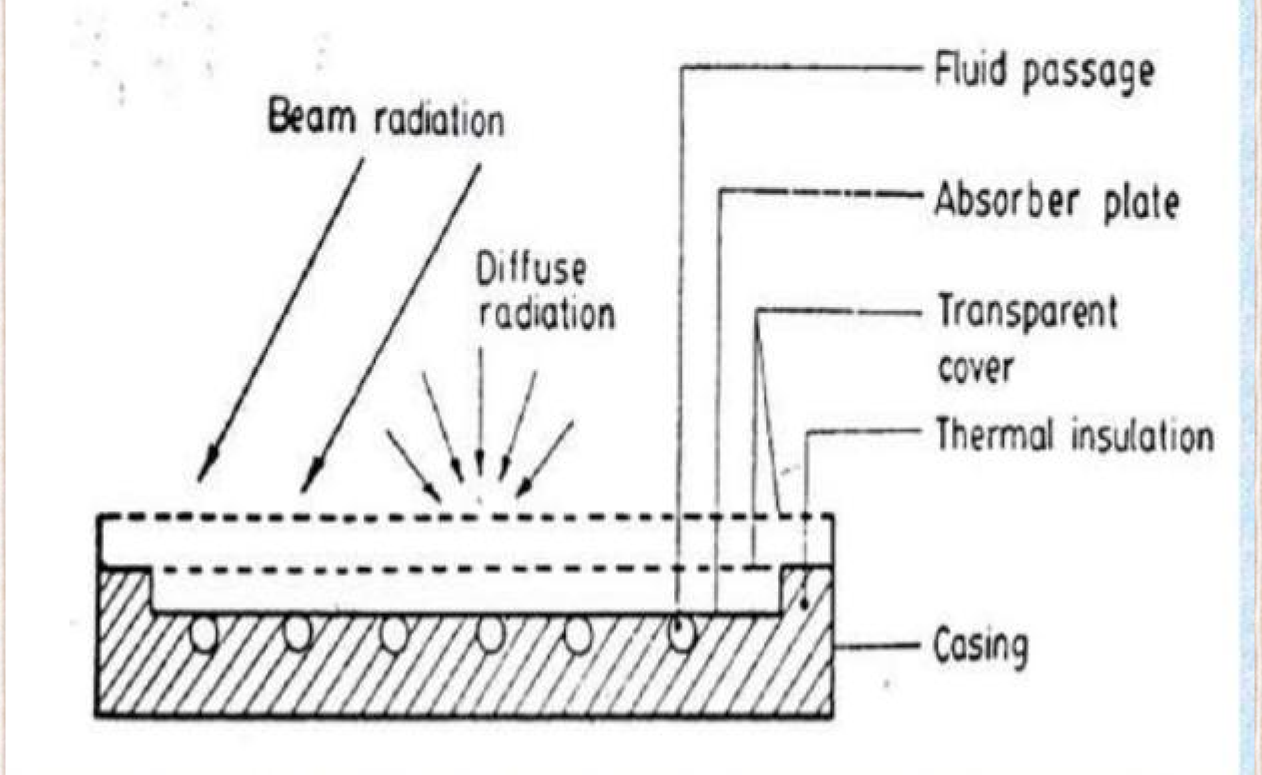
Insulation (paddy husk, saw dust, glass wool) provided to the absorber plate to avoid loss of heat by conduction.

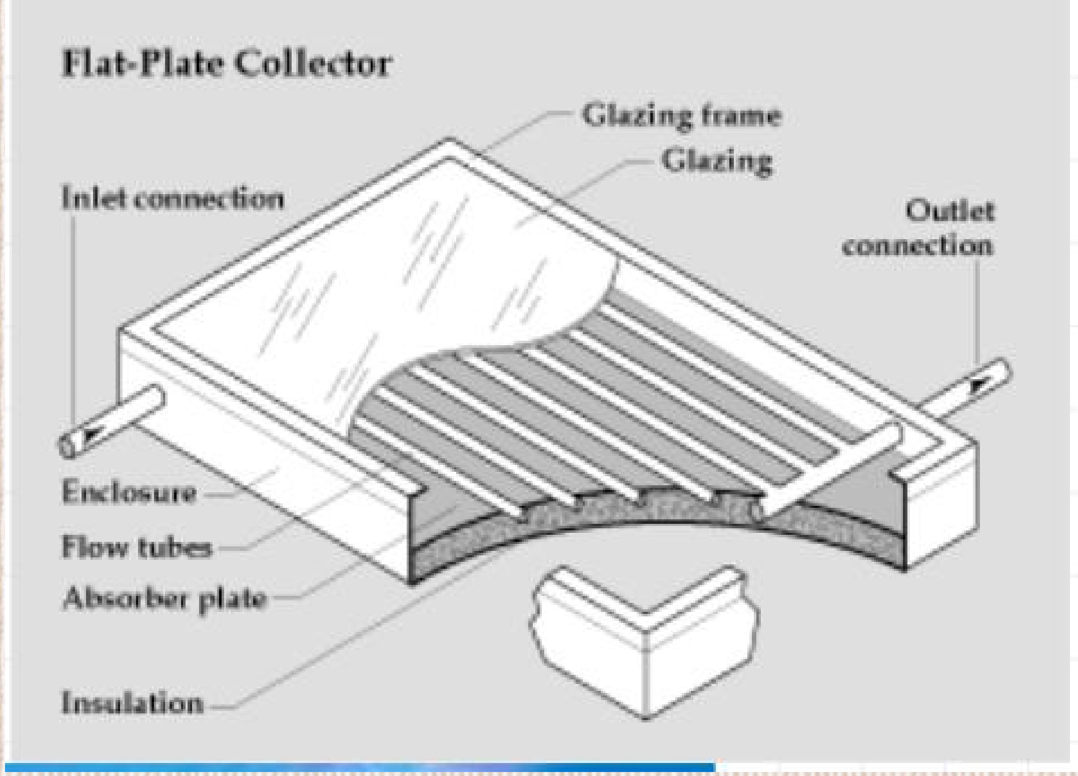
Loss of heat by re-radiation is avoided by having good absorber coating

The convective loss is reduced by minimizing the air gap between the glass covers.

Solar Energy

Solar Collector





Solar Energy

Solar Collector

Characteristics of Flat Plate Collector

- Used for moderate temperature up to 100 C
- Normally do not need tracking of sun
- Mechanically simple
- Best for water heating, air conditioning, boiler feed water etc.

Solar Energy

Solar Collector

Another kind of collector that can be used for water heating is the **evacuated tube collector**.

The collector contains an array of evacuated glass tubes.

Each tube contains a long thin balck absorber plate thermally attached to a pipe inside the glass tube.

The vacuum inside the tube prevents heat loss, and water temperature upto $100\ ^0$C can be reached.

Solar Energy

Concentrated Solar Collector

Main types of concentrating collectors are:

- Parabolic trough collector
- Mirroe strip reflector
- Flate plate collector with adjustable morrors
- Compounded parabolic concentrator

Solar Energy

Concentrated Solar Collector

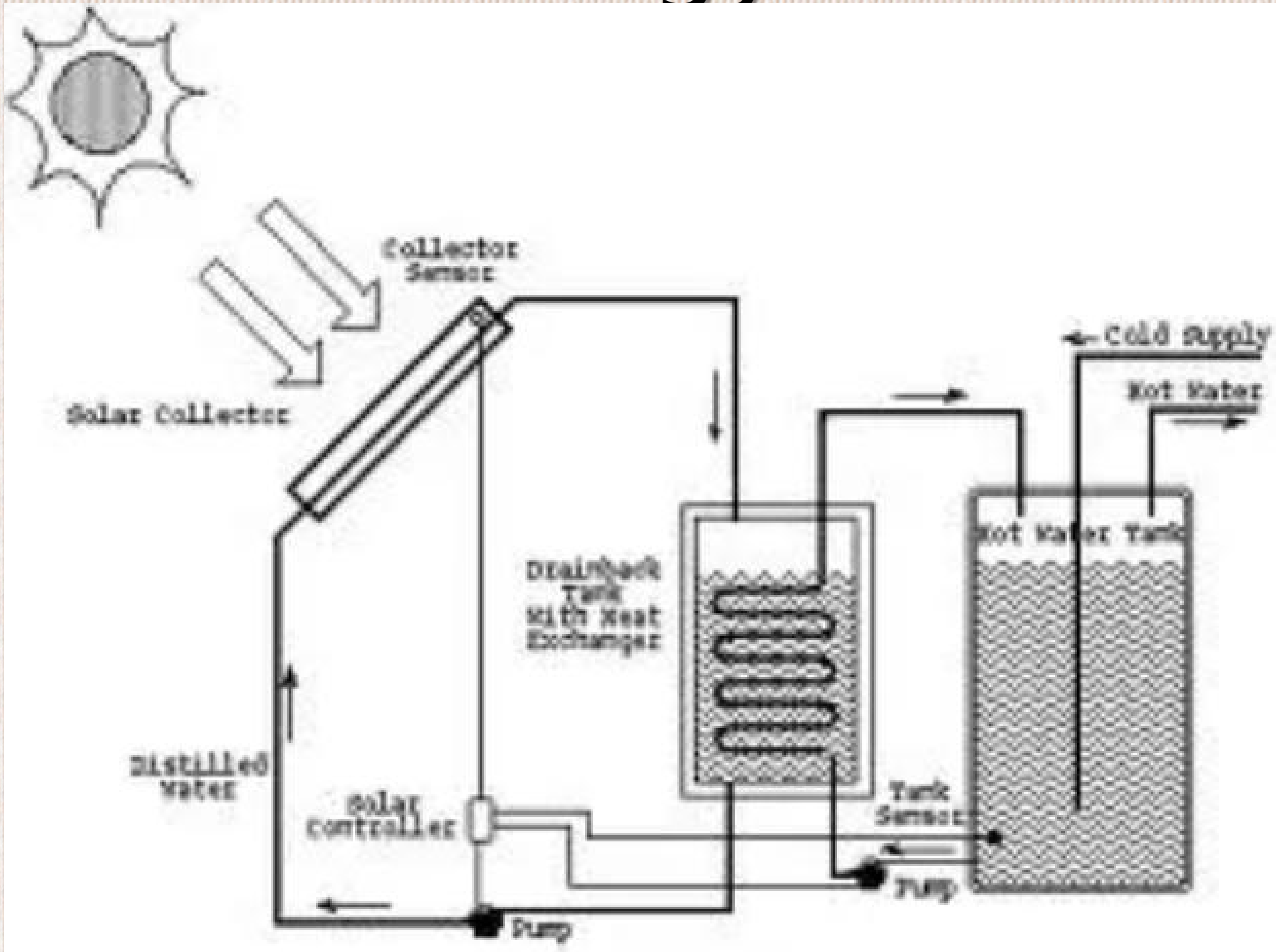
Concentrating collectors have large mirror systems to focus beam solar radiation onto a pipe containing water or liquid or on to a small receiver.

The mirror is moved manually or automatically to follow the movement of the sun.

These collectors produces higher temperature than flat plate collectors.

Solar Energy

Solar Water Heater



Solar Energy

Solar Water Heater

The Sun rays fall on the Solar Collector. A black absorbing surface (absorber) inside the collector, which absorbs solar radiation and transfers the heat energy to water flowing. Heated water is collected in a tank which is insulated to prevent heat loss. Then Circulation of water from the tank through the collector and back to the tank continues automatically.

Solar Energy

Solar Water Heater

A Solar Water Heater consists of a Collector panel to collect solar energy and an Insulated Storage Tank to store hot water.

Solar water heating systems uses vaccum tubes made of borosilicate glass with special coating to absorb the solar energy and are called as Evacuated Tube Collector System (ETC Systems)

Solar Energy

Solar Water Heater

Air between the gap of two glass tubes is evacuated. it results in high level of vacuum which acts as the best insulation to minimize the heat loss from inner tube. The black coating on the inner tube absorbs the solar energy and transfers it to the water. The water on the upper side of vaccum tube becomes hot and thus lighter so it starts moning upwards inthe tank. At the same time cold water which is heavy comes is stored at the bottom.

Solar Energy

Solar Cooling System

Solar cooling is a system that converts heat from the sun into cooling that can be used for refrigeration and air conditioning. A solar cooling system collects solar power and uses it in a thermally driven cooling process which is in turn used to decrease and control the temperature for purposes like generating chilled water or conditioning air for a building.

Solar Energy

Solar Cooling System

There are many different cooling cycle techniques using various different principals to function. Three of the most popular techniques include:

- absorption cycles
- desiccant cycles
- solar mechanical cycles

Solar Energy

Solar Cooling System (**Working**)

Regardless of the technique being used, a solar cooling system typically includes three core components:

- A solar collector, such as a solar panel, which is used to convert solar radiation into heat or mechanical work.
- A refrigeration or air conditioning plant that is used to produce the cooling.
- A heat sink that collects any rejected heat and radiates it away from the system.

Solar Energy

Solar Cooling System (**Working**)

While techniques used to achieve solar cooling vary, the end goal remains the same: utilize an external heat source, like a solar panel, to collect ambient temperature and then use that heat with a refrigerant to create pressure within a closed loop of refrigerant, thus enabling the solar cooling system to work.

A refrigerant is a substance or mixture that absorbs heat from the environment and can create refrigeration or air conditioning if it is combined with the other necessary components, like compressors and evaporators. In most cooling cycles, the refrigerant will transition from the liquid phase to the gas phase and then back again to achieve its cooling purpose.

Solar Energy

Solar Cooling System (**Working**)

In absorption cycles, the cooling process relies on the evaporative cooling of a refrigerant. Since vaporization requires energy input, the process takes heat from the system, leaving the remaining fluid cooler than before. Absorption cycles complete pressurization by dissolving a refrigerant in an absorbent, or something that soaks up liquid easily, instead of using a mechanical compressor. Absorption cooling cycles possess four specific, major components: an absorber, a generator, a condenser and an evaporator. The evaporator is, essentially, the refrigeration or air conditioning plant used in all cooling systems since it is where the cooling occurs.

Solar Energy

Solar Cooling System (Working)

In an absorption cycle, the cooling process progresses as follows:

i) The absorber holds an absorbent-refrigerant mixture that is delivered to the generator through a liquid pump.

ii) The generator takes the absorbent-refrigerant mixture and heats it up using the external solar energy that has been collected through a source such as a solar panel. The solution starts to boil in reaction to the heat, turning water into vapor which flows to the condenser.

Solar Energy

Solar Cooling System (Working)

iii) The condenser liquefies the water vapor, rejecting heat in the process which is collected by the heat sink. The new liquid condensate is then directed towards the evaporator through an expansion valve.

iv) Finally, evaporation of the refrigerant at low pressure causes the evaporator to absorb the heat from the cooled space, creating the cooling effect.

At the end, the vaporized refrigerant returns to the absorber and the cycle repeats. Solar power is responsible for driving this cycle.

Solar Energy

Solar Cooling System (**Working**)

Desiccant cooling systems rely on cycling dehumidification–humidification processes. It uses substances and materials that readily attract water from their surroundings for dehumidification. These materials are known as desiccants. The desiccants are regenerated in the cycle by applying solar power.

Solar Energy

Solar Cooling System (Working)

Desiccant cooling systems can operate with both liquid and solid desiccants. The desiccant cooling process progresses as follows:

1. Desiccants absorb the water vapor and remove the moisture from the process air in the dehumidification, or absorber, unit. A transfer results from the difference in vapor pressure, thus releasing heat due to the condensation of water and creating a heat exchange.

2. The air is then introduced into the space or into an evaporative cooler for further cooling while the diluted desiccant is sent to the regenerator. However, before the diluted desiccant can enter the regenerator, it must pass through a liquid–liquid heat exchanger and a heating coil in order to raise its temperature.

Solar Energy

Solar Cooling System (Working)

3. Once in the regenerator, the heated, diluted desiccant is exposed to regenerative air, causing moisture to transfer from the diluted solution to the air. This transfer is due to the created difference in vapor pressure.

4. Next, the resulting, more concentrated desiccant passes through the liquid–liquid heat exchanger once again as well as a cooling coil and then moves back into the dehumidification unit, allowing the cycle to repeat.

Solar Energy

Solar Cooling System (Working)

The third technique, solar mechanical cycles, works very differently from the absorption and desiccant cycles. Instead of creating an entirely new system, solar mechanical cycles attempt to combine solar powered mechanics with conventional cooling systems. In this cycle, solar power is used to fuel the actual engine that produces the energy used to operate the entire cooling system instead fueling the absorption chiller, like it does in both the absorption and desiccant cycles.

Solar Energy

Solar Cooling System (**Application**)

Solar cooling is primarily intended for two main purposes: refrigerating food storage and space cooling, or air conditioning. Solar cooling can be seen in vehicles like RVs and campers which use the system for refrigeration. Vapor absorption refrigeration systems, which are used in industries where extremely low process temperatures are required as well as large thermal capabilities, also display the use of solar cooling.

Solar Energy

Solar Cooling System (**Application**)

Perhaps the most beneficial application of solar cooling is its ability to provide cooling systems to countries that otherwise would not be able to handle the total electric and energy cost and burden required by conventional cooling systems. Solar cooling greatly reduces the amount of energy required to refrigerate necessities such as vaccines and agricultural products, which, in turn, creates cost savings and benefits the environment by using renewable energy and reducing the use of ozone depleting materials.

Solar Energy

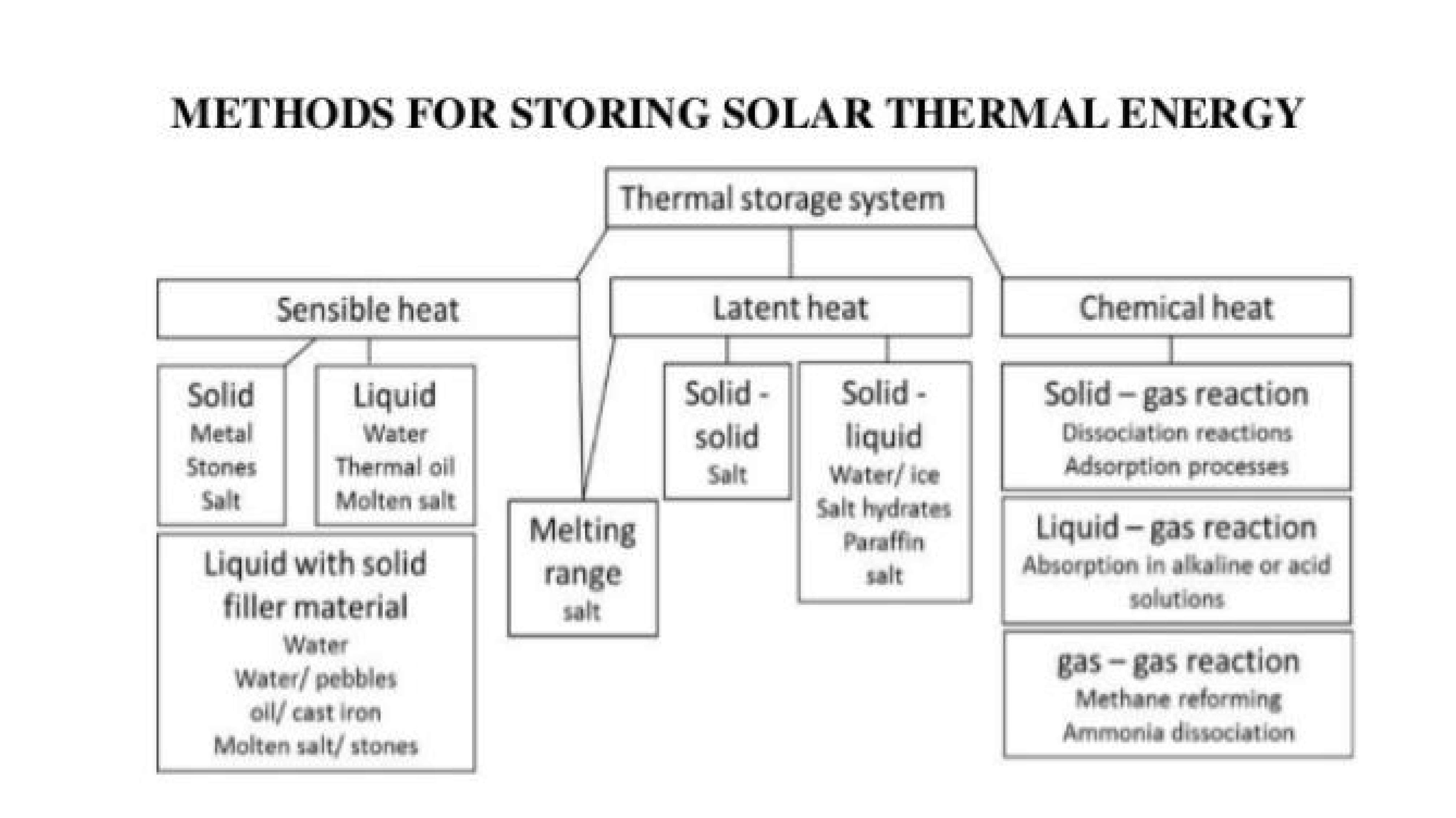
Solar Energy Storage

Definition:

A device that reserves energy for later consumption that is charged by a connected solar system. The stored electricity is consumed after sundown, during energy demand peaks, or during a power outage. Most common on residential or commercial buildings.

Solar Energy

Solar Energy Storage



Solar Energy

Solar Energy Storage (**Sensible Heat Storage**)

- Heating a liquid or solid which does not vhange phase comes under this category.
- Heat that causes a change in temperature in an object is called sensible heat.
- The quantity of heat stored is proprtional to the temperature rise of the material

Solar Energy

Solar Energy Storage (Latent Heat Storage)

- All pure sunstances in nature are able to change their state: from solid to liquid and liquid to gas)
- In this system heat is stored in a material when it melts and heat is extracted from the system when it freezes.
- Heat can also be stored when liquid changes to gaseous state. But as the volume change is large, such a system is not economical.

Solar Energy

Solar Energy Storage (**Thermo Chemical Storage**)

- With a thermo chemical storage system, solar heat energy can start an endothermic chemical reaction and the new products of reaction remain intact.
- To extract energy, a reverse exothermic reaction is allowed to take place.