– Unit II

Solar Thermal

Conversion and Solar

PV Systems

- Solar technologies convert sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation.

 This energy can be used to generate electricity or be stored in batteries or thermal storage.

Solar thermal energy

 Clean, cheap and abundantly available renewable energy which has been used since ancient times.

 The sun is a sustainable source of providing solar energy in the form of radiations, visible light and infrared radiation.

 Captured naturally by different surfaces to produce thermal effect or to produce electricity by means of photovoltaic or day lighting of the buildings.

 Converted into ‘thermal energy’ by using solar collector.

 It can be converted into ‘electricity’ by using photovoltaic cell.

 ‘Solar collector’surface is designed for high absorption and low emission.

Advantages & Disadvantages

 Easily and abundantly available

Re-usable source of energy

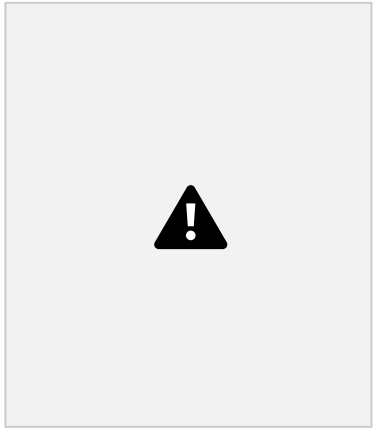
Eco-friendly (i.e. pollution free)

Reduces Green-house gas emissions

 Availability is limited to sun hours

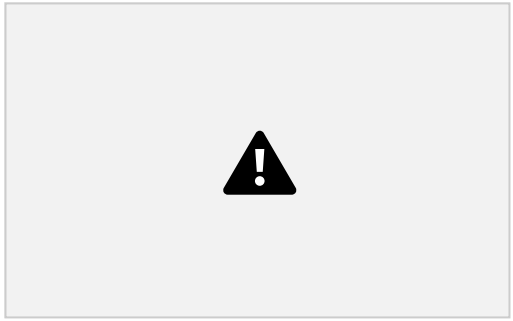
 Need of storage

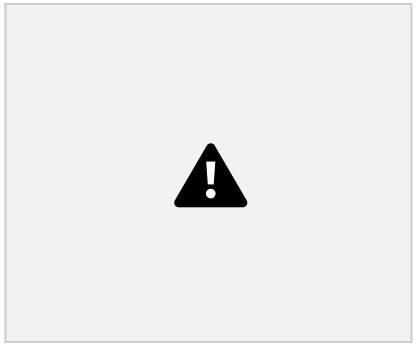
 Large area entails high capital cost To change in the position of sun, tracking is required



Solar water heating

Applications

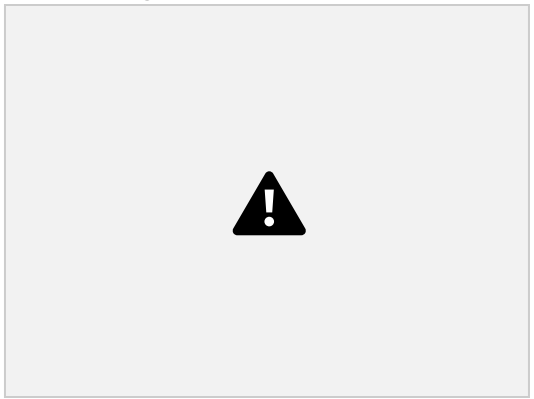


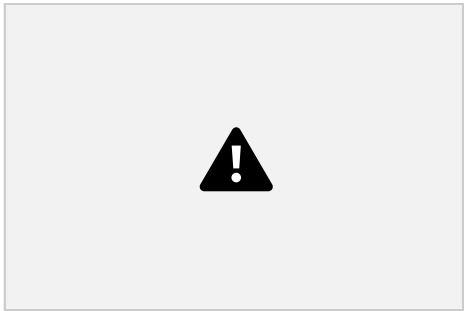


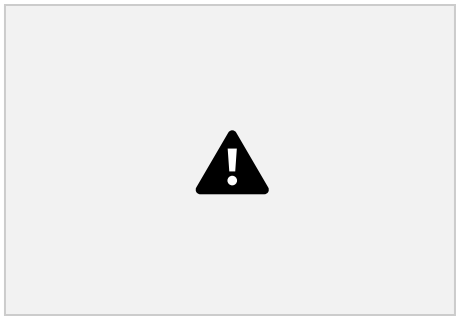
Solar pumping

Solar distillation

Solar cooking

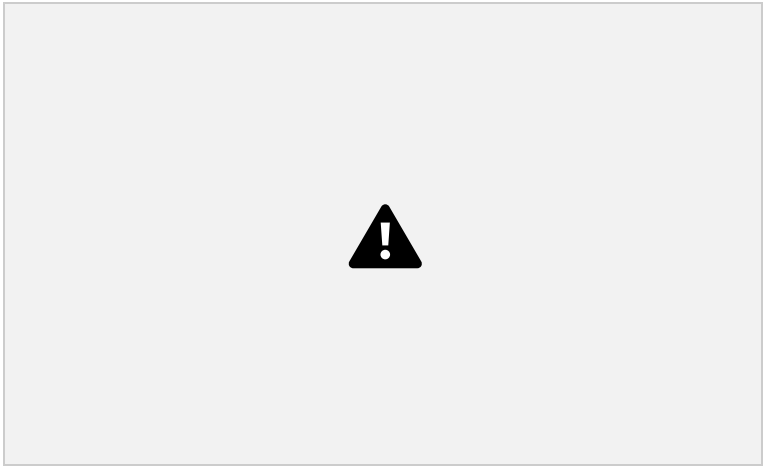






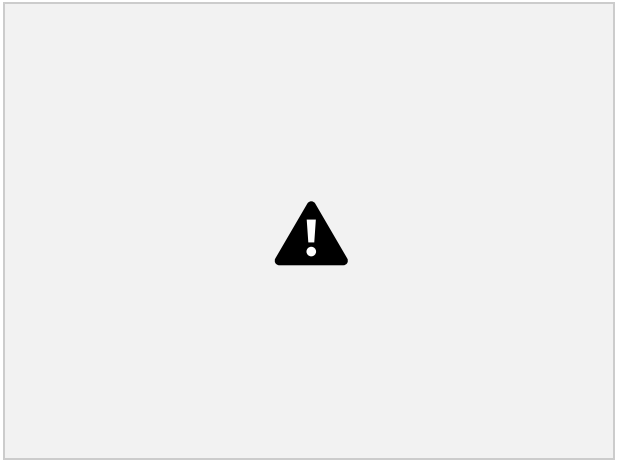
Solar Furnace Solar power generation Solar steam generation

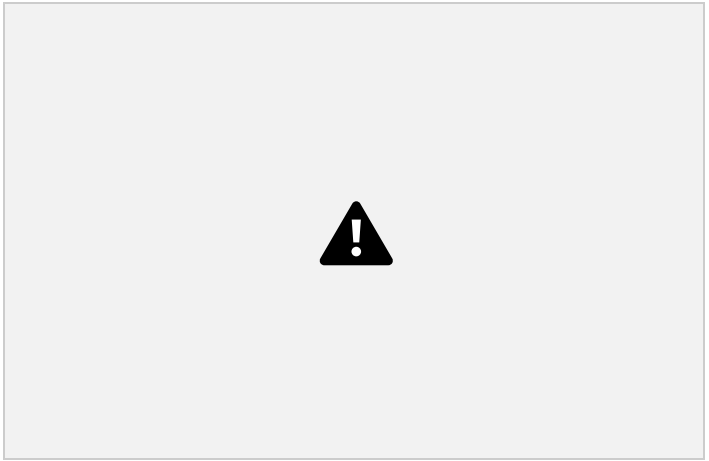
A device that collects and/or concentrates solar radiation from the Sun



- Solar power has low density per unit area (1 kW/sq. m. to 0.1 kW/sq. m.).
- It is to be collected by covering large ground area by solar thermal collectors.
- Solar thermal collector essentially forms the first unit in a solar thermal system.
- It absorbs solar energy as heat and then transfers it to heat transport fluid efficiently.
- The heat transport fluid delivers this heat to thermal storage tank / boiler / heat exchanger, etc., to be utilized in the subsequent stages of the system.

Non-concentrating or Flat-plate type Concentrating or Focusing type

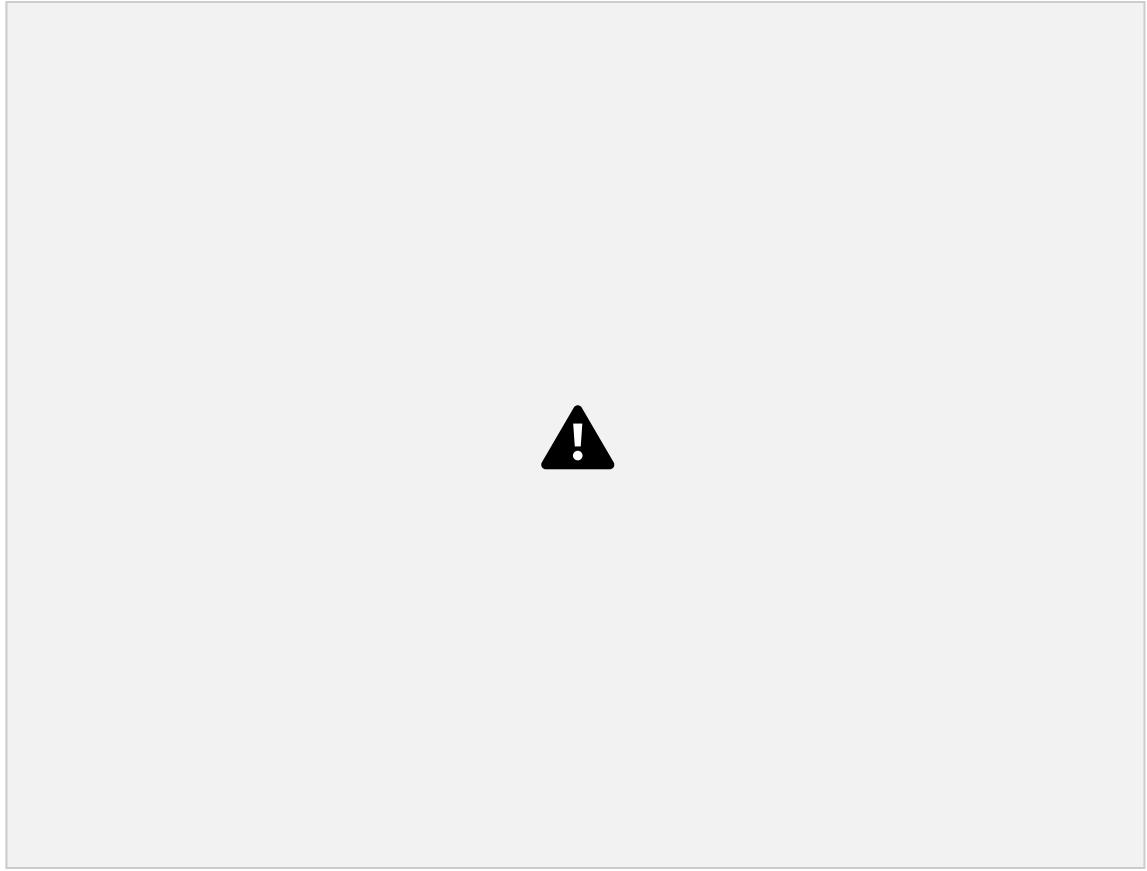


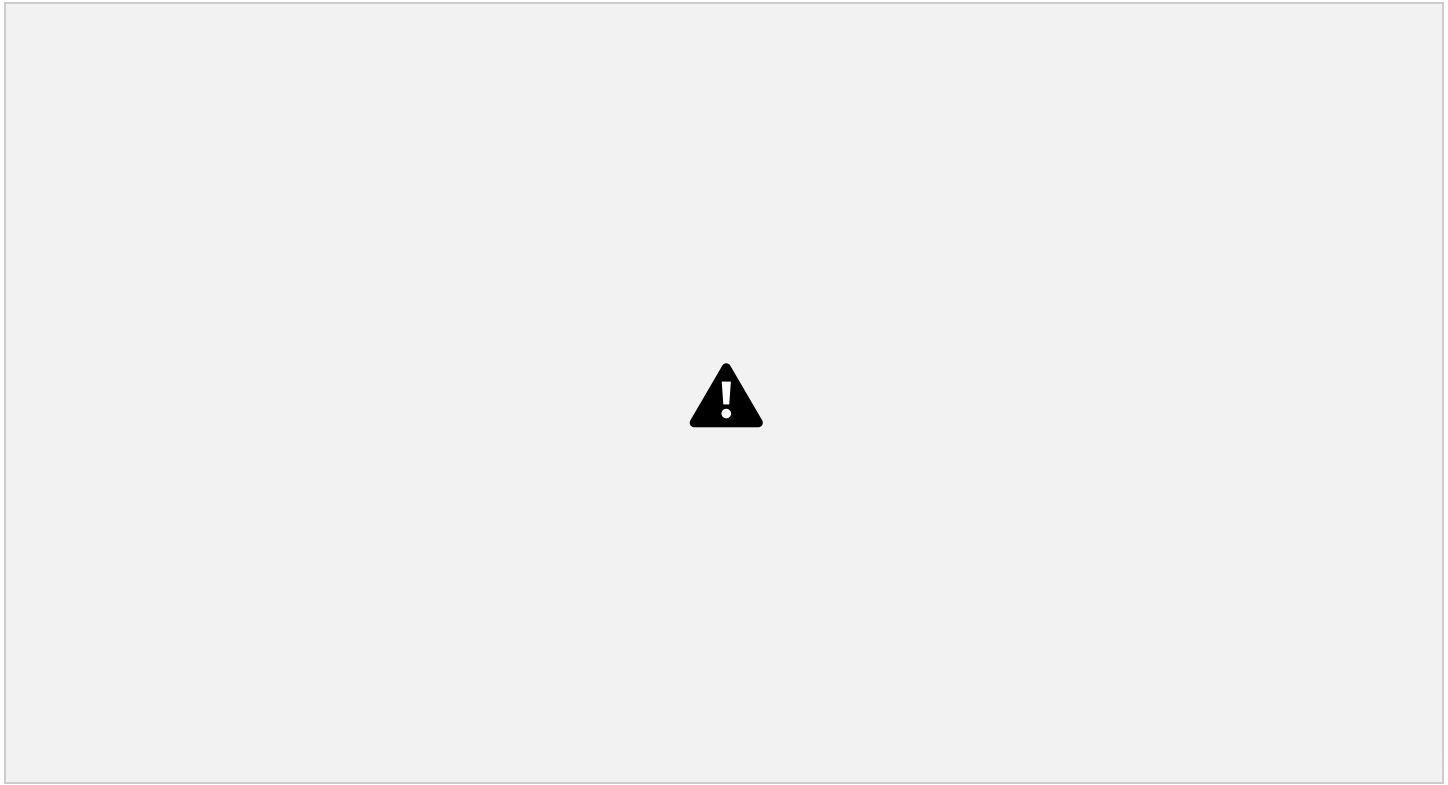


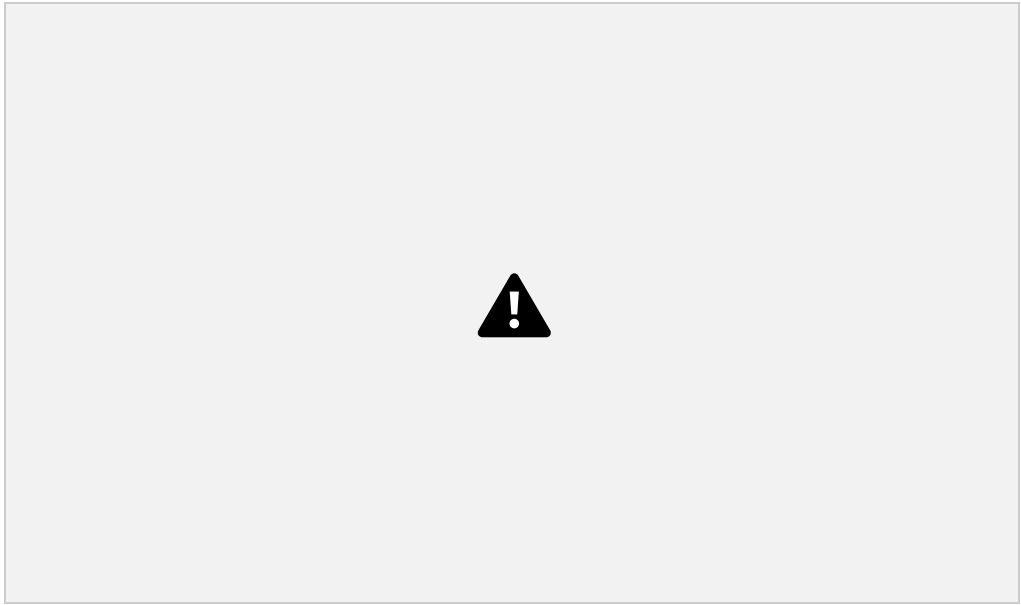
The area of a collector to grasp the solar radiation is equal to the absorber plate and has concentration ratio of 1.

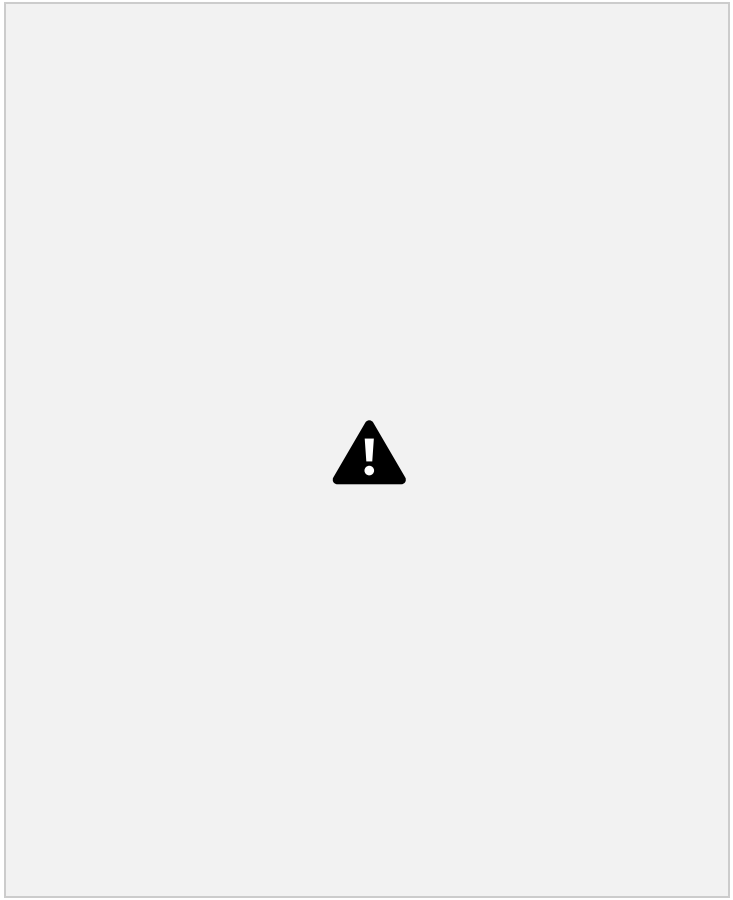
The area of collector is kept less than the aperture through which the radiation passes, to concentrate the solar flux and has high concentration ratio.

Flat-plate collectors	**Focus Non Focus**	
	Parabolic trough collector	Compound parabolic concentrator (CPC)
	Mirror strip collector	
Evacuated Collectors	Fresnel lens collector	Flat-plate collector with adjustable mirrors
	Parabolic dish collector	



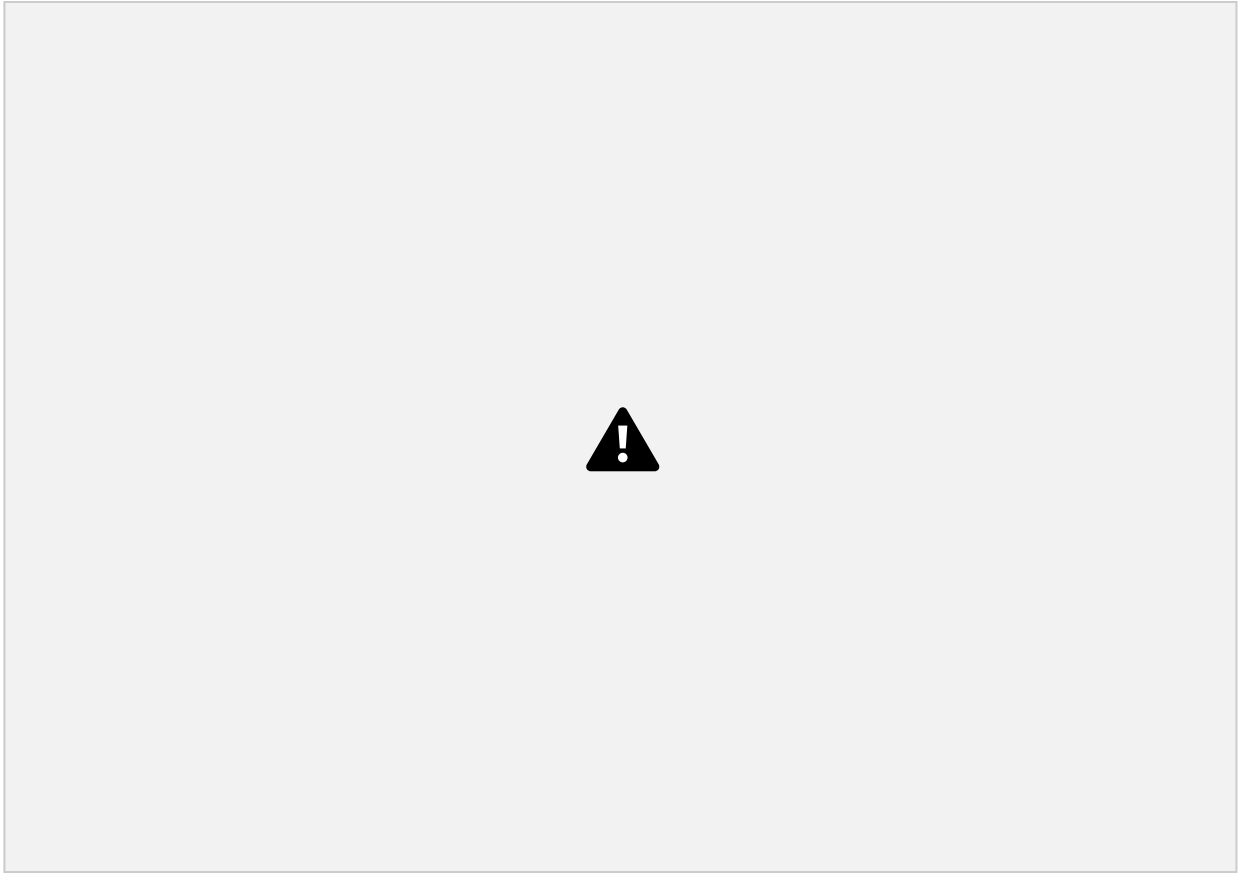






A heat transport fluid (usually air or water) is used to extract the energy collected and passes over, under or

through passages which form an integral part of the plate.



An evacuated-tube collector consists of parallel rows of glass tubes connected to a header pipe.

loss through convection and radiation

Applications:

- **Water heating**
- **Air heating**
- **Desalination**

Its working process is based on the following steps:

(1) Water (heat transfer fluid) flows through the header pipe,

(2) The water is guided toward the copper U-pipe that is surrounded by the evacuated tube, and

(3) The heat transfer fluid absorbs the energy of sunlight while it goes through the U-pipe.

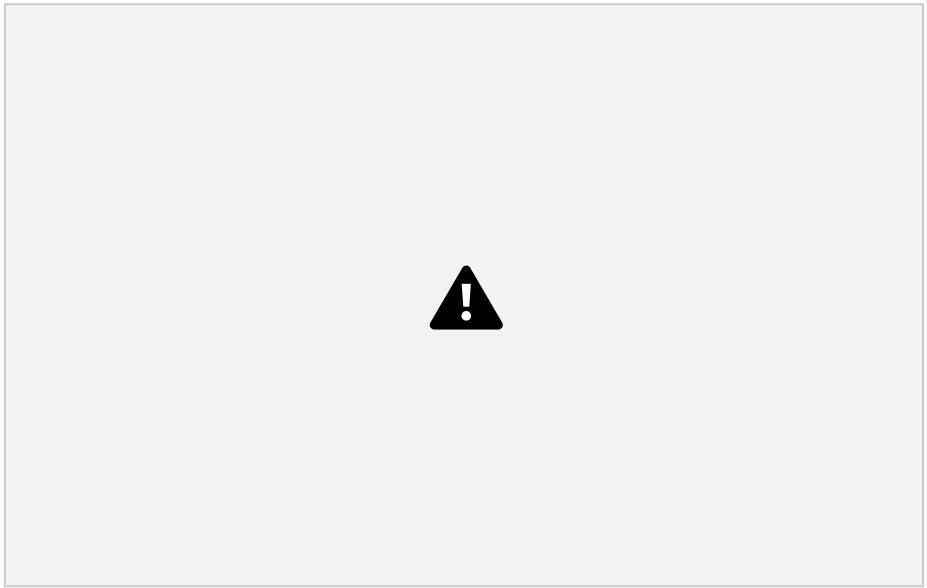
A device to collect solar energy with high intensity of solar radiation on the absorbing surface by the help of reflector or refractor

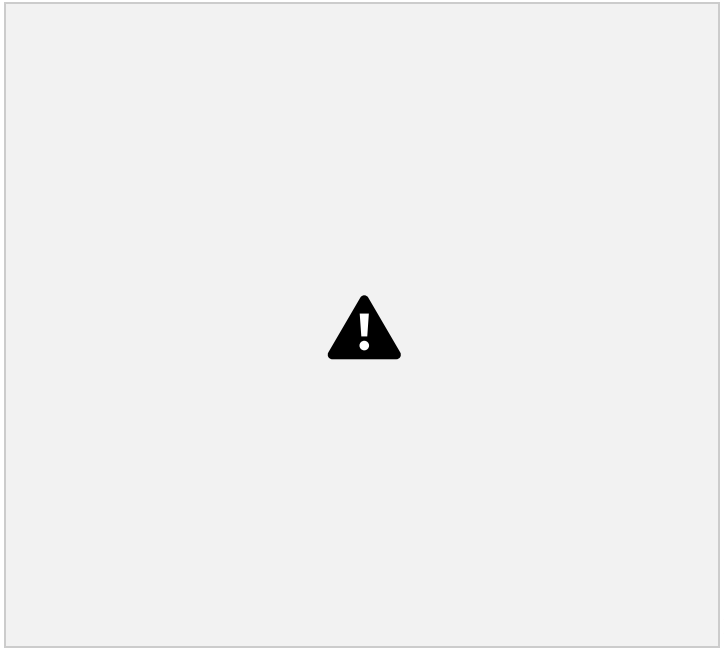
 It is a special form of flat-plate collector modified by introducing a reflecting (or refracting) surface (concentrator) between the solar radiations and the absorber Have radiation increase from low value of 1.52 to high values of the order of 10,000. Radiation falling on a relatively large area is focused on to a receiver (or absorber) of considerably smaller area.

 As a result of the energy concentration, fluids can be heated to temperatures of 500°C or more.

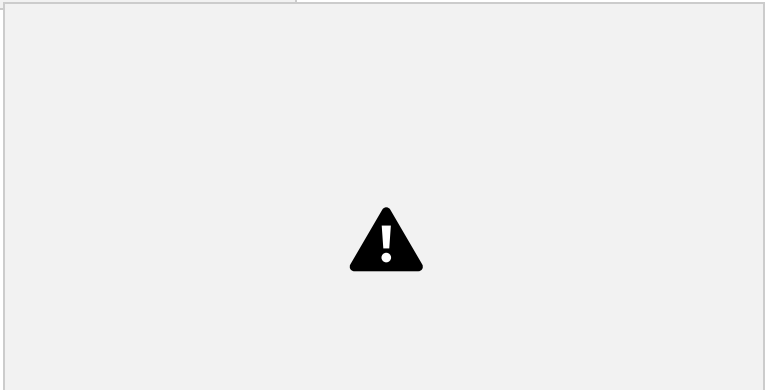
- Orientation of sun from earth changes from time to time.
- So to harness maximum solar rays it is necessary to keep our collector facing to sun rays direction.
- This is the reason why orientation in concentrating collector is necessary.
- This is achieved by the use of “Tracking device”.

Solar radiation coming from the particular direction is collected over the area of reflecting surface and is concentrated at the focus of the parabola, if the reflector is in the form of a trough with parabolic cross-section, the solar radiation is focused along a line.

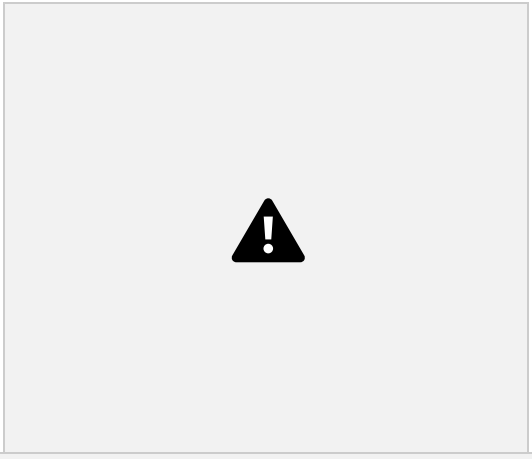




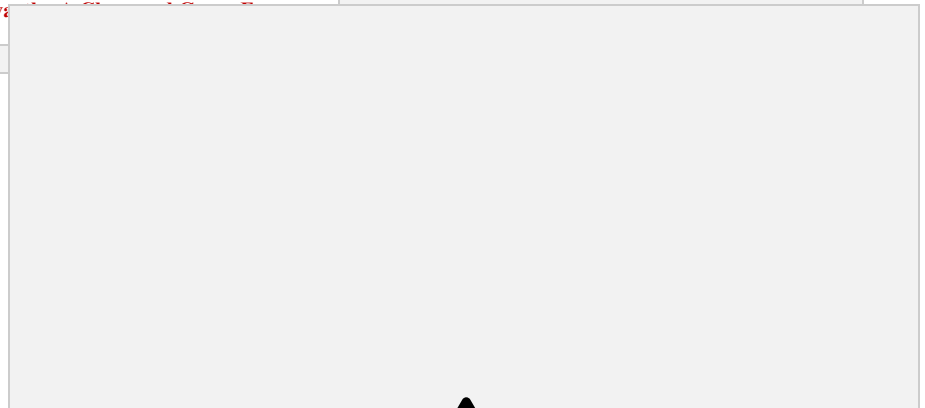
- A mirror strip collector has a number of planes or slightly curved or concave mirror strips which are mounted on a base.



- These individual mirrors are placed at such angles that the reflected solar radiations fall on the same focal line where the pipe is placed.
- In this system, collector pipe is rotated so that the reflected rays on the absorber remain focused with respect to changes in sun's elevation.



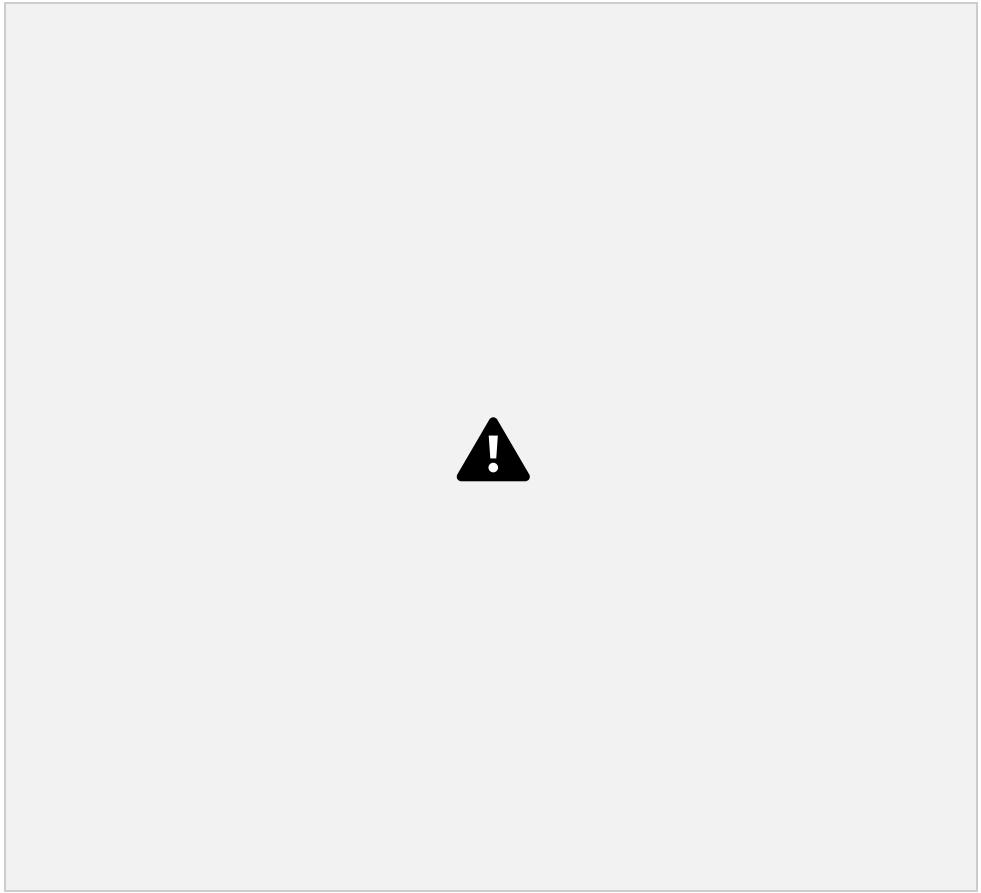
Dr Dheepanchakkrava

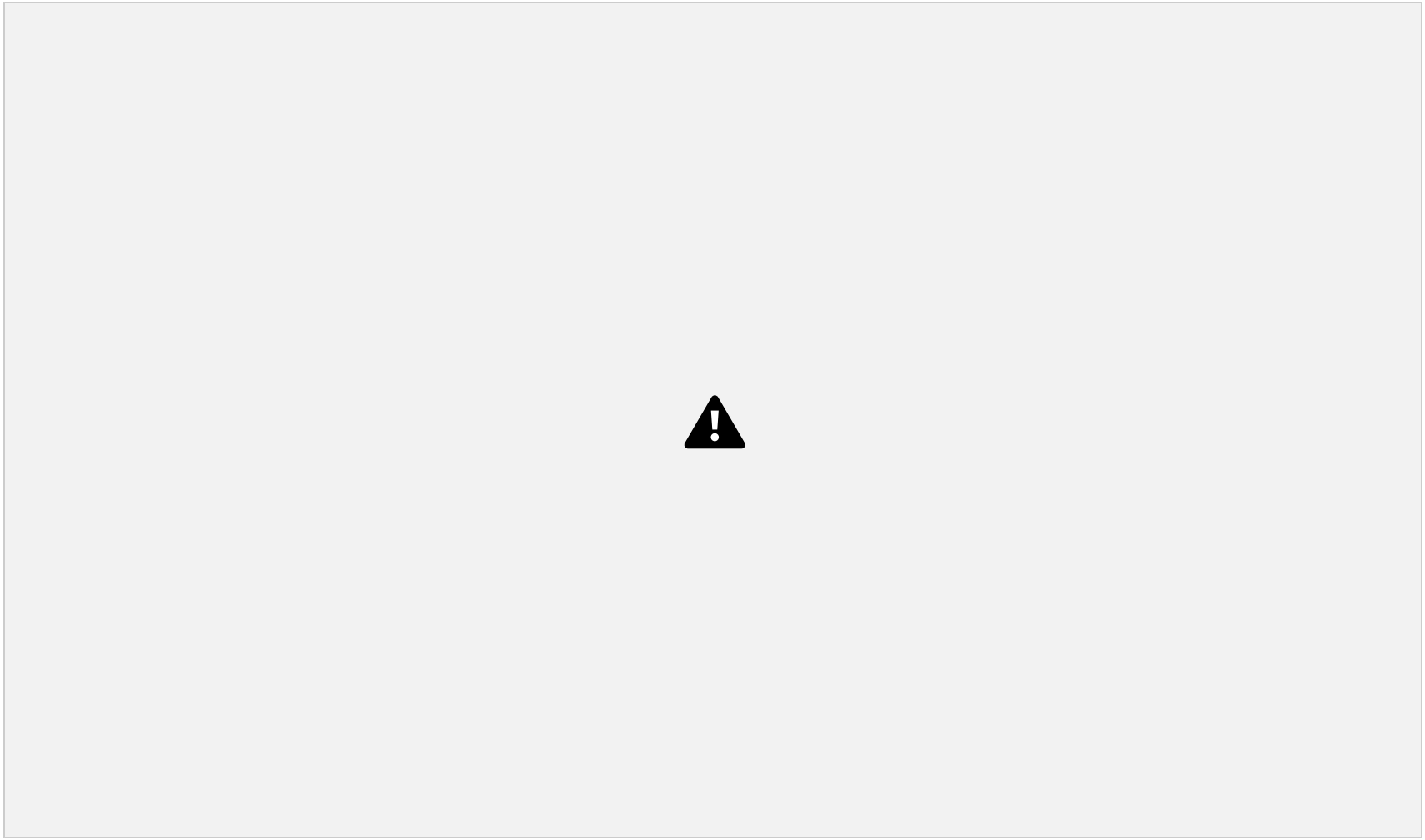


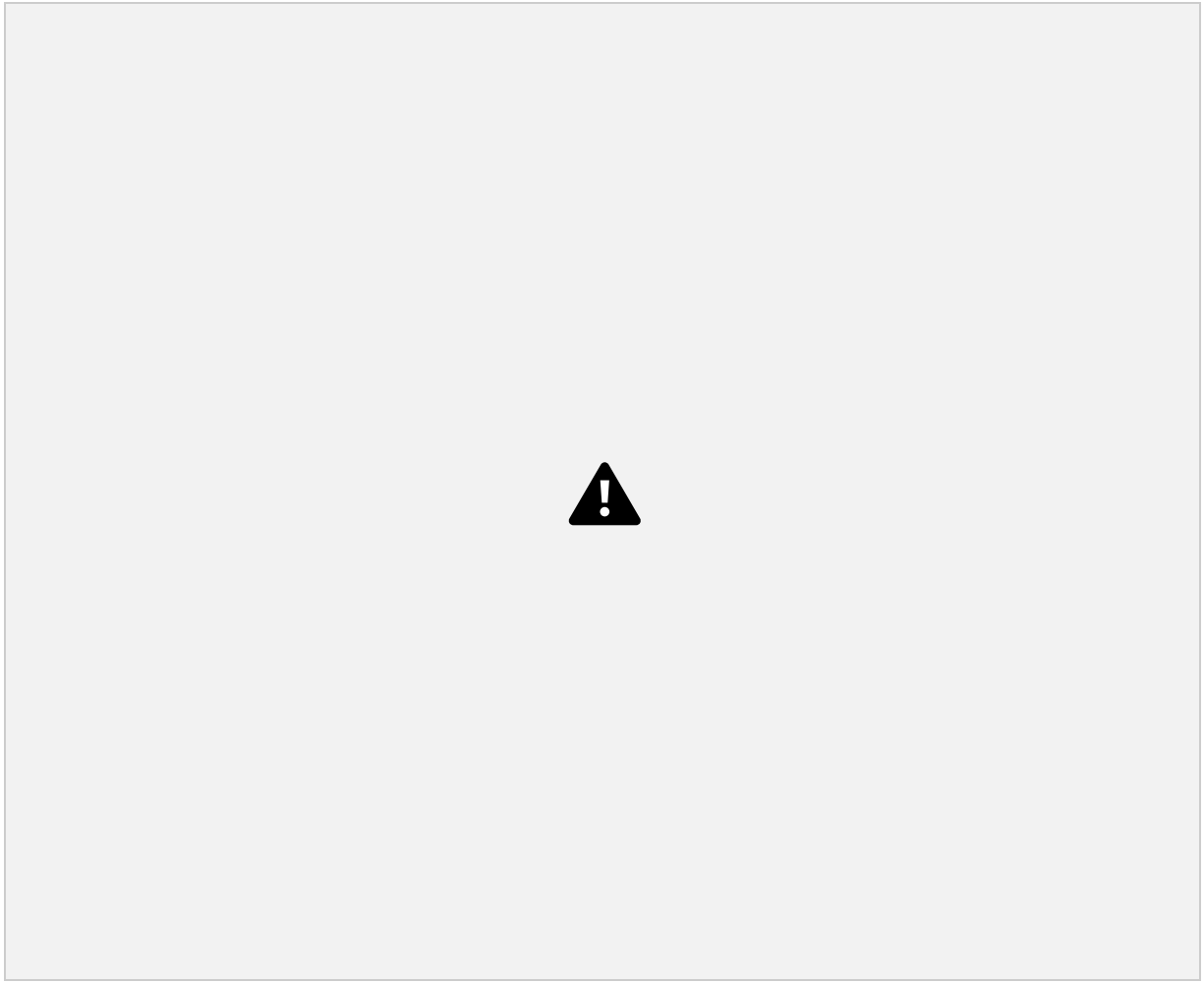
- A Fresnel lens is used in which linear grooves are present on one side and flat

surface on the other.

- The solar radiations which fall normal to the lens are refracted by the lens and are focused on the absorber (tube).
- Both glass and plastic can be used as refracting materials for Fresnel lenses.







 Good conductor of electricity
Number of valence electrons : 1 or 2

kel, Brass & steel, Salt

Valence and

conduction band overlaps each other

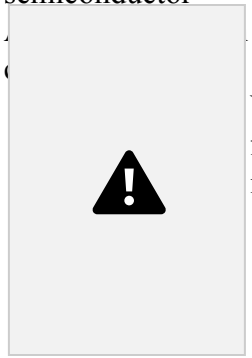
 Poor conductor of electricity
Outermost orbit Completely filled

 Conductivity lying between conductor and insulator

 Outermost orbit Partially filled

Glass, ceramic, plastics, & wood carbon, silicon, and germanium are semiconductors.

semiconductor

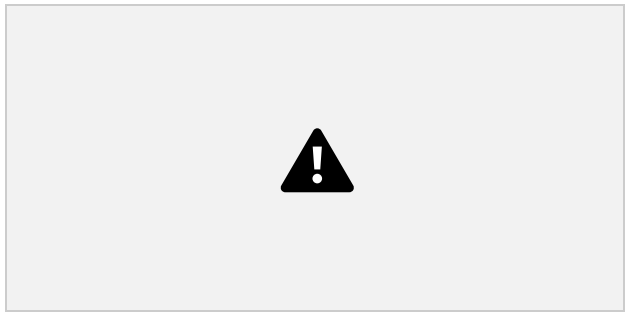


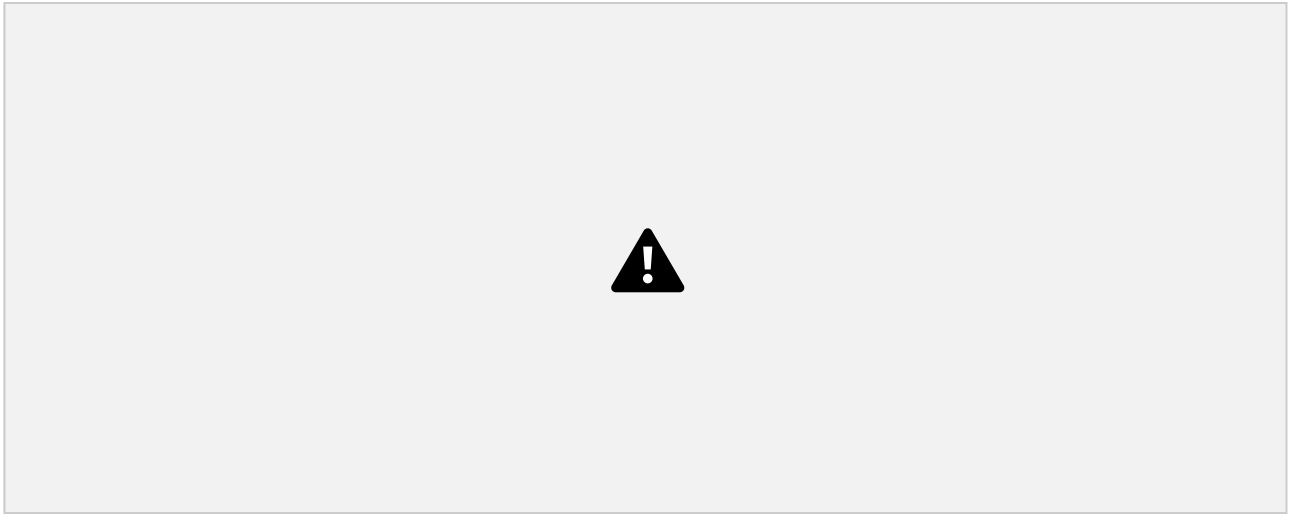
the valence band and empty

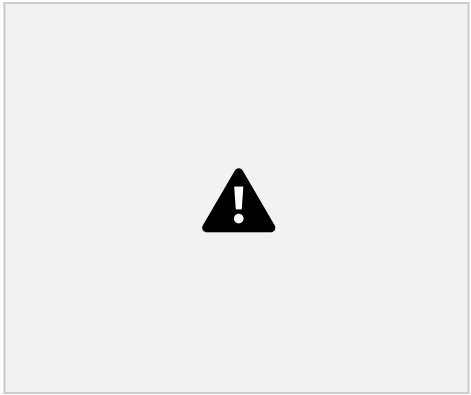
Valence band is partially filled and conduction band is almost empty

 Intrinsic Semiconductors: A pure

 Extrinsic semiconductors: Impurity Semiconductors (P & N Type semiconductor)
 Doping: The process of adding impurity to the Intrinsic Semiconductors
 N Type: A small amount of pentavalent impurities such as arsenic, antimony or phosphorous is added to pure Semiconductors
P Type: A small amount of trivalent impurities such as aluminium or boron is added to the pure semiconductor

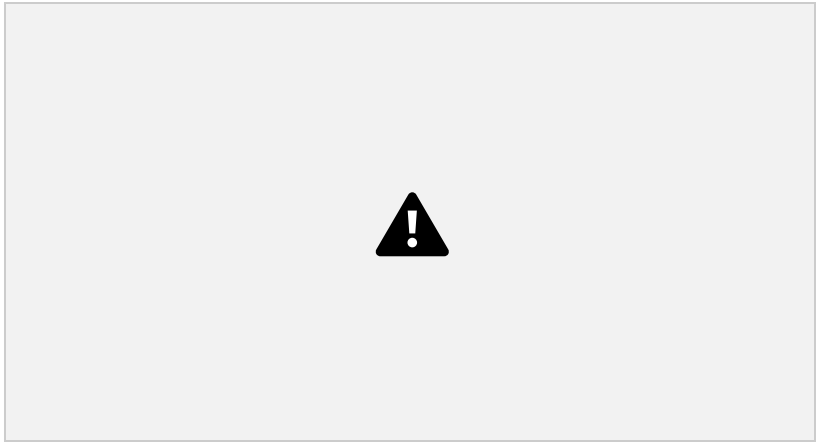






Construction Schematic symbol

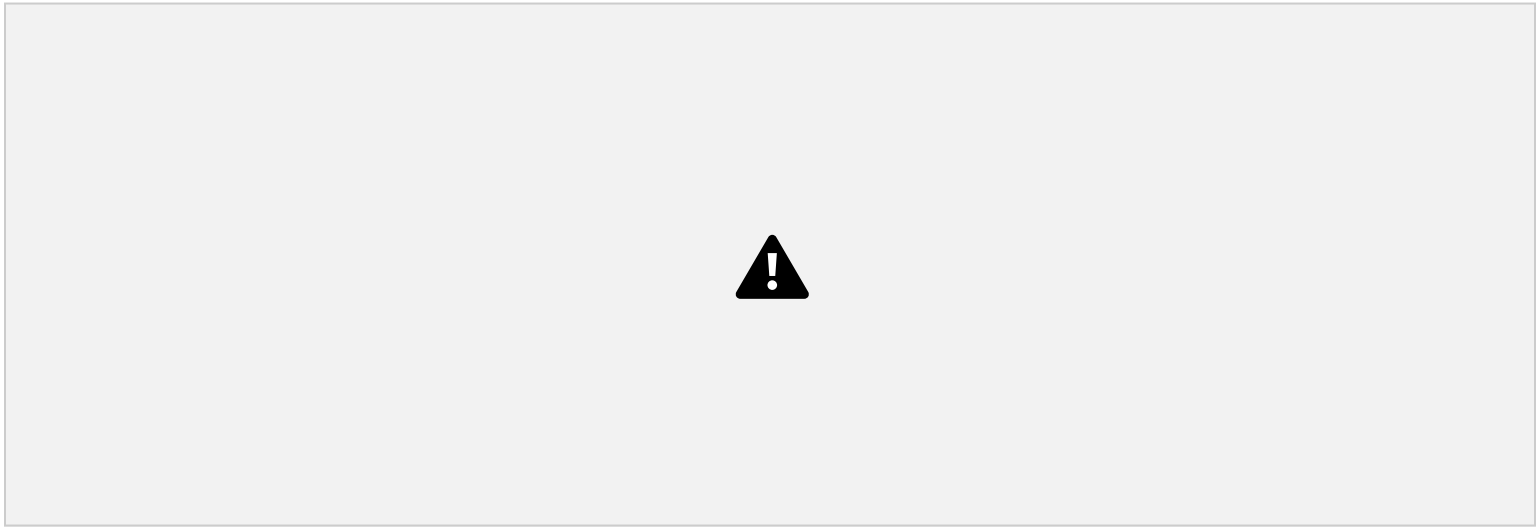
 When a solar cell (p-n junction) is illuminated, electron

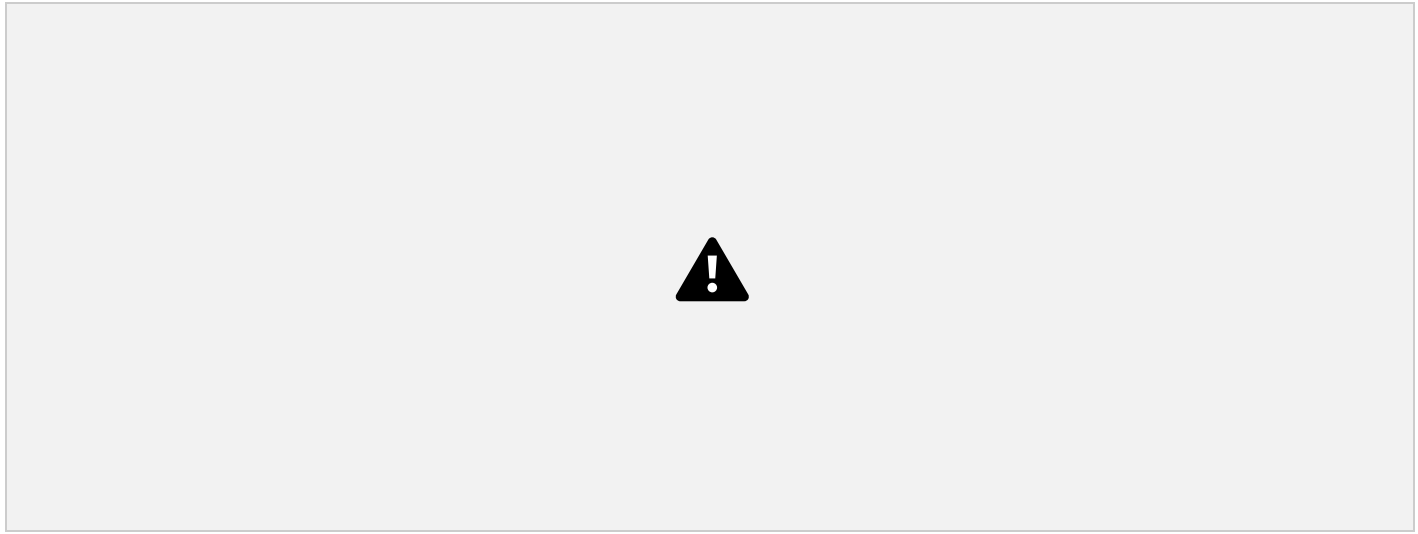


hole pairs are generated and the electric current I is obtained.

 I is the difference between the solar light generated

current I_L and the diode current I_j





When external resistance R is high (mega-ohms range or infinity) the condition is called ‘Open-circuit‘.

 The open-circuit voltage V_{oc} of a solar cell is about 0.5 V.D.C. It is the maximum voltage across a PV cell. Open-circuit current is zero. If R is reduced gradually and the readings of the terminal voltage V and load current I are taken, we get V-I, characteristics of the PV cell (Above Fig). As R is reduced from high value to low value, the terminal voltage of the cell falls and current increases. A steep characteristic OK is obtained. At knee point ‘K‘, the characteristic undergoes a smooth change and becomes flat for the portion Ks

 When the R is shorted, the short-circuit current I_{sc} is obtained. The V for the SC conditions is zero and maximum current delivered by the cell is I_{sc}.

Maximum power (P_{max}) = V_{mp} I_{mp}

Maximum efficiency (η_{max}): The ratio of maximum electric power output to incident solar radiation

Fill factor (FF): the ratio of the peak power to the product of open circuit voltage and short circuit current

- Solar cell designers strive to increase the FF values, to minimize internal losses.

- FF for a good silicon cell is about 0.8

Voltage factor: It is determined by the basic properties of the materials in the cell

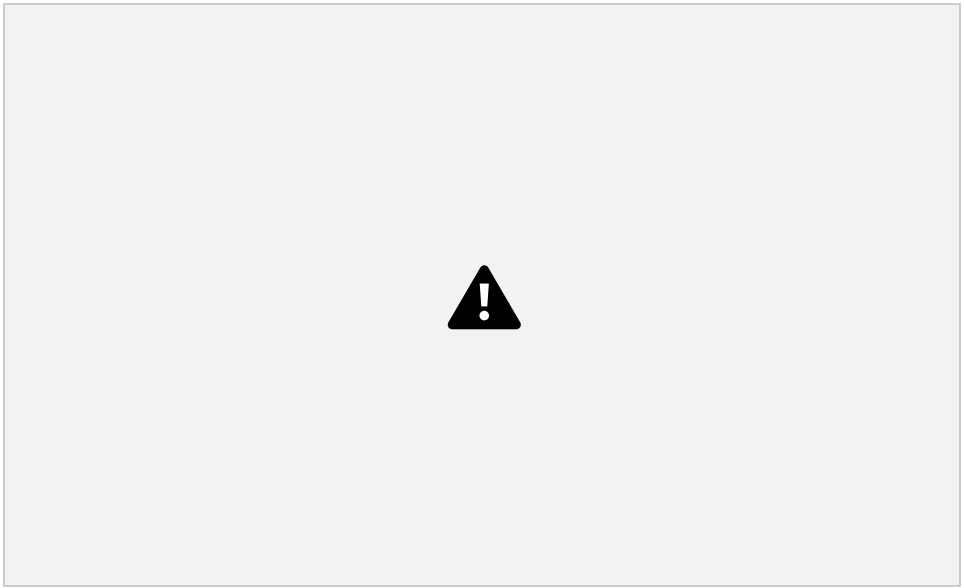
- About 0.5 for a silicon cell
- Eg = Forbidden energy gap

The efficiency of a photovoltaic cell is 15% only

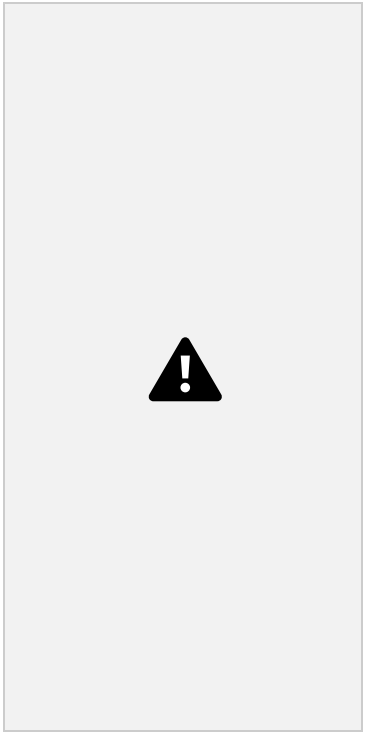
The major losses which lead to the low efficiency of the cell are:

 Temperature of the cell rises due to **solar radiation**, **leakage** across the cell **increases**. Consequently, power output, relative to solar energy input, **decreases**. For silicon, the output decreases by **0.5% per °C**. The **excess energy** of active photons given to the electrons **beyond the required amount** to cross the band gap cannot be recovered as **useful electric power**. It appears as heat, about **33 per cent**, and is lost. The electric current (generated) flows out of the top surface by a mesh of metal contacts provided to reduce **series resistance losses**. These contacts cover a definite area which **reduces the active surface** and proves an **obstacle to incident solar radiation**.

 To achieve maximum efficiency the semiconductor with optimum band gap should be used.



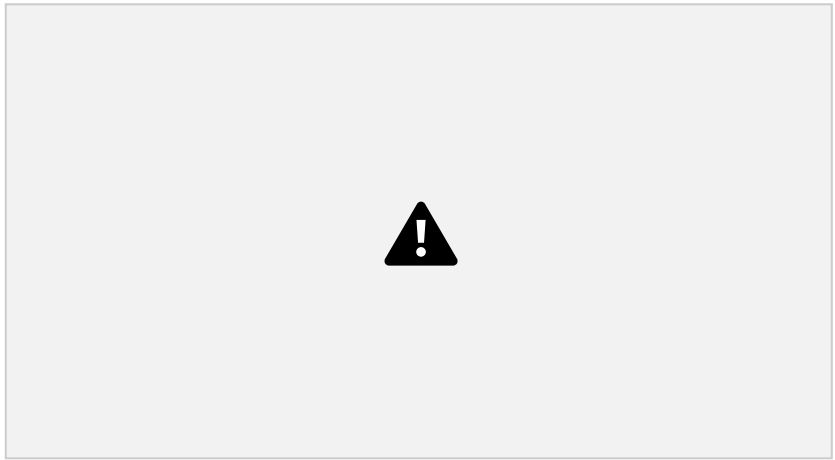
Pumping Systems

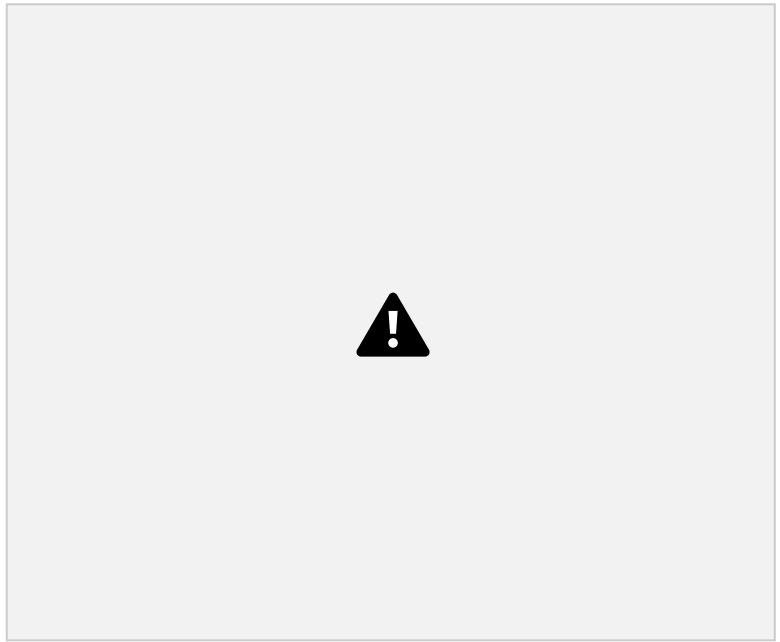


Street Lights

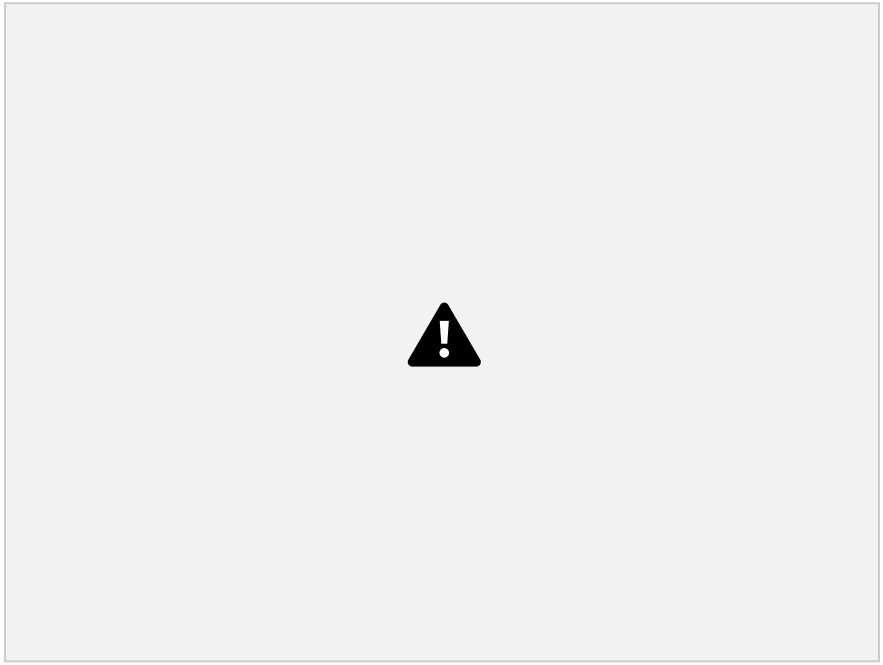
Traffic Signals

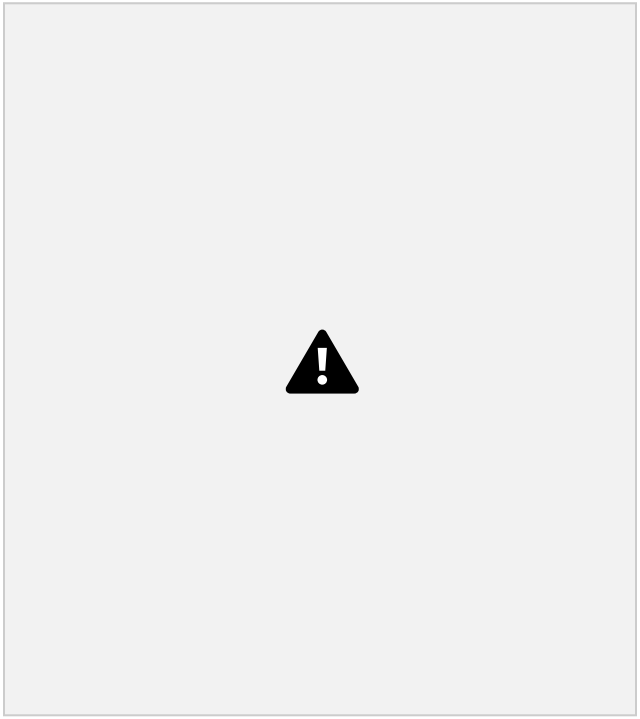
Water



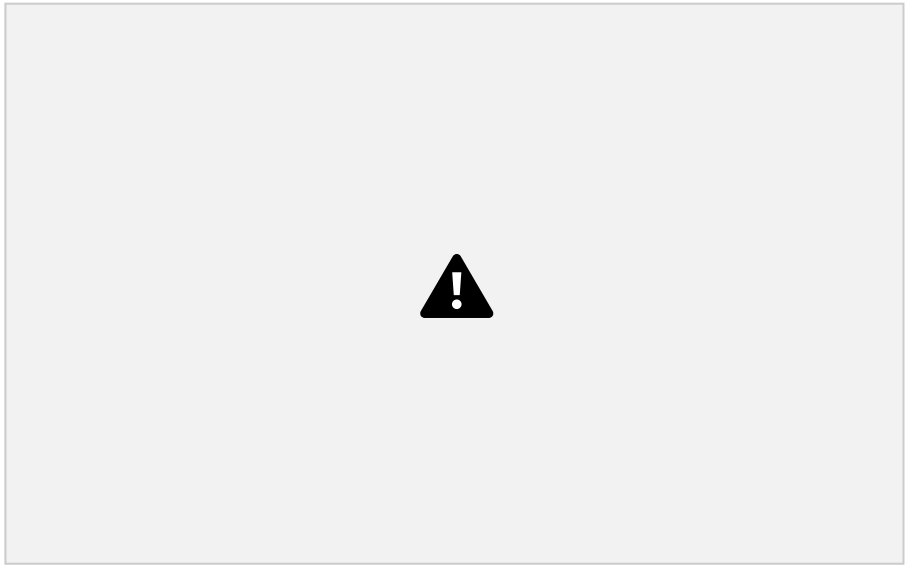


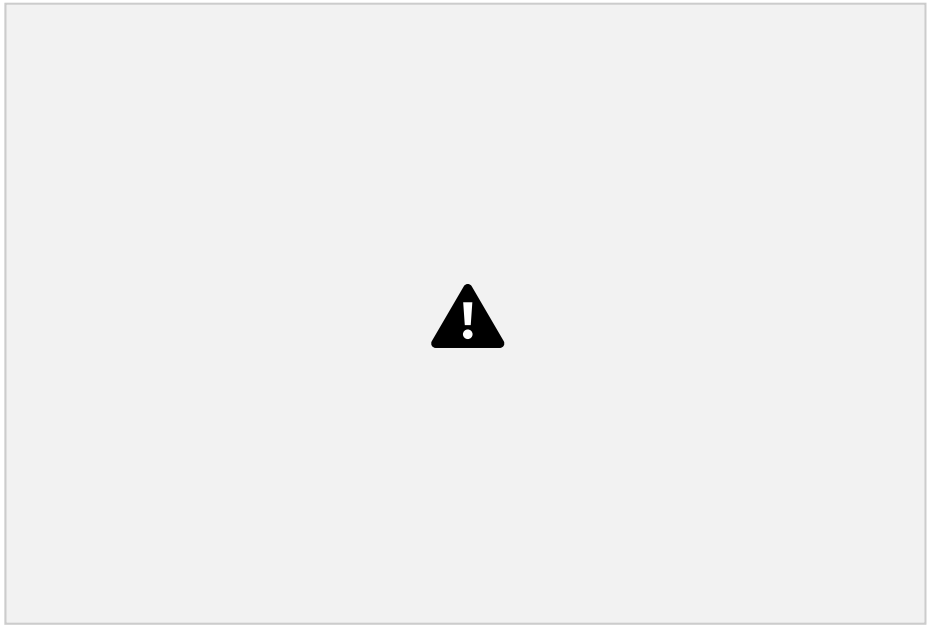
Home lighting systems Solar vehicles





Medical Refrigeration Solar vehicles





Weather monitoring Battery charging