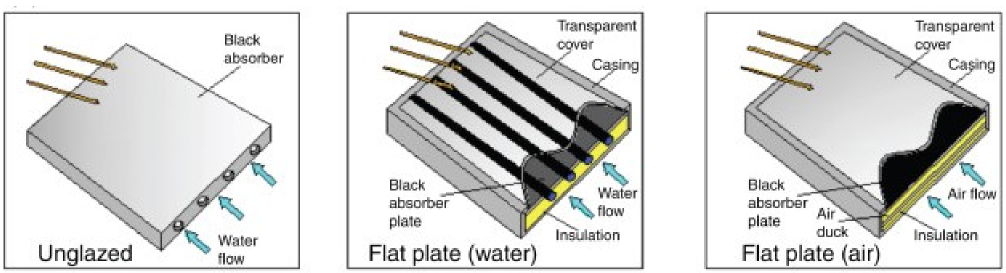
	CMR INSTITUTE OF TECHNOLOGY	
	Renewable Energy Systems -17EE563	Date: 15/10/2019
	Internal Assesment Test-1 . Solution Manual	Semester: V Dept. EEE/ECE/ISE

Answer any five FULL Questions. Sketch neat figures wherever necessary.

1. (a) Explain air flat plate collector with a neat sketch

- Solar collectors are heat exchangers.
- Absorbs the solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil).
- The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment, or to a thermal energy storage tank from which can be drawn for use at night and/or cloudy days.
- Solar collectors can be classified according to their collecting characteristics, the way in which they are mounted and the type of transfer fluid they use.
- Types of fluid:
  - A collector will usually use either a liquid or a gas as the transfer fluid.
  - The most common liquids are water or a water-ethylene glycol solution. The most common gas is air.
- **Air-type Flat plate collector**
  - Air type collectors are more commonly used for agricultural drying and space heating applications.
  - Their basic advantages are low sensitivity to leakages and no need for an additional heat exchanger for drying and space heating applications.
  - However, because of the low heat capacity of the air and the low convection heat transfer coefficient between the absorber and the air, a larger heat transfer area and higher ow rates are needed.
  - Common absorber materials include corrugated Al or galvanised steel sheets, black metallic screens or simply any black painted surface.



(b) Explain liquid flat plate collector with a neat sketch

- **Glazing:** One or more covers of transparent material like glass, plastics, etc.
- Glazing may be left out for some low temperature applications.
- Glass which transmits shorter wavelength solar radiation, but blocks the longer wavelength radiation from the absorber.
- **Absorber:** A plate with tubes or passages attached to it for the passage of working fluid.
- The absorber is usually painted at black or electroplated with a selective absorber.
- Header or manifolds: To facilitate the flow or heat transfer fluid.

- Insulation: To minimise heat loss from the back and the sides.

(c) Write two differences between glazed and unglazed flat plate collector.

- **Glazed flat plate collectors**
  - Used in high temperature applications
  - Efficiency is around 70 - 80 %.
  - Costly
- **Unglazed flat plate collectors**
  - Used in low temperature applications
  - Efficiency is around 60 - 70 %.
  - Less costlier

2. (a) Explain compound parabolic solar thermal collector with neat sketch.

- **Compound Parabolic Collector**
- It is also called CPC or wins ton collector.
- It is a non-focusing type.
- Compound parabolic concentrators can accept incoming radiation over a relatively wide range of angles.
- It has a trough like arrangement with two parabolic mirrors.
- Because of this arrangement, it collects both beam & diffuse radiation.
- CPCs are usually covered with glass to avoid dust and other materials from entering the collector and thus reducing the reflectivity of its walls.
- The orientation of a CPC collector is related to its acceptance angle (θ_c).
- Also depending on the collector acceptance angle, the collector can be stationary or tracking.
- A CPC concentrator can be orientated with its long axis along either the north-south or the east-west direction and its aperture is tilted directly towards the equator at an angle equal to the local latitude.
- As the acceptance angle of the concentrator along its long axis is wide, seasonal tilt adjustment is not necessary.

(b) State the advantages and disadvantages of concentrated collectors over a flat plate collector
Main advantages of the focusing systems over flat plate type collectors:

- Reflecting surfaces requires less material and are structurally simpler than flat-plate collectors. For a concentrator system the cost per unit area of solar collecting surface is therefore potentially less than that of the flat plate collector.
- The absorber area of a contractor system is smaller than that of a flat plate system of same solar energy collection and the insolation intensity is therefore greater.
- As it is found that in case of solar energy concentrating collector the energy lost to the surrounding is less than that for flat plate collector and the insolation on the absorber is more concentrated, the working fluid can attain higher temperatures in a concentrating system than that in a flat plate collector of the same solar energy collecting surface.
- Little or no antifreeze is required to protect the absorber in concentrator systems whereas the entire solar energy collection surface requires antifreeze protection in a flat-plate collector.

The concentrating systems also have some disadvantages as given below:

- Out of the beam and diffuse solar radiation, components, only beam component is collected in case of focusing collectors because diffuse component cannot be reflected and is thus lost.
- Additional requirement of maintenance particularly to retain the quality of reflecting surface against dirt, weather, oxidation etc.
- Non-uniform flux on the absorber whereas flux in flat-plate collector is uniform.

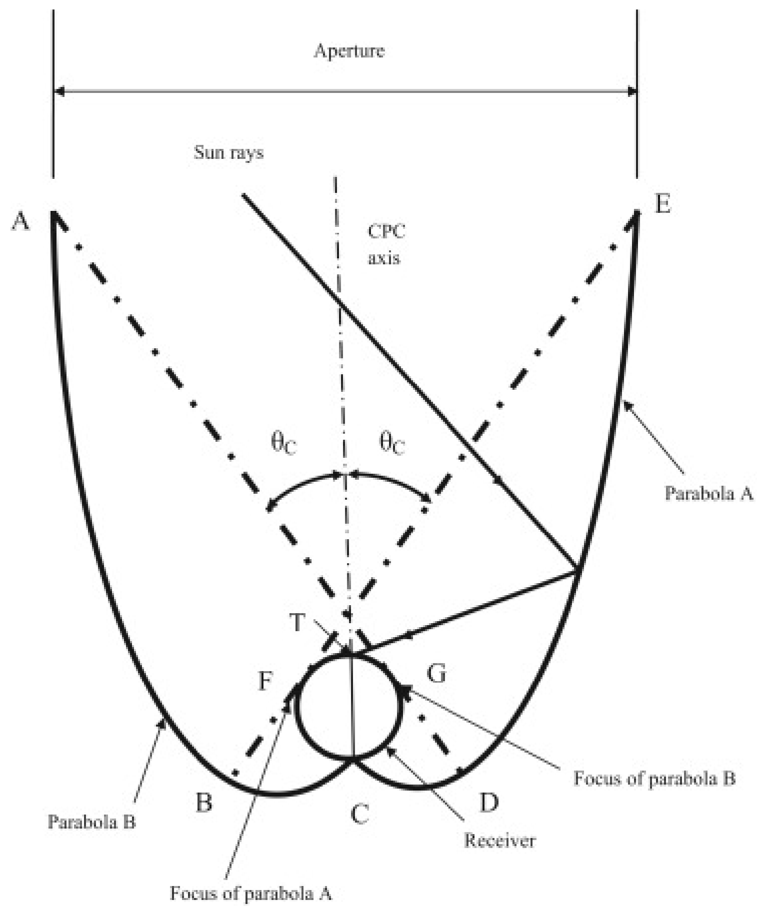


Figure 1: Compound Parabolic Collector

- Additional optical losses such as reflectance loss and the intercept loss, so they introduce additional factors in energy balances.

3. (a) Draw the schematic of Heliostat electric field generating plant
   (b) Explain the layers of solar pond with a neat sketch
4. (a) Draw the schematic and working of solar air heating system
   (b) Write advantage and disadvantages of solar cooker
5. (a) Explain the different types of practical solar cells.
   (b) Plot the graph of a typical I-V characteristic of a solar cell. Show the relation between the output voltage and output current of a solar cell with the help of PV circuit models.

   By applying Kirchoff's current law (KCL) for the ISPV circuit shown in Fig. 3(a), $V - I$ characteristic equation is given by,

$$i_{pv} - i_{ph} + i_s \left(e^{\frac{qv_{pv}}{kT_cA}} - 1 \right) = 0 \tag{1}$$

   Fig. 3(b) shows the modified ISPV which includes R_{sh} and is referred as ISPV-1. By applying KCL for the ISPV-1 it's $V - I$ equation is given by,

$$i_{\rm pv} - i_{\rm ph} + i_{\rm s} \left(e^{\frac{v_{\rm pv}}{V_t A}} - 1 \right) + \frac{V_{\rm pv}}{R_{\rm sh}} = 0 \tag{2}$$

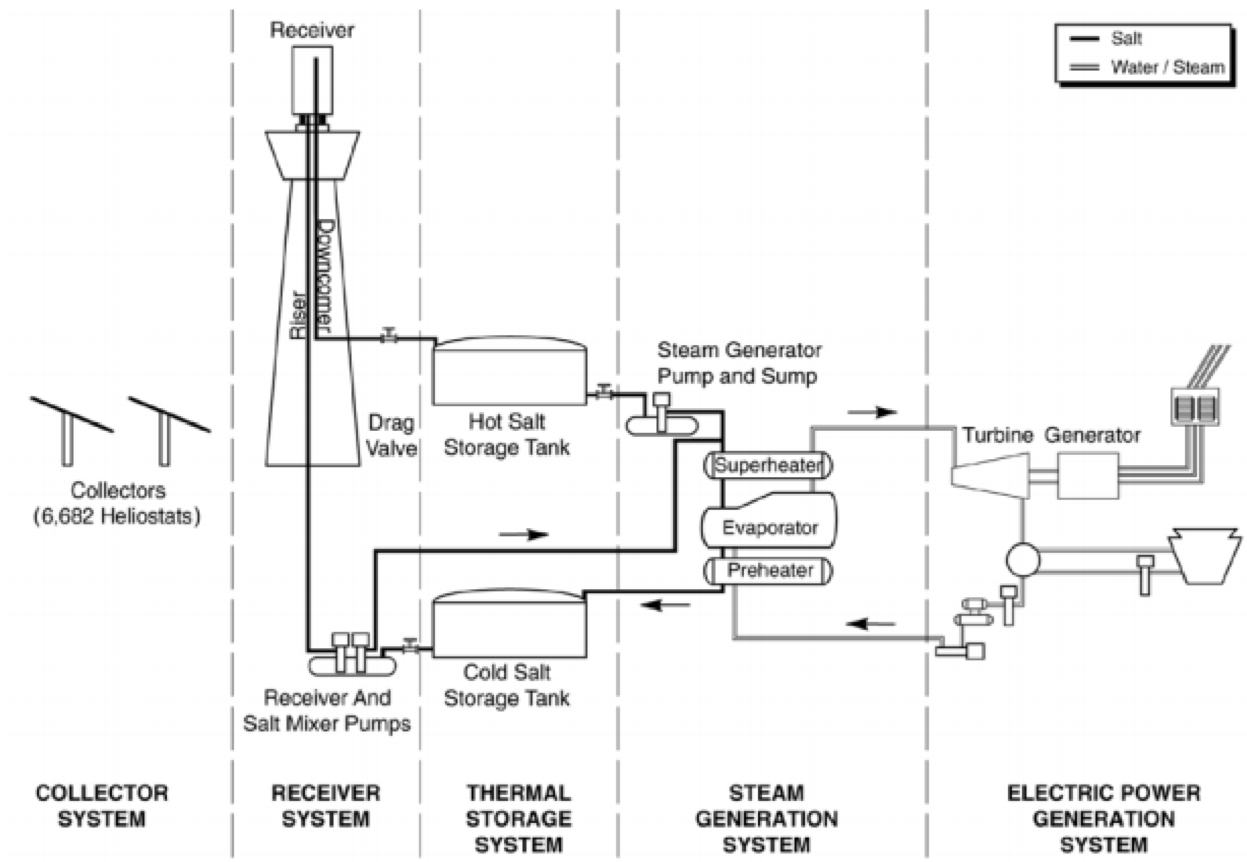


Figure 2: Compound Parabolic Collector

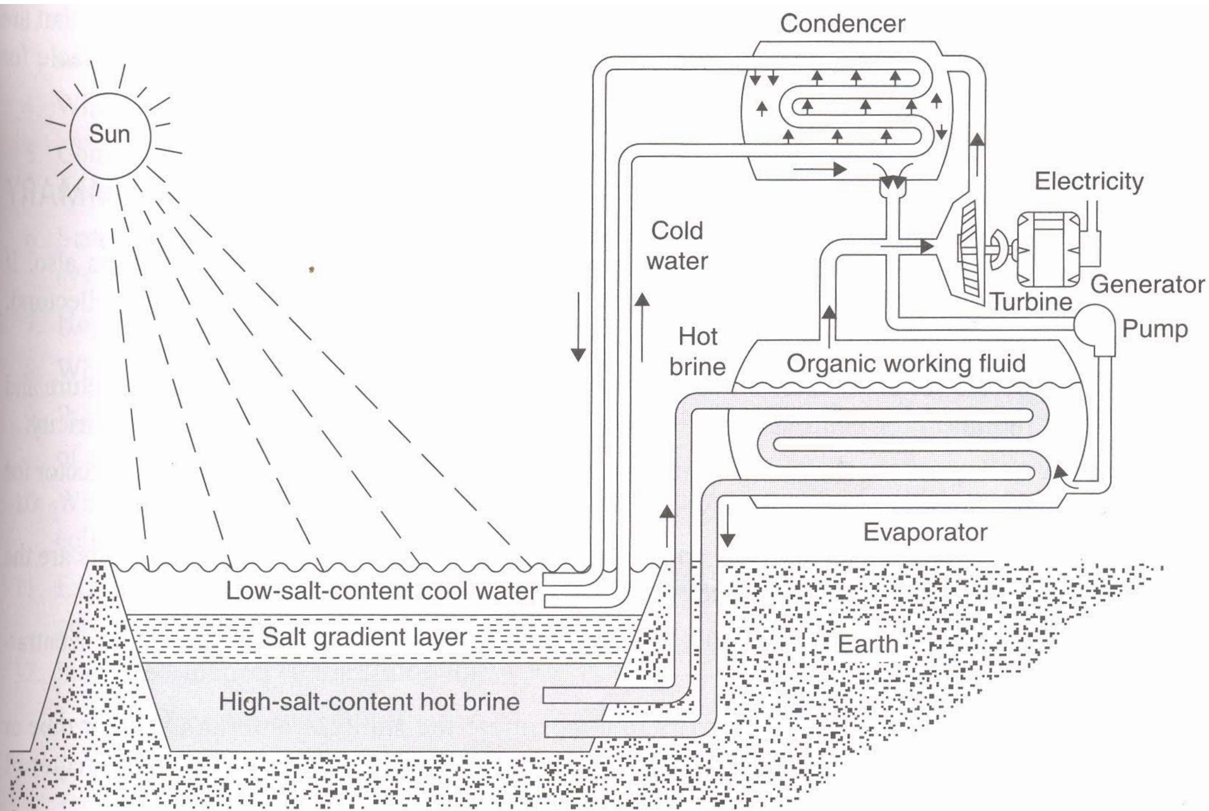
3.17 SOLAR POND

One of the best ways of harnessing solar energy is through solar ponds. It is basically a pool of water that collects and also stores solar energy. The peculiarity of the solar pond is that it has layers of salt solutions of differing concentrations, and thus, different densities to a certain depth. Once this depth is reached, then water with uniform, high salt concentration is obtained. The solar pond is a relatively low technology and low cost approach for harvesting solar energy. To develop a solar pond, pond is filled with three layers of water as shown in Figure 3.28.

1. The top layer is cold and has relatively little salt content.
2. Next is the intermediate insulating layer that has a salt gradient that maintains a density gradient. It is this density gradient that helps in preventing heat exchange with the natural convection of water.
3. The bottom layer is hot up to 100°C and has a high salt content.

It is because of these different salt contents in the different layers of water that the different layers have different densities. With the different densities in the water, the development of convection currents is prevented, which would have transferred heat to the surface of the pond, and then to the air above. Without these convection currents, heat is trapped in the salty bottom layer of the solar pond, which is used for heating of buildings, industrial processes, generation of electricity, and other purposes. In addition to the abovementioned uses, solar ponds can also be used in water desalination and for storage of thermal energy.

In this system, a large salty lake is used as a plate collector. With the right salt concentration in the water, the solar energy can be absorbed at the bottom of the lake. The heat is insulated by different densities of the water, and at the bottom, the heat can reach 90°C, which is high enough to run a vapour cycle engine; at the top of the pond, the temperature can reach 30°C. There are



Source: http://www.powerfromthesun.net/Book/chapter06/chapter06.html

Figure 3.28 Solar pond

three different layers of water in a solar pond: the top layer has less concentration of salt, the intermediate layer acts as a thermal insulator, and finally, the bottom layer has a high concentration of salt. These systems have a low solar to electricity conversion efficiency, less than 15% (having an ambient temperature of 20°C and storage heat of 80°C). One advantage of this system is that because the heat is stored, it can run day and night if required. Further, due to its simplicity, it can be constructed in rural areas in developing countries.

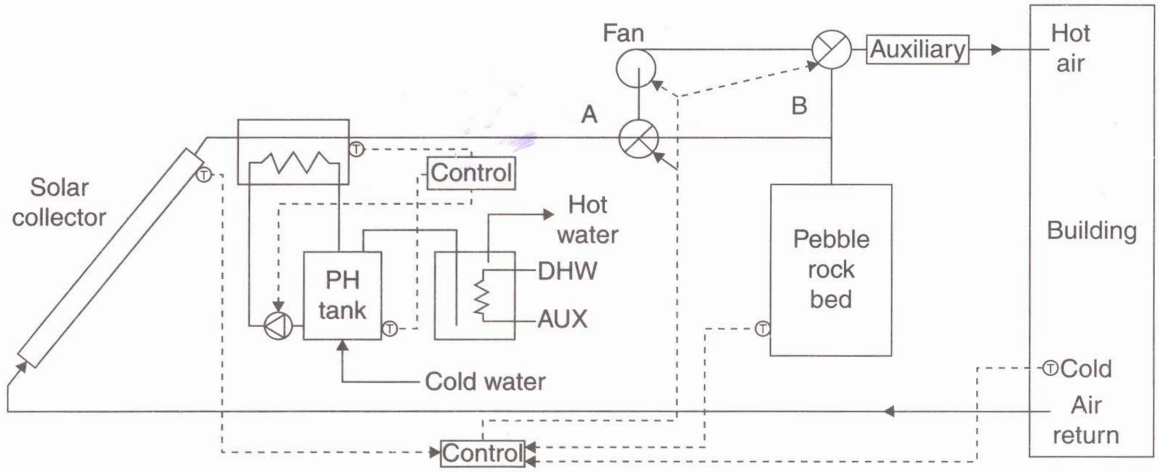


Figure 3.16 Schematic of solar air heating system

Schematic representation of a typical space heating system with air collectors is given in Figure 3.16. Dampers is indicated for the solar rock-bed charging mode. The main components of the building heating systems are as follows:

1. Air handling unit: a fan and two motor-driven dampers.
2. Heat storage unit (rock bed)
3. Temperature control system
4. Solar collectors

Depending on the position of dampers A and B, three modes of system operation can be achieved.

1. *Dampers A and B open*: This is the normal day time solar heating mode. The storage unit is bypassed. If the temperature sensor in the top of the collector array is below a necessary limit required for space heating, the auxiliary furnace is automatically turned on.
2. *Damper A open and damper B closed*: This mode is used whenever solar heat is collected but no space heating is required at the same time. The fan blows the solar heated air through the rock bed for thermal storage.
3. *Damper A closed and damper B open*: This mode is used during cloudy periods or during the night hours. The return air from the building is now pulled through the rock bed, where it picks up solar heat. The auxiliary furnace is activated automatically if the temperature is insufficient to meet the demand.

3.16.2 Advantages

Solar energy cooking has a variety of advantages, out of which the most important are as follows:

1. Cooking with solar energy saves fuel wood and/or chemical fuels.
2. Cooking with solar energy is clean and healthy and reduces health problems related to kitchen smoke.
3. Solar cooking enables individual families to do without commercial fuels, and thus, money can be saved.
4. Solar cooking saves time and effort that would otherwise be spent in collecting fuel wood.
5. Food cooked in box-type solar cookers cannot burn and does not have to be stirred or watched.
6. Food cooked in box-type solar cooker is cooked gently so that more of the nutrients and flavour of the food are conserved than when cooking on the fire.

3.16.3 Solar cooker Disadvantages

The following are some disadvantages related to the principle of solar cooking.

1. Solar cooking requires good weather with relatively steady sunshine.
2. Solar cooking cannot completely replace the conventional wood, gas, or kerosene fire.
3. Solar cooking is only possible during the daytime and not in the mornings and evenings (except with storage-type solar cookers).
4. Most types of solar cookers require industrially manufactured components. These can easily be destroyed, and it is difficult or impossible to repair or replace them with local material.
5. Some solar cooking boxes do not attain high temperatures. This requires long cooking time.
6. Boiling, roasting, and grilling require high temperatures, and thus, it is only possible in a few types of solar cookers
7. Some reflector-type solar cookers demand understanding, skill, and almost constant attention when handling and cooking with them.
8. The person doing the cooking has to stay out in the sun to avoid the risks of being dazzled or burnt.
9. Generally, families that need solar cookers mostly cannot afford them.

Table 4.1 Efficiency of Different Types of practical Solar Cells

Cell Material	Theoretical Efficiency (%)	Practical Efficiency (%)	Technology
Mono or multi-crystalline silicon	20–26	12–18	Ingot or wafer
Amorphous silicon	12–14	5 – 10	Thin film
Copper indium diselenide	16–18	8–10	Thin film
Cadmium telluride	15–16	5–8	Thin film
Gallium arsenide	26–32	18–25	Ingot or wafer
Ribbon-grown silicon	10–16	10–12	Ingot or wafer
Ovshinsky silicon	8–10	≤10	Thin film

1. *Crystalline silicon cells*: They dominate the photovoltaic market. To reduce the cost, these cells are now often made from multi-crystalline material, rather than from the more expensive single crystals. Crystalline silicon cell technology is well established. The modules have long lifetime (20 years or more) and their best production efficiency is approaching 18%.
2. *Amorphous silicon solar cells*: They are cheaper (but also less efficient) type of silicon cells made in the form of amorphous thin films that are used to power a variety of consumer products; however, larger amorphous silicon solar modules are also becoming available.
3. *Cadmium telluride and copper indium diselenide*: Thin-film modules are now beginning to appear on the market and hold the promise of combining low cost with acceptable conversion efficiencies.
4. *High-efficiency solar cells*: From gallium arsenide, indium phosphide, or their derivatives are used in specialized applications, for example, to power satellites or in systems that operate under high-intensity concentrated sunlight.

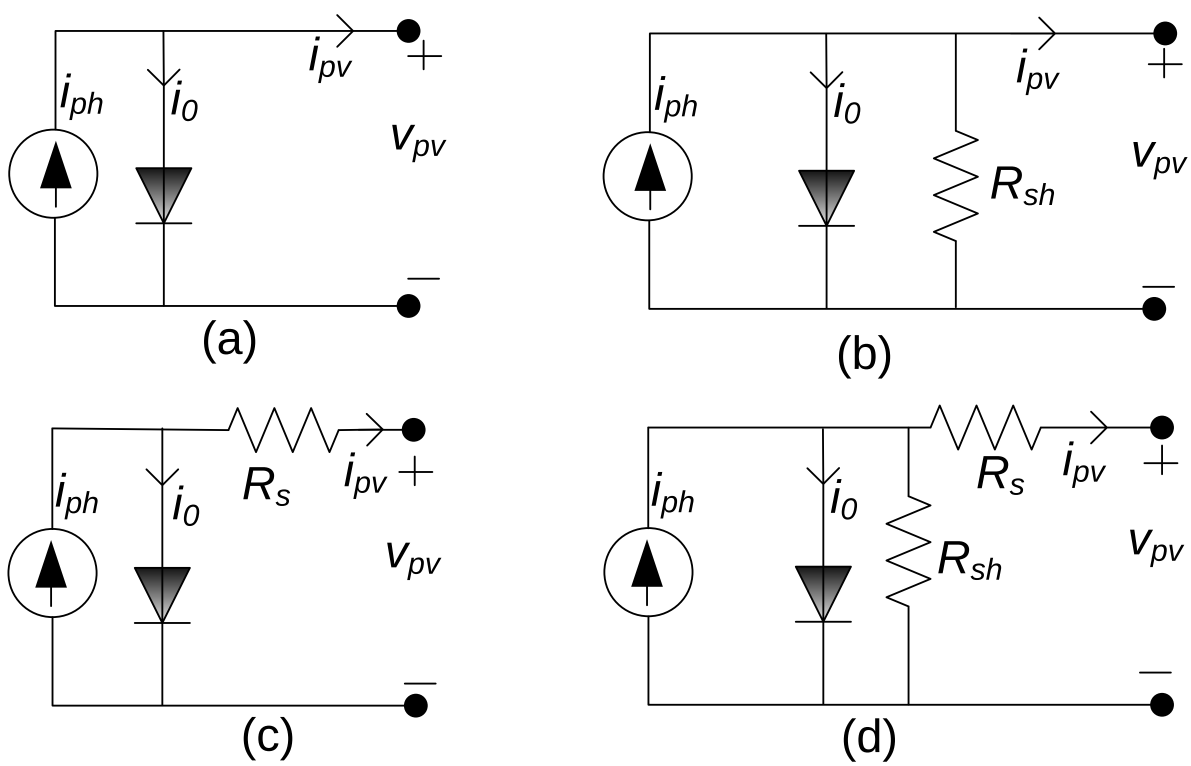


Figure 3: Equivalent circuit of PV models (a) ISPV (b) ISPV-1 (c) ISPV-2 (d) CSPV

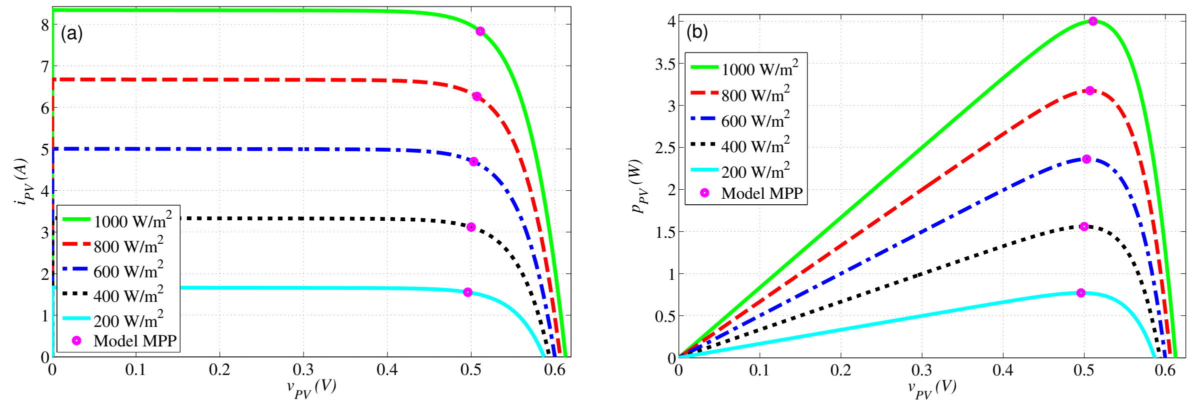


Figure 4: (a) $I - V$ curve (b) $P - V$ curve of PV cell under varying irradiance

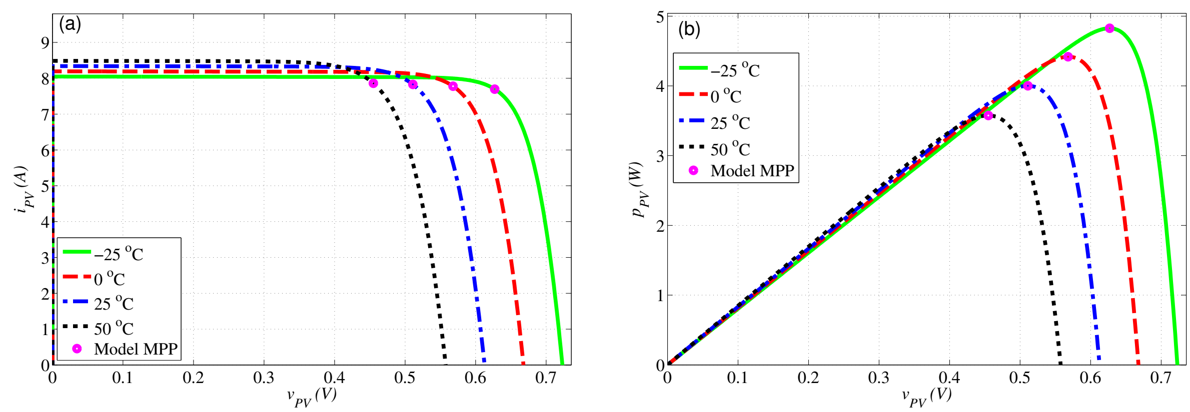


Figure 5: (a) $I - V$ curve (b) $P - V$ curve of PV cell under varying temparature

Fig. 3(c) shows a modified configuration of ISPV with a series resistance R_s and is referred to as ISPV-2. By applying KCL for the ISPV-2, following V-I equation is obtained.

$$i_{\mathrm{pv}} - i_{\mathrm{ph}} + i_{\mathrm{s}} \left(e^{\frac{(v_{\mathrm{pv}} + i_{\mathrm{pv}} R_{\mathrm{s}})}{V_t A}} - 1 \right) = 0 \tag{3}$$

Fig. 3(d) shows ISPV with R_s and R_{sh} and is referred to as CSPV. By applying KCL for the CSPV, it's $V - I$ equation is given by,

$$i_{\mathrm{pv}} - i_{\mathrm{ph}} + i_{\mathrm{s}} \left(e^{\frac{(v_{\mathrm{pv}} + i_{\mathrm{pv}} R_{\mathrm{s}})}{V_t A}} - 1 \right) + \frac{(v_{\mathrm{pv}} + i_{\mathrm{pv}} R_{\mathrm{s}})}{R_{sh}} = 0 \tag{4}$$

(c) Explain the factors that limits the efficiency of a solar cell

4.6.2 Factors Limiting the Efficiency of the Cell

1. *Wavelength of solar spectrum*: Cell response to only a portion of wavelength available in the solar spectrum. Photon with wavelength > 1.1 μm does not have sufficient energy to create electron–hole pair in silicon cell.
2. *Temperature*: Normal operating temperature of silicon cells can reach 60°C in peak sunlight and these temperature decreases the efficiency of the cells. Therefore, it is important to provide heat sinks of the best quality available. Gallium arsenide cells are capable of operating at high temperature where focused energy can be used.
3. *Mounting of the cells*: It should be to a heat sink (usually an aluminium plate) either heat conductive but electrically insulated. This will reduce operating temperatures and make the cell more efficient. In case free water source is available, heat sinks can be water cooled.
4. *Arrangement and maintenance of solar cell*: The negative side of the cells usually faces the sun and has antireflection coatings. These coatings should be protected from dust, bird dropping, by a clear plastic or glass cover. Accumulated dust on the cover will reduce the output power by about 10%.
5. *Position of the cell*: The cell or panel should be positioned either facing south in the north of equator or facing north in the south of equator for maximum power output and fixed panel applications. The angle off the ground should be equal to the latitude of the place for year around average or can be changed monthly to face the sun at noon for more efficiency.