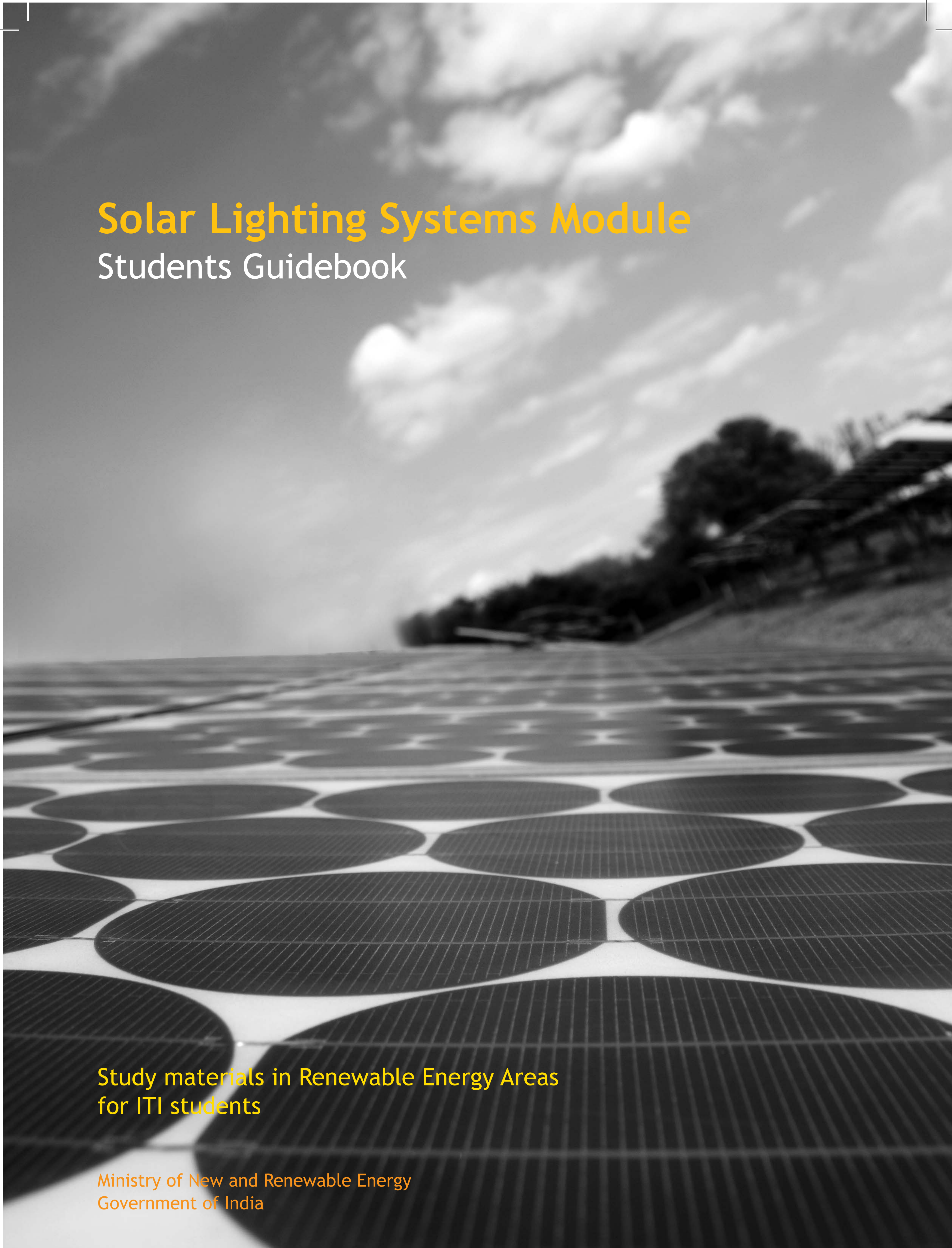
Solar Lighting Systems Module

Students Guidebook



Study materials in Renewable Energy Areas
for ITI students

Ministry of New and Renewable Energy
Government of India

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Unit 1: Solar energy and Photovoltaic

Q1. Why we should go for solar energy?

Ans: About half the incoming solar energy is absorbed by water and land; the rest is reradiated back into space.

Earth continuously receives 174 petawatts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by the atmosphere, oceans and land masses. After passing through the atmosphere, the insolation spectrum is split between the visible and infrared ranges with a small part in the ultraviolet.

The absorption of solar energy by atmospheric convection (sensible heat transport) and evaporation and condensation of water vapor (latent heat transport) powers the water cycle and drives the winds. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. The conversion of solar energy into chemical energy via photosynthesis produces food, wood and the biomass from which fossil fuels are derived.

Solar radiation along with secondary solar resources such as wind and wave power, hydroelectricity and biomass account for over 99.9% of the available flow of renewable energy on Earth. The flows and stores of solar energy in the environment are vast in comparison to human energy needs.

- The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3850 zettajoules (ZJ) per year.
- Global wind energy at 80 m is estimated at 2.25 ZJ per year.
- Photosynthesis captures approximately 3 ZJ per year in biomass.
- Worldwide electricity consumption was approximately 0.0567 ZJ in 2005.
- Worldwide energy consumption was 0.487 ZJ in 2005.

1 zettajoule = 10^{21} joules.

1 petawatts = 10^{15} watts

Q2. What are the applications of solar energy?

Ans: Solar energy technologies use solar radiation for practical ends. Solar technologies such as photo-voltaic and water heaters increase the supply of energy and may be characterized as supply side technologies. Technologies such as passive design and shading devices reduce the need for alternate resources and may be characterized as demand side. Optimizing the performance of solar technologies is often a matter of controlling the resource rather than simply maximizing its collection.

Q3. What do you mean by '*Photovoltaic*'?

Ans: First used in about 1890, the word has two parts: *photo*, derived from the Greek word for light, and *volt*, relating to electricity pioneer Alessandro Volta. So, *photovoltaics* could literally be translated as *light-electricity*. And that's what photovoltaic (PV) materials and devices do — they convert light energy into electrical energy (Photoelectric Effect), as discovered by renowned physicist Albert Einstein .

Commonly known as *solar cells*, individual PV cells are electricity-producing devices made of semiconductor materials. PV cells come in many sizes and shapes — from smaller than a postage stamp to several inches across. They are often connected together to form PV *modules* that may be up to several feet long and a few feet wide. Modules, in turn, can be combined and connected to form PV *arrays* of different sizes and power output.

The size of an array depends on several factors, such as the amount of sunlight available in a particular location and the needs of the consumer. The modules of the array make up the major part of a PV *system*, which can also include electrical connections, mounting hardware, power-conditioning equipment, and batteries that store solar energy for use when the sun isn't shining.

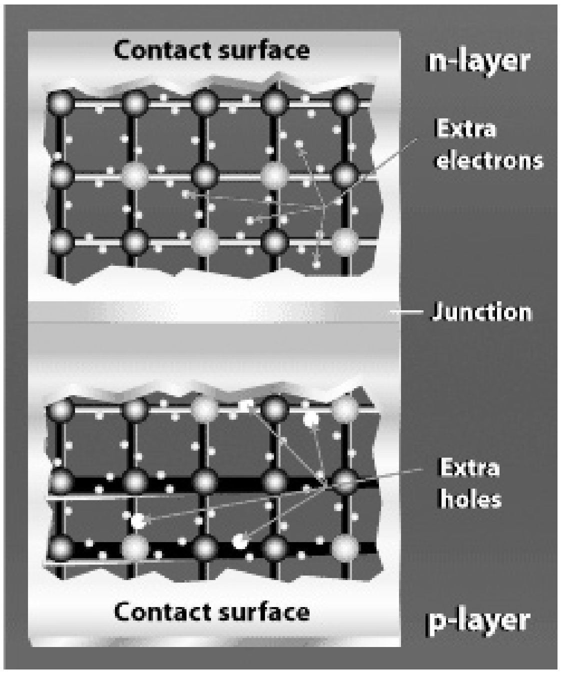
Simple PV systems provide power for many small consumer items, such as calculators and wristwatches. More complicated systems provide power for communications satellites, water pumps, and the lights, appliances, and machines in some people's homes and workplaces. Many road and traffic signs along highways are now powered by PV. In many cases, PV power is the least expensive form of electricity for performing these tasks.

Q4. What is the difference in Photovoltaic and Photoelectric effect?

Ans: The **photovoltaic effect** involves the creation of a voltage (or a corresponding electric current) in a material upon exposure to electro-magnetic radiation. Though the process is directly related to the photoelectric effect, the two processes are different and should be distinguished. In the **photoelectric effect** electrons are ejected from a materials surface upon exposure to radiation of sufficient energy. The photovoltaic effect is different in that the generated electrons are transferred from one material to another resulting in the buildup of a voltage between two electrodes.

In most photovoltaic applications the radiation is sunlight and for this reason the devices making use of the photovoltaic effect to convert solar energy into electrical energy are known as solar cells. In the case of a p-n junction solar cell, illumination of the material results in the creation of an electric current as excited electrons and the remaining holes are swept in different directions by the built in electric field of the depletion region.

Q5. How does a photovoltaic cell work?



Ans: The energy of the absorbed light is transferred to electrons in the atoms of the PV cell. With their newfound energy, these electrons escape from their normal positions in the atoms of the semiconductor PV material and become part of the electrical flow, or current, in an electrical circuit. A special electrical property of the PV cell—what we call a "built-in electric field"—provides the force, or voltage, needed to drive the current through an external "load," such as a light bulb.

To induce the built-in electric field within a PV cell, two layers of somewhat differing semiconductor materials are placed in contact with one another. One layer is an "n-type" semiconductor with an abundance of electrons, which have a negative electrical charge. The other layer is a "p-type" semiconductor with an abundance of "holes," which have a positive electrical charge.

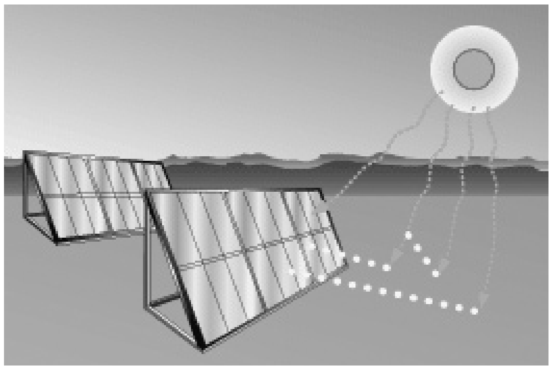
Although both materials are electrically neutral, n-type silicon has excess electrons and p-type silicon has excess holes. Sandwiching these together creates a p/n junction at their interface, thereby creating an electric field.

When n- and p-type silicon come into contact, excess electrons move from the n-type side to the p-type side. The result is a buildup of positive charge along the n-type side of the interface and a buildup of negative charge along the p-type side.

How do we make the p-type ("positive") and n-type ("negative") silicon materials that will eventually become the photovoltaic (PV) cells that produce solar electricity? Most commonly, we add an element to the silicon that either *has* an extra electron or *lacks* an electron. This process of adding another element is called doping.

Q6. What is a direct radiation and diffused radiation?

Ans: As we have noted, the Earth's atmosphere and cloud cover absorb, reflect, and scatter some of the solar radiation entering the atmosphere. Nonetheless, an enormous amount of the sun's energy reaches the Earth's surface and can therefore be used to produce PV electricity. Some of this radiation is direct and some is diffuse, and the distinction is important because some PV systems (flat-plate systems) can use both forms of light, but concentrator systems can only use direct light.



Flat-plate collectors, which typically contain a large number of solar cells mounted on a rigid, flat surface, can make use of both direct sunlight and the diffuse sunlight reflected from clouds, the ground, and nearby objects.

- Direct light consists of radiation that comes straight from the sun, without reflecting off of clouds, dust, the ground, or other objects. Scientists also talk about direct-normal radiation, referring to the portion of sunlight that comes directly from the sun and strikes the plane of a PV module at a 90-degree angle.
- Diffuse light is sunlight that is reflected off of clouds, the ground, or other objects. It obviously takes a longer path than a direct light ray to reach a module. Diffuse light cannot be focused by the optics of a concentrator PV system.
- Global radiation refers to the total radiation that strikes a horizontal surface. Global sunlight is composed of direct-normal and diffuse components of sunlight.

Q7. What do you understand by Insolation?

Ans: The actual amount of sunlight falling on a specific geographical location is known as insolation—or "incident solar radiation."

When sunlight reaches the Earth, it is distributed unevenly in different regions. Not surprisingly, the areas near the Equator receive more solar radiation than anywhere else on the Earth. Sunlight varies with the seasons, as the rotational axis of the Earth shifts to lengthen and shorten days with the changing seasons

Unit 2: Solar Cell Materials and Structures

Q1. Write a brief note on PV devices.

Ans: Photovoltaic devices can be made from various types of semiconductor materials, deposited or arranged in various structures, to produce solar cells that have optimal performance.

The first type is silicon, which can be used in various forms, including single-crystalline, multicrystalline, and amorphous. The second type is polycrystalline thin films, with specific discussion of copper indium di selenide (CIS) cadmium telluride (CdTe), and thin-film silicon. The third type of material is single-crystalline thin film, focusing especially on cells made with gallium arsenide.

Q2. How band gap is defined?

Ans: The band gap of a semiconductor material is an amount of energy. Specifically, it's the minimum energy needed to move an electron from its bound state within an atom to a free state. This free state is where the electron can be involved in conduction. The lower energy level of a semiconductor is called the "valence band." And the higher energy level where an electron is free to roam is called the "conduction band." The bandgap (often symbolized by Eg) is the energy difference between the conduction band and valence band.

Q3. Write short notes on each of the following:

Ans:

Homojunction devices

Crystalline silicon is the primary example of this kind of cell. A single material—crystalline silicon—is altered so that one side is p-type, dominated by positive holes, and the other side is n-type, dominated by negative electrons. The p/n junction is located so that the maximum amount of light is absorbed near it. The free electrons and holes generated by light deep in the silicon diffuse to the p/n junction, then separate to produce a current if the silicon is of sufficient high quality.

Hetrojunction devices

An example of this type of device structure is a CIS cell, where the junction is formed by contacting two different semiconductors—CdS and $CuInSe_2$. This structure is often chosen for producing cells made of thin-film materials that absorb light much better than silicon. The top and bottom layers in a heterojunction device have different roles.

Multijunction devices

This structure, also called a cascade or tandem cell, can achieve higher total conversion efficiency by capturing a larger portion of the solar spectrum. In the typical multijunction cell, individual cells with different band gaps are stacked on top of one another. The individual cells are stacked in such a way that sunlight falls first on the material having the largest bandgap.

Unit 3: Solar Chargers, Batteries and Inverters

Q1. What is a solar charge controller?

Ans: A charge controller, or charge regulator is similar to the voltage regulator in your car. It regulates the voltage and current coming from the solar panels going to the battery. Most "12 volt" panels put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging. Most batteries need around 14 to 14.5 volts to get fully charged.

Solar charge controllers are an essential element to any solar electric panel system. At a most basic level charge controllers prevent batteries from being overcharged and prevent the batteries from discharging through the solar panel array at night.

The basic functions of a controller are quite simple. Charge Controllers block reverse current and prevent battery overcharge. Some controllers also prevent battery over-discharge, protect from electrical overload, and/or display battery status and the flow of power. Let's examine each function individually.

Q2. How to Block Reverse current?

Ans: Photovoltaic panels work by pumping current through your battery in one direction. At night, the panels may pass a bit of current in the reverse direction, causing a slight discharge from the battery. (Our term "battery" represents either a single battery or bank of batteries.) The potential loss is minor, but it is easy to prevent.

In most controllers, charge current passes through a semiconductor (a transistor) which acts like a valve to control the current. It is called a "semiconductor" because it passes current only in one direction. It prevents reverse current without any extra effort or cost.

In some controllers, an electromagnetic coil opens and closes a mechanical switch. This is called a relay. (You can hear it click on and off.) The relay switches off at night, to block reverse current.

Q3. How to prevent overcharge?

Ans: When a battery reaches full charge, it can no longer store incoming energy. If energy continues to be applied at the full rate, the battery voltage gets too high. Water separates into hydrogen and oxygen and bubbles out rapidly. (It looks like it's boiling so we sometimes call it that, although it's not actually hot.) There is excessive loss of water, and a chance that the gasses can ignite and cause a small explosion. The battery will also degrade rapidly and may possibly overheat. Excessive voltage can also stress your loads (lights, appliances, etc.) or cause your inverter to shut off.

Preventing overcharge is simply a matter of reducing the flow of energy to the battery when the battery reaches a specific voltage. When the voltage drops due to lower sun intensity or an increase in electrical usage, the controller again allows the maximum possible charge. This is called "voltage regulating." It is the most essential function of all Charge Controllers. The controller "looks at" the voltage, and regulates the battery charging in response.

Some controllers regulate the flow of energy to the battery by switching the current fully on or fully off. This is called "on/off control." Others reduce the current gradually. This is called "Pulse Width Modulation" (PWM). Both methods work well when set properly for your type of battery.

A PWM Type Solar Charge Controllers holds the voltage more constant. If it has two-stage regulation, it will first hold the voltage to a safe maximum for the battery to reach full charge. Then, it will drop the voltage lower, to sustain a "finish" or "trickle" charge. Two-stage regulating is important for a system that may experience many days or weeks of excess energy (or little use of energy). It maintains a full charge but minimizes water loss and stress.

The voltages at which the controller changes the charge rate are called set points. When determining the ideal set points, there is some compromise between charging quickly before the sun goes down, and mildly overcharging the battery. The determination of set points depends on the anticipated patterns of usage, the type of battery, and to some extent, the experience and philosophy of the system designer or operator. Some controllers have adjustable set points, while others do not.

Q4. What precautions should be taken to prevent over discharging?

Ans: The deep-cycle batteries used in renewable energy systems are designed to be discharged by about 80 percent. If they are discharged 100 percent, they are immediately damaged. Imagine a pot of water boiling on your kitchen stove. The moment it runs dry, the pot overheats. If you wait until the steaming stops, it is already too late!

Similarly, if you wait until your lights look dim, some battery damage will have already occurred. Every time this happens, both the capacity and the life of the battery will be reduced by a small amount. If the battery sits in this overdischarged state for days or weeks at a time, it can be ruined quickly.

The only way to prevent over-discharge when all else fails, is to disconnect loads (appliances, lights, etc.), and then to reconnect them only when the voltage has recovered due to some substantial charging. When over discharge is approaching, a 12 volt battery drops below 11 volts (a 24 V battery drops below 22 V).

A low voltage disconnect circuit will disconnect loads at that set point. It will reconnect the loads only when the battery voltage has substantially recovered due to the accumulation of some charge. A typical LVD reset point is 13 volts (26 V on a 24 V system).

Q5. What should be done for overload protection?

Ans: A circuit is overloaded when the current flowing in it is higher than it can safely handle. This can cause overheating and can even be a fire hazard. Overload can be caused by a fault (short circuit) in the wiring, or by a faulty appliance (like a frozen water pump). Some Charge Controllers have overload protection built in, usually with a push-button reset.

Built-in overload protection can be useful, but most systems require additional protection in the form of fuses or circuit breakers. If you have a circuit with a wire size for which the safe carrying capacity (ampacity) is less than the overload limit of the controller, then you must protect that circuit with a fuse or breaker of a suitably lower amp rating.

Q6. Write down the types of charge controllers?

Ans: Charge controllers come in 3 general types (with some overlap):

- Simple 1 or 2 stage controls which rely on relays or shunt transistors to control the voltage in one or two steps. These essentially just short or disconnect the solar panel when a certain voltage is reached. For all practical purposes these are dinosaurs, but you still see a few on old systems. Their only real claim to fame is their reliability - they have so few components, there is not much to break.]
- 3-stage and/or PWM: These are pretty much the industry standard now, but you will occasionally still see some of the older shunt/relay types around, such as in the very cheap systems offered by discounters and mass marketers.
- Maximum power point tracking (MPPT). These are the ultimate in controllers, with prices to match - but with efficiencies in the 94% to 98% range, they can save considerable money on larger systems since they provide 15 to 30% more power to the battery.

Q7. What do you mean by equalization?

Ans: Equalization does somewhat what the name implies - it attempts to equalize - or make all cells in the battery or battery bank of exactly equal charge. Essentially it is a period of overcharge, usually in the 15 to 15.5 volt range. If you have some cells in the string lower than others, it will bring them all up to full capacity. In flooded batteries, it also serves the important function of stirring up the liquid in the batteries by causing gas bubbles. Of course, in an RV or boat, this does not usually do much for you unless you have been parked for months, as normal movement will accomplish the same thing. Also, in systems with small panels you may not get enough current to really do much bubbling.

Q8. What is the function of an typical Inverter?

Ans: An inverter is a device that converts battery power (DC) into alternating current (AC) of a higher voltage. This means that most inverters are installed and used in conjunction with a battery bank of some sort - a common set up in off grid solar installations. To explain how solar inverters work, we must start from the basics. The sun shines down onto photovoltaic PV cells. These cells are made of semiconductor layers of crystalline silicon or gallium arsenide, and they are arranged into panels.

The semiconductor layers are a combination of both positive and negative layers, and they are connected through a junction.

Basically, as the sun shines down, the semiconductor material absorbs the light, transferring the light's energy to the PV cell. This energy knocks electrons loose, and they move from one layer to the other, thereby producing an electric current. This is a direct current (DC). The energy created is then generally either stored in a battery bank for later use or sent directly to an inverter, depending on the set up and type of system.

For regular consumer use, and alternating current (AC) is needed –230 volt AC powered home appliances require AC electricity. This is where an inverter comes in. The inverter takes the direct current and, in simplified terms, runs it through a transformer. It is almost as though the inverter is tricking the transformer into thinking it is getting AC by forcing the DC to act in a way similar to AC – the inverter runs the DC through two or more transistors that are rapidly turned on and off and feeding two different sides of the transformer.

Q9. Describe in brief: Electric batteries.

Ans: A battery is a device that converts chemical energy directly to electrical energy.It consists of a number of voltaic cells; each voltaic cell consists of two half cells connected in series by a conductive electrolyte containing anions and cations. One half-cell includes electrolyte and the electrode to which anions (negatively-charged ions) migrate, i.e. the anode or negative electrode; the other half-cell includes electrolyte and the electrode to which cations (positively-charged ions) migrate, i.e. the cathode or positive electrode. In the redox reaction that powers the battery, reduction (addition of electrons) occurs to cations at the cathode, while oxidation (removal of electrons) occurs to anions at the anode. The electrodes do not touch each other but are electrically connected by the electrolyte. Many cells use two half-cells with different electrolytes. In that case each half-cell is enclosed in a container, and a separator that is porous to ions but not the bulk of the electrolytes prevents mixing.

Q10. What is a breadboard? Why it is used?

Ans: A breadboard s a construction base for a one-of-a-kind electronic circuit, a prototype. In modern times the term is commonly used to refer to a particular type of breadboard, the solderless breadboard.

Because the solderless breadboard does not require soldering, it is reusable, and thus can be used for temporary prototypes and experimenting with circuit design more easily. Other, often historic, breadboard types don't have this property. This is also in contrast to stripboard (veroboard) and similar prototyping printed circuit boards, which are used to build more permanent soldered prototypes or one-offs, and cannot easily be reused. A variety of electronic systems may be prototyped by using breadboards, from small analog and digital circuits to complete central processing units (CPUs).

Unit 4: PV Devices in India

Q1. How do a CFL work?

Ans: CFLs work much like standard fluorescent lamps. They consist of two parts: a gas-filled tube, and magnetic or electronic ballast. The gas in the tube glows with ultraviolet light when electricity from the ballast flows through it. This in turn excites a white phosphor coating on the inside of the tube, which emits visible light throughout the surface of the tube.

CFLs with magnetic ballasts flicker slightly when they start. They are also heavier than those with electronic ballasts. This may make them too heavy for some light fixtures. Electronic ballasts are more expensive, but light immediately (especially at low temperatures). They are also more efficient than magnetic ballasts. The tubes will last about 10,000 hours and the ballast about 50,000 hours. Most currently available CFLs have electronic ballasts.

CFLs are designed to operate within a specific temperature range. Temperatures below the range cause reduced output. Most are for indoor use, but there are models available for outdoor use. You can find a CFL's temperature range on most lamp packages. You should install outdoor CFLs in enclosed fixtures to minimize the adverse effects of colder temperatures.

Q2. Describe the typical models of solar home lighting systems.

Ans:

MODEL – 1 (1 Light Point)

Component Specifications

PV Module 1X 18 W under STC

Lamps 1X CFL (9W/11W)

Battery 1X 12V, 20 AH Tubular plate Lead Acid or VRLA Gel Type

Other components: control electronics, module mounting hardware, battery box, inter-connecting wires/cables, switches, etc. Operation, instruction and, maintenance manual.

MODEL - 2 (2 Lights)

Component Specifications

PV Module 1X 37 W under STC

Lamps 2X CFLs (9W/11W)

Battery 1X 12V, 40 AH Tubular plate Lead Acid or VRLA Gel Type

Other components: control electronics, module mounting hardware, battery box, inter-connecting wires/cables, switches, etc. Operation, instruction and maintenance manual.

MODEL - 3 (2 lights and 1 fan)

Component Specifications

PV Module(s) 2X 37 W or 1 X 74 W under STC

Lamps 2X CFLs (9W/11W)

Fan 1X DC Fan (with wattage less than 20 W)

Battery 1X 12V, 75 AH Tubular Plate Lead Acid or VRLA GEL Type

Other components: control electronics, module mounting hardware, battery box, inter-connecting wires/cables, switches, etc. Operation, instruction and maintenance manual.

MODEL - 4 (4 lights)

Component Specifications

PV Module(s) 2X 37 W or 1 X 74 W under STC

Lamps 4 X CFLs (9W/11W)

Battery 1X 12V, 75 AH Tubular Plate Lead Acid or VRLA Gel Type

Other components: control electronics, module mounting hardware, battery box, inter-connecting wires/cables, switches, etc. Operation, instruction and maintenance manual.

Notes:

i) All models will have a socket to provide power for a 12V DC TV set which can be purchased separately.

ii) A small white LED may be provided as an optional feature, with an independent switch.

Q3. What is a solar Street Lighting System? Name its various parts.

Ans: A stand alone solar photovoltaic street lighting system comprises a compact fluorescent lamp, lead acid battery, PV module(s), control electronics, inter-connecting wires/cables, module mounting hardware, battery box, Operation, instruction and maintenance manual. The main parts of a solar streetlight are:

I. Lamp
II. Battery
II. Electronics
III. PV Module (S)

Q4. What provisions should be done for electronic protection of a typical street lighting system?

Ans:

(i) Adequate protection is to be incorporated under no load conditions, e.g. when the lamps are removed and the system is switched ON.
(ii) The system should have protection against battery overcharge and deep discharge conditions.
(iii) Fuses should be provided to protect against short circuit conditions.
(iv) A blocking diode, should be provided as part of the electronics, to prevent reverse flow of current through the PV module(s), in case such a diode is not provided with the PV module(s).
(v) Full protection against open circuit, accidental short circuit and reverse polarity should be provided.
(vi) Electronics should operate at 12 V and should have temperature compensation for proper charging of the battery through out the year

Q5. What is a LED?

Ans: Light Emitting Diode (LED) is a device, which emits light when an electric current passes through it. A LED based solar home lighting system aims at providing solar electricity for operating LED lights and/or other small DC loads for specified hours of operation per day.

Q6. Give different types of LED based Solar Home Lighting System.

Ans: Following are the different types of Solar Home Lighting System:

Model I

PV Module: 8 Wp under STC, measured at 16.4 V as Vload

Module Voc minimum of 21 V

Battery Sealed maintenance free, 12 V- 7 AH @ C/20, Max DoD 75%

Model II

PV Module 12 Wp under STC, measured at 16.4 V as Vload

Module Voc minimum of 21 V

Battery: Lead acid flooded or VRLA, 12 V- 20 AH @ C/10, Max DoD 75%

Q7. What are the different parts in a Typical Home Lighting system?

Ans: The parts of a typical home lighting system are:

I. Lamps

(i) The lamps will be of compact fluorescent (CFL) type, 4 - Pin type, with ratings of 9W or 11W with a suitable pre-heating circuit.

(ii) The light output from the lamps should be around 550 +/- 5 % lumens (for 9 W CFL) and 850 +/- 5 % lumens (for 11 W CFL). Also please see (iii) of VI given below.

(iii) The lamps should be housed in an assembly suitable for indoor use, with a reflector on its back. While fixing the assembly, the lamp should be held in a base up configuration.

II. Battery

(i) The battery will be of flooded electrolyte, positive tubular plate type, low maintenance lead acid or gel type VRLA.

(ii) The battery will have a minimum rating of 12V, 20 or 40 or 75 Ah (at C/10) discharge rate depending on Model.

(iii) 75 % of the rated capacity of the battery should be between fully charged & load cut off conditions.

III. Electronics

(i) The inverter should be of quasi sine wave/sine wave type, with frequency in the range of 20 - 30 KHz. Half-wave operation is not acceptable.

(ii) The total electronic efficiency should be not less than 80 %.

(iii) No blackening or reduction in the lumen output by more than 10% should be observed after 1000 ON/OFF cycles (two minutes ON followed by four minutes OFF is one cycle).

(iv) The idle current consumption should not be more than 10 mA

IV. PV Module (S)

(a) The PV module (s) shall contain mono/multi crystalline silicon solar cells. It is preferable to have certificate for the supplied PV module as per IEC 61215(revised) specifications or equivalent National or International Standards. In case if the supplied PV module is not a regular PV module of the manufacturer and does not have certificate as per IEC 61215(revised) specifications ,then the manufacturer should have the required certification for at least one of their regular modules. Further, the manufacturer should certify that the supplied module is also manufactured using same material design and process similar to that of certified PV module.

(b) The power output of the module(s) under STC should be a minimum of 18 W or 37 W or 74 W. In case of Model 4 & 5 either two modules of 37 W each or one module of 74 W should be used.

(c) The operating voltage corresponding to the power output mentioned above should be 16.4 V.

(d) The open circuit voltage of the PV modules under STC should be at least 21.0 Volts.

(e) The terminal box on the module should have a provision for opening for replacing the cable, if required.

(f) A strip containing the following details should be laminated inside the module so as to be clearly visible from the front side:

g) Name of the Manufacturer or distinctive Logo

h) Model or Type No.

i) Serial No.

j) Year of make

V. DC Fan

The wattage of the fan should not be more than 20 Watts and it should operate at 12V DC.

Q8. Give brief information about solar lanterns.

Ans: Light Emitting Diode (LED) is a device which emits light when an electric current passes through it. A Solar lantern) is a lighting system consisting of a lamp, battery and electronics, all placed in a suitable housing, made of metal, plastic or fiber glass, and a PV module. The battery is charged by electricity generated through the PV module. The lantern is basically a portable lighting device suitable for either indoor or outdoor lighting, covering a full range of 360 degrees. A LED based solar lantern system aims at providing solar electricity for operating LED lights for specified hours of operation per day.

The broad performance specifications of a white Light Emitting Diode (LED) light source based solar lantern system are given below.

Q9. Give and describe different parts of a typical Solar Lantern.

Ans:

Light Source

The light source will be of white LED type. Single lamp or multiple lamps can be used. Wider view angles preferred. The luminous performance of LEDs used should not be less than 55 lumen/watt. White colour, higher light output will be preferred. The colour temperature of white LEDs used in the system should be in the range of 5500o K – 6500o K. Use of LEDs which emit ultraviolet light is not permitted.

- The light output from the white LED light source should be constant though out the ty cycle.
- The lamps should be housed in an assembly suitable for indoor and outdoor use.
- The make, model number, country of origin and technical characteristics of white LEDs used in the lighting system must be furnished to the test centers and to the buyers. In absence of this data the solar lantern may not be tested by the test center.

Battery

(i) Sealed maintenance free battery. Battery should conform to latest BIS standards or international standards. A copy of the test certificate for the battery (including its make, country of origin and model number) used in the system should be provided to the test center and buyer.

(ii) At least 75 % of the rated capacity of the battery should be between fully charged & load cut off conditions.

Electronics

(i) The total electronic efficiency should be at least 80 %.

(ii) Electronics should operate at 4.5/6/12 V and should have temperature compensation for proper charging of the battery through out the year.

(iv) The light output should remain constant with variations in the battery voltages.

(v) Necessary lengths of wires/cables, switches suitable for DC use and fuses should be provided.

PV Module

- The PV modules based on crystalline silicon solar cells or thin films may be used. In all cases a test report is required from authorized test center.
- The power out put of the PV module must be reported under standard test conditions (STC) at loading voltage. I_V curve of the sample module should be submitted to the test center at the time of system qualification testing.
- The open circuit voltage of the PV modules under STC should be at least ….. Volts.
- The terminal box on the module should have a provision for opening for replacing

the cable, if required.

- A strip containing the following details should be laminated inside the module so as to be clearly visible from the front side:
  - a) Name of the Manufacturer or distinctive Logo
  - b) Model or Type No.
  - c) Serial No.
  - d) Year of make

Q10. What provisions should be given to protect a typical solar Lantern?

Ans: Following provisions should be made:

- Adequate protection is to be incorporated under no load conditions, e.g. when the lamps are removed and the system is switched ON.
- The system should have protection against battery overcharge and deep discharge conditions. The numerical values of the cut off limits must be specified, while submitting the samples for the testing purposes.
- Fuses should be provided to protect against short circuit conditions.
- A blocking diode should be provided as part of the electronics, to prevent reverse flow of current through the PV module(s), in case such a diode is not provided with the PV module.
- Full protection against open circuit, accidental short circuit and reverse polarity should be provided.

Q11. Describe in short LED based solar streetlights.

Ans: Light Emitting Diode (LED) is a device, which emits light when an electric current passes through it. A LED based solar street lighting system aims at providing solar electricity for operating LED lights for specified hours of operation per day.

The broad performance specifications of a White Light Emitting Diode (LED) light source based solar street lighting system are given below.

Q12. What provisions should be given to protect a typical LED based solar streetlights?

Ans: Following provisions should be made:

1. The system should have protection against battery overcharge and deep discharge conditions. The numerical values of the cut off limits must be specified, while submitting the samples for the testing purposes.
2. Fuses should be provided to protect against short circuit conditions.
3. A blocking diode should be provided as part of the electronics, to prevent reverse flow of current through the PV module(s), in case such a diode is not provided with the PV module.
4. Full protection against open circuit, accidental short circuit and reverse polarity should be provided.

Unit 5: Maintenance and Troubleshooting

Q1. Describe in brief how the maintenance of solar electric system should be done.

Ans: A solar electric system that is properly maintained requires very little maintenance. In fact the work involved in maintaining a solar electric system is much less that that required maintaining a diesel or petrol powered generator. The best maintenance practice is tomake regular inspections of the equipment (especially the batteries and modules), to make sure that things are kept clean and all electrical contacts are tight. Following points should be remembered

Battery maintenance

- Cleaning (once a month)
- Checking and Topping up Electrolyte level (monthly)
- Checking the state of Charge
- Equalizing Charge

Q2. Write a note on Troubleshooting.

Ans: Troubleshooting means facing problems as they occur. Although if the equipment is properly installed, systems are unlikely to fail, some problems that need attending to may arise. Following table gives the problems and troubleshooting.

Lamps or appliances do not work One or more lamp or appliance fails to come On when connected	Lamps Switch is off Bad tube or globe Bad ballast inverter Bad connection in wire Tubes or globes have very short lifetimes Appliances Switch is OFF Bad connection in wire Bad socket Broken appliance	Lamps Turn switch on Replace with new Replace inverter Repair connection Check if system voltage is too high or low Appliances Turn switch On Repair Replace socket Try appliance where there is good power supply, repair or replace

Blown Fuse When the fuse is removed the wire inside is broken	Short circuit along were in module Fuse too small Lighting/power surge	Repair short circuit Use fuse 20% larger than combined power of load Replace fuse
Battery Charge is low "Battery low" indicator comes on Low voltage disconnect turns off load Battery state of charge is constantly below 1.5 V	There is no solar charge Battery acid I low Bad connection to control terminal Defective battery or cell Loose or corroded battery terminal Dusty modules Blown fuse Overuse of system Battery will not accept charge Voltage drop between module and battery high Defective controller	Check and fix connection Add dist water to cells Check for broken wire or loose contact Clean and tighten battery terminals Clean Blown fuse section above Leave appliances Off for a week to recharging Find out age and history of battery Check voltage drop replace cable wire if required Check operation of charge controller and repair if required
No Solar Charge Solar charge indicator does not light up during day There is no current from wires to module	Short circuit along wires to module Loose connection in wires connecting battery to terminal Blown fuse Dust or damage to module	Locate and repair short circuits Repair loose connections Blown fuse section above Clean module with water and soft cloth Check PV module is facing south and angle of inclination is equal to latitude. Ensure the module is in shadow free location

Q3. Design A 600Wp.Spv Power Pack:

Ans:

Module Size: 12V- 75Wp SPV

Inverter: 800VA, -2 X 12- 240AH

Battery: 24 V

Distance Between SPV module & Inverter Room: 8mtrs.

Battery/Cable Size: From the chart given.