Solar Engineering Course

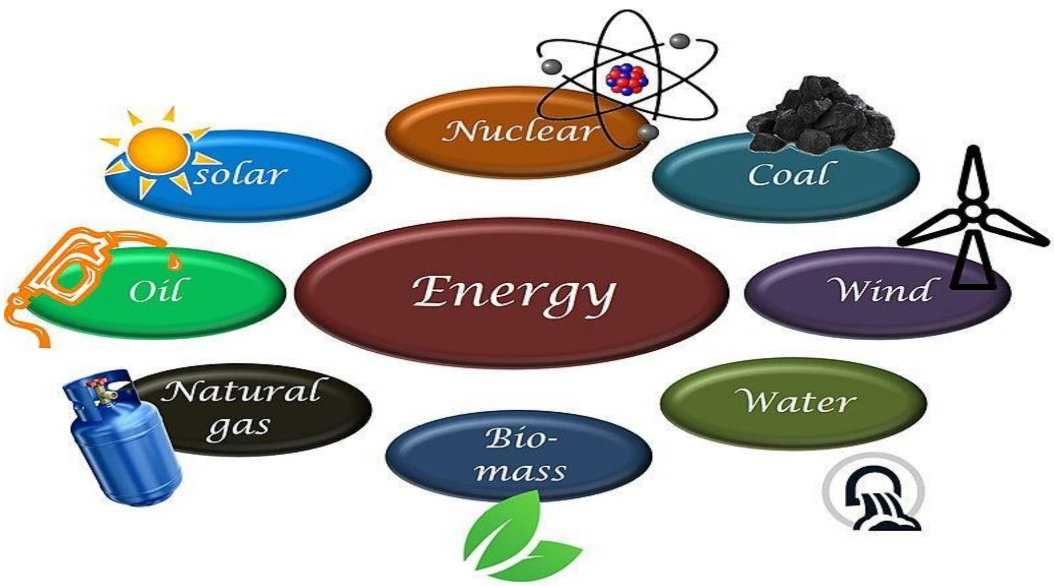
Chapter 1: Energy

1.1 What is energy?

Energy is defined as the ability to do work. Any change caused needs energy, it is transferred from one physical system to another. The different types of energy include **thermal energy, radiant energy, chemical energy, nuclear energy, electrical energy, motion energy, sound energy, elastic energy and gravitational energy**.

1.2 Principle of energy

The principle of energy states that energy can neither be created nor destroyed. It may transform from one type to another.



1.3 Renewable Sources of Energy

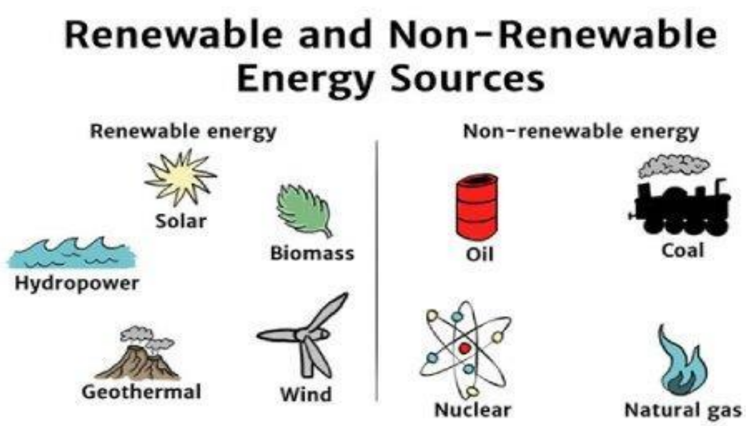
Renewable energy is energy produced from sources that do not deplete or can be replenished. Examples: wind, solar, hydropower, biomass.

1.3.1 Renewable Energy Sources:

- Solar energy from sun
- Geothermal energy from heat inside the earth
- Wind energy
- Biomass from plants.
- Hydropower from flowing water.

1.4 Non-Renewable Sources of Energy

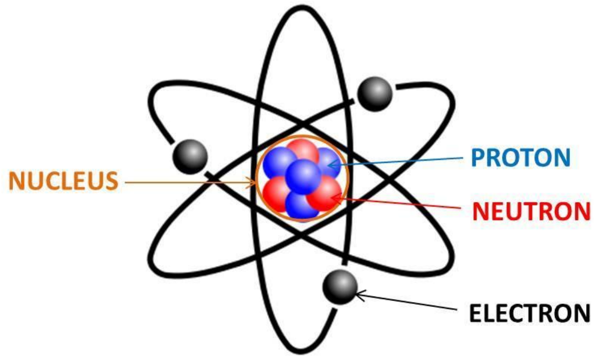
Non-Renewable energy is energy produced from sources that depleteor can run out and can take millions of years to form, so once they are used, they can't be replaced in a lifetime. Example: fossil fuel(coal, petroleum, natural gas),uranium.



1.5 Electrical energy:

Electrical energy is **the power an atom's charged particles have to cause an action or move an object**. The movement of electrons from one atom to another is what results in electrical energy. Every time you plug a toaster or mobile charger into a wall outlet, electrical energy is powering those devices.

1.5.1 Atoms- Atoms are the smallest particles of any matter which we cannot see from human eyes. Everything is made up of atoms.



There are two Subatomic particles 1. Nucleus which is located in the center of an atom like the sun in a solar planet and in the nucleus, we have **protons(p+)** and **neutrons(n)**. 2. **Electrons (e-)** which move in orbits similar to planets revolve around the sun.

Protons are positively charged, electrons are negatively charged and neutrons are neutral; it means they do not have any charge.

Chapter 2: Electricity

2.1 What is Electricity?

What makes the lights in your room turn on? Why does the flashlight come on when you press that switch button? They happen because there is energy flow in the form of electrical energy.

Electricity is the **flow of electrical power or charge**. It is a secondary source of energy that we get from the conversion of other sources of energy, like coal, natural gas, oil, nuclear power and other natural sources, which are called primary sources.

2.2 Voltage, Current, Resistor

2.2.1 Voltage - Voltage is the pressure or force that pushes charged electrons through a conducting loop, enabling them to do work such as illuminating a light. In brief, voltage = pressure, and it is measured in volts (V).

2.2.2 Current - An electric current is a stream of charged particles, such as electrons or ions, moving through an electrical conductor or space. It is measured as the net rate of flow of electric charge.

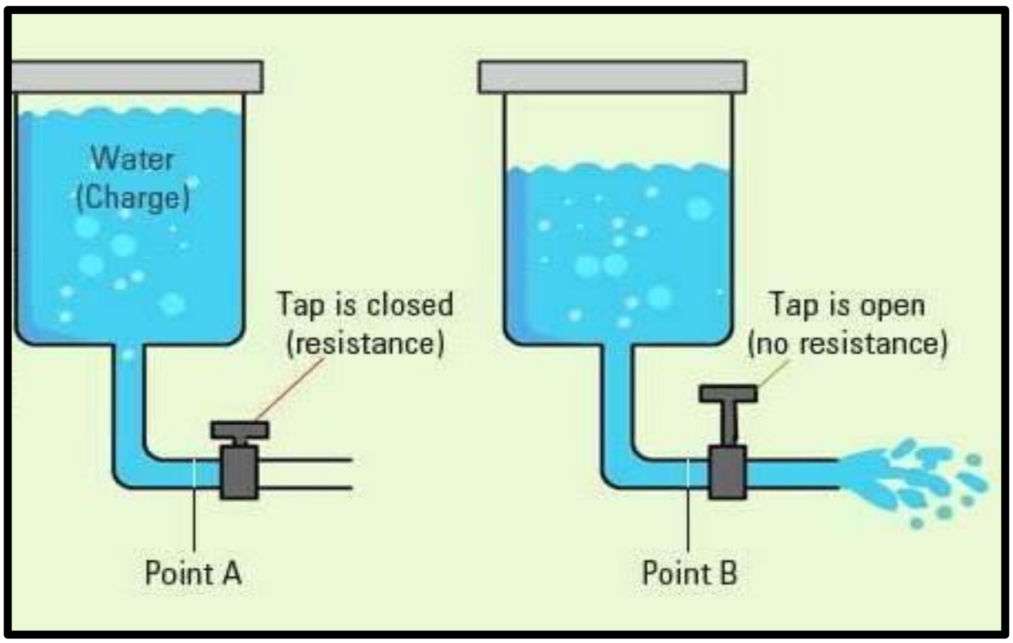
Let’s understand voltage and current concept in a simple way

Water = Charge
Pressure = Voltage
Flow = Current

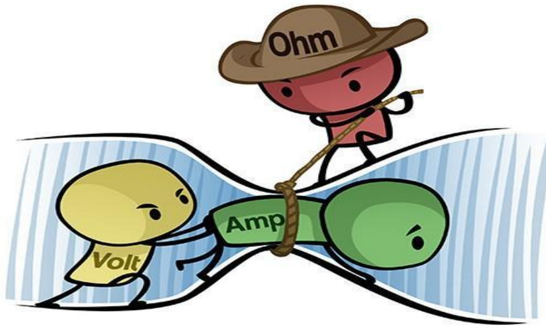
The water in the tank represents electric charge. More is the water in the tank, more is the charge. Voltage is like pressure. More the water, higher the pressure (voltage) at the end of the pipe.
In the diagram above, there is voltage at point A, but no current, because the tap is closed and the water is NOT flowing. This means there can be voltage without current, but no current without voltage.

At point B, the tap is opened and water flows. At this point, there is both voltage and current because there is a flow.

If we open the tap to drain some water out, the pressure will reduce (lower voltage).



2.2.3 Resistance - A resistor is an electrical component that limits or regulates the flow of electrical current in an electronic circuit. Unit of resistor is ohm (symbol of ohm is Ω). Symbol for resistor is R.



2.3 Ohm's law:

This law states that electric current is proportional to voltage and inversely proportional to resistance.

Ohm's law can be mathematically expressed as:

$$R = V / I$$

V= Voltage

I = Current

R= Resistance

Ohm's law is used to calculate the relationship between voltage, resistance and current in an electrical circuit.

2.4 Electric power:

Electric power is the rate at which work is done or energy is transformed into an electric circuit. Simply put, it is a measure of how much energy is used in a span of time. The SI Unit of power is watt, joule per second. The formula for electric power is given by

$$P = V I$$

2.5 AC (Alternating Current)

Alternating current (AC) is defined as a flow of charge that exhibits a periodic change in direction. It is the form in which electric power is delivered to businesses and residences, and it is the form of electrical energy that consumers typically use when they plug kitchen appliances, televisions, fans and electric lamps into a wall socket.

2.6 DC (Direct Current)

Direct current (DC) is electrical current which flows consistently in one direction. The current that flows in a flashlight or another appliance running on batteries is direct current.

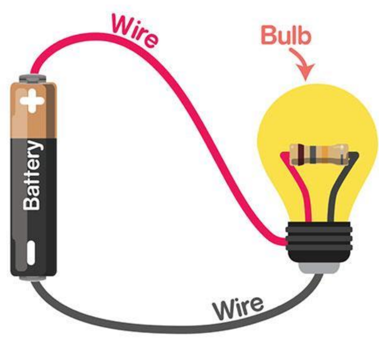
2.7 Relationship between the parameters

Parameter	Measuring Unit	Relationship
Voltage	volt (V or E)	$E = I \times R$
Current	amp (I)	$I = \frac{E}{R}$
Resistance	ohm (R or Ω)	$R = \frac{E}{I}$
Conductance	mho (G or ℧)	$G = \frac{I}{R} = \frac{I}{E}$
Power	watt (W)	$P = I \times E$ or $P = I^2R$
Inductance	henry (L or H)	$V_L = -L\left(\frac{\Delta I}{\Delta t}\right)$
Capacitance	farad (C)	$C = \frac{Q}{E}$ (Q = charge)

Chapter 3: Circuits and Components

3.1 What is circuit?

Circuit is a closed path through which electrons flow in electronic components. An electronic circuit is composed of individual electronic components, such as resistors, transistors, capacitors, inductors and diodes, connected by conductive wires or traces through which electric current can flow.



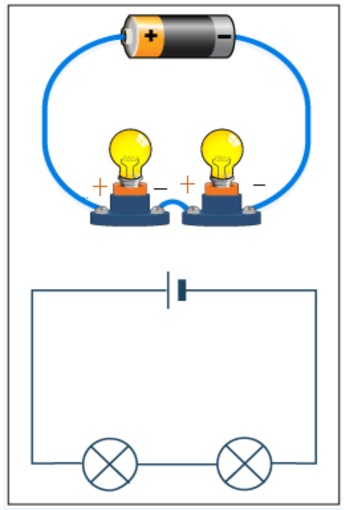
Circuit will include three main parts:

1. A source of energy
2. A closed path
3. A Load (device that uses energy)

There are two types of connection series and parallel connection

3.2 Series Circuit:

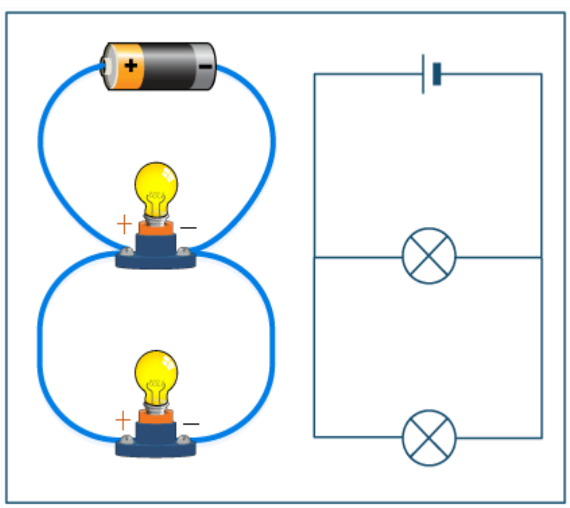
A circuit is said to be a series circuit when the flow of current is the same throughout all the components in the circuit. In series circuits, the current has only a single path. The current through each series element is the same and equal to the source current (Is). In contrast, the voltage across each series element varies.



In a Series circuit, if a fault occurs at one point, the total circuit will break and all the components are arranged in a single line.

3.3 Parallel Circuit:

A parallel circuit refers to a circuit with two or more two paths for the current to flow. In a parallel circuit, all the components have the same voltage. In a parallel circuit, the voltage across each element is the same and equal to the source voltage (Vs), and the current through each element varies.



In a parallel circuit, if any one component gets damaged, the current does not stop and continues to flow through the other components; hence other components work efficiently and all the components are arranged parallel to each other.

3.4 Battery

3.4.1 What is a battery?

A battery is a device that converts chemical energy to electrical energy. A battery's chemical reactions involve the flow of electrons from one material (electrode) to another via an external circuit.

3.4.2 Types of battery:

- Nickel Cadmium Battery
- Lithium-Ion Battery
- Lead Acid Battery
- Metal Hydride Battery
- Rechargeable NiMH Batteries

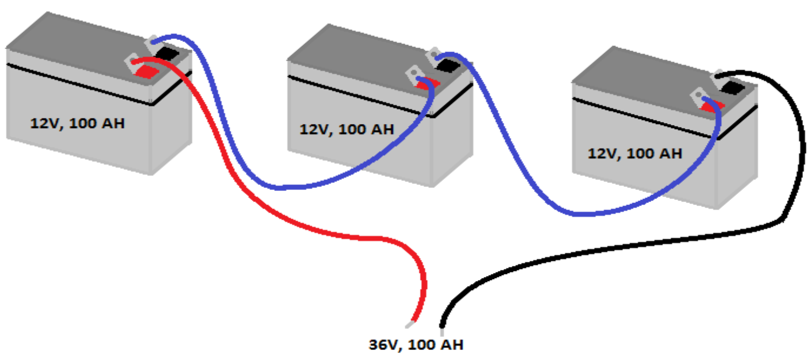
3.4.3 Battery parameters:

- Energy Density
- Specific power
- Cell voltage

- Charge and discharge current
- State of charge
- Depth of charge
- Self-discharge

3.4.4 Series connection of batteries:

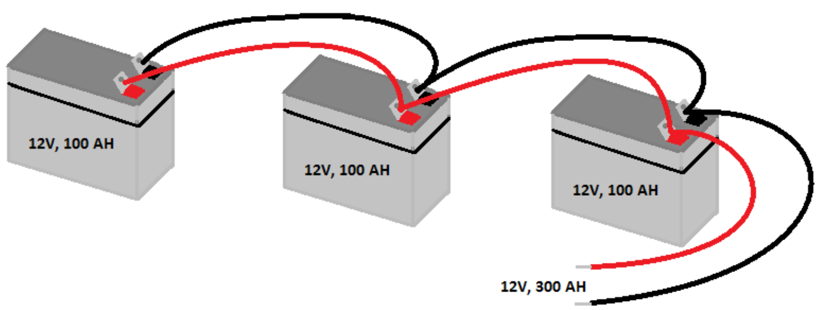
Connecting a battery in series is when you connect two or more batteries together to increase the battery systems overall voltage, connecting batteries in series does not increase the capacity only the voltage.



Battery Connection in Series

3.4.5 Parallel connection of batteries:

Parallel connections involve connecting 2 or more batteries together to increase the amp-hour capacity of the battery bank, but your voltage stays the same.



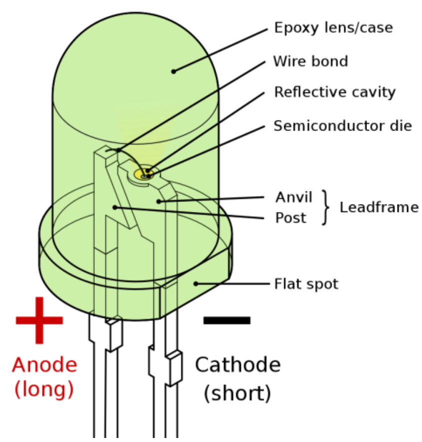
Battery Connection in Parallel

3.5 LED(light emitting diode):

A light-emitting diode (LED) is a semiconductor device that emits light when an electric current is passed through it.

3.5.1 How does LED work?

LED stands for light emitting diode. LED lighting products produce light up to 90% more efficiently than incandescent light bulbs. An electrical current pass through a microchip, which illuminates the tiny light sources we call LEDs and the result is visible light.

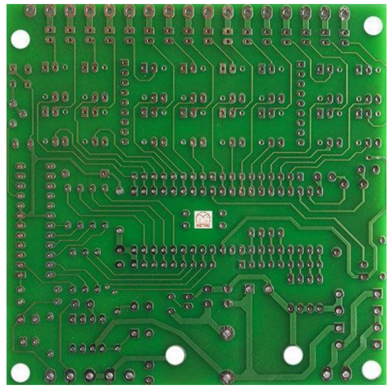


3.5.2 How does LED get its color?

LEDs produce different colors by using various materials which produce photons at different wavelengths. Those individual wavelengths appear as light of different colors. LEDs use materials that can handle the necessary levels of electricity, heat, and humidity.

3.6 PCB (Printed circuit board)

A printed circuit board or PCB, is a non-conductive material with conductive lines printed or etched. Electronic components are mounted on the board and the traces connect the components together to form a working circuit or assembly.



3.7 Multimeter

An instrument for measuring the properties of an electrical circuit (such as resistance, voltage, or current). A multimeter is an electrical tool used to measure electricity.

Chapter 4: Basic Mathematics and Unit Conversion

4.1 Unit Conversion

A unit conversion expresses the same property as a different unit of measurement. For instance, time can be expressed in minutes instead of hours, while distance can be converted from miles to kilometers, or feet, or any other measure of length.

4.2 Electricity bill calculation

Electricity consumption is calculated in kWh (killo-Watt-hour).

4.2.1 What is a kW and a kWh?

A “watt” is the unit used to measure quantities of power and is named after the Scottish inventor and engineer James Watt (1736-1819). A kilowatt, or kW, is equal to a thousand watts. So, the number of kW is the amount of power an electrical device uses in order to run, and a kilowatt-hour (kWh) is the amount of energy that an appliance uses every hour. For example, if your electric radiator is rated at 3 kW and is left on for an hour, it would use 3 kWh of electricity.

More importantly, a kWh is the unit that electricity suppliers use to bill you for the electricity you use. They do this by either reading your usage for you, or by having you send them the reading from your meter. Usually, you are given a unit charge for your electricity; this multiplied by the number of kWh you use gives you the cost of the electricity on your bill.

4.2.2 How do you calculate the number of kWh used per day?

If you want to know how many kWh you use daily, simply divide your total kWh number by the number of days covered by the bill. In reality, you are not going to use exactly the same amount of electricity every day. This change depending upon how long you spend at home, what you do while you are there, the time of year, and the temperature.

You can even work out the number of kWh used by each appliance per day based on how long each is on for. If you use a 3 kWh heater example, it will use 15 kWh of electricity if you have it on for 5 hours.

4.2.3 How do you calculate the number of kWh from watts?

If you want to know how many kWh an appliance uses, and already know how many watts it uses, the calculation is pretty straightforward.

First, you need to convert the number of watts into kW. To do that, you divide the number of watts by 1,000. So 100 W is 0.1 kW, 60 W is 0.06 kW, and 1500 W is 1.5 kW.

To get the number of kWh, you just multiply the number of kW by the number of hours the appliance is used for.

For example, a device rated at 1500 W that's on for 2.5 hours:

1500 ÷ 1000 = 1.5. That's 1.5 kW. 1.5 x 2.5 = 3.75. So, a 1500 W appliance that's on for 2.5 hours uses 3.75 kWh.

4.2.4 How do I calculate kW to kWh?

Calculating kWh from kW is even easier, as you already know the number of kW for the appliance. All you need to do is multiply the kW number by the time in hours. The 3 kW heater, if used for 3.5 hours, would use (3 x 3.5) 10.5 kWh of electricity.

Chapter 5: Solar energy

5.1 What is Solar Energy?

Solar energy is any type of energy that is generated by the sun. The total amount of solar energy received on earth is much more than the world's current and anticipated energy requirements.

Advantages of solar energy:

1. Reduces power bill.
2. Saves water
3. Low maintenance
4. Reduces the use of fossil fuel.
5. Reduces the need to rely on traditional and non-renewable power sources.

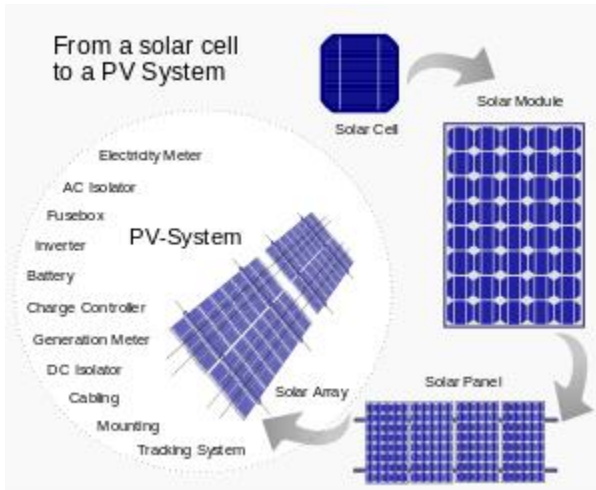
5.2 Solar Panel

A *solar panel is* also known as a *PV panel* or module, is a device that collects sunlight and converts it into electric current.

Solar panels are made of several layers of material. The top layer of glass protects the individual smaller units called solar cells. Solar cells have two layers of semiconductor silicon. Silicon gathers electrons and allows them to move around through a positive and negative charge. Each solar cell is interconnected to form the solar panel.

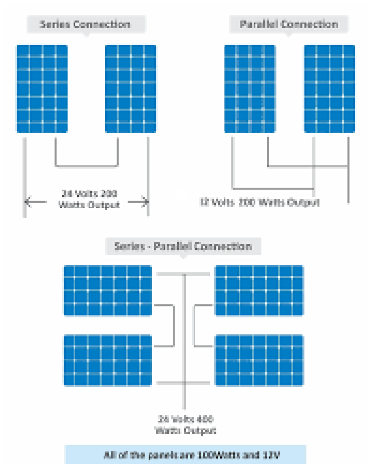
5.3 How do solar panels convert sunlight into electricity?

Solar panels use the photons produced by sunlight to generate direct current (DC) electricity. When the photons hit the panel they are absorbed by the panel's semiconducting silicon material. During this process electrons separate from the atoms and move around the solar cell. This movement of the electrons is what generates Direct Current (DC) electricity. The DC electricity then flows to the system's inverter where it's converted to alternating current (AC) electricity. AC is the type of electricity needed to supply the property with power.



5.4 Series and Parallel Connection of Solar Cells

In a series circuit, all components are connected end-to-end, forming a single path for current flow. In a parallel circuit, all components are connected across each other, forming exactly two sets of electrically common points.



Solar panels are wired in series to increase the voltage in order to meet the minimum operating requirements of the inverter. If solar modules are wired in parallel, the positive terminal of one module is connected to the positive terminal of another module, which increases the amperage of the system.

5.5 Benefits of using Solar Panel

- Reduces Air Pollution. Fossil fuels create a lot of pollutants.
- Reduce Water Usage.
- Reduces Dependence on Nonrenewable Energy Sources.
- Improves Humanity's Health In The Long-run.
- Helps Fight Climate Change.

5.6 Testing using a multimeter.

5.6.1 Specifications

Voltage DC	**Accuracy**	**±(0.09% + 2)**
Voltage AC	Max. resolution	0.1 mV
	Maximum	1000 V

5.6.2 Testing of battery

In pre-employment testing, a test battery refers to a set of tests grouped together and administered to applicants for a particular position. Test batteries vary from position to position depending on the job's requirements and the needs of the employer.

5.6.3 Testing of solar panel

Keeping the multimeter pins in the same position, turn the regulator towards ’DCV’ at mode 20, the probes are connected to the pin of the solar panel. Keeps the solar panel facing direct sunlight. The multimeter should show a voltage of around 5.5 V when there is good sunlight. If the multimeter reading is very low, then the panel is faulty.

5.6.4 Testing of LED

1. Connect the black lead to the COM terminal on the multimeter.
2. Connect the red lead to the Ω terminal, unless your particular model differs.
3. Turn the dial to the diode symbol on the multimeter. This allows for the electric current to travel in one direction and not the other.
4. Turn the multimeter on. The display window should indicate either 0L or OPEN.
5. Choose a regular RED light.
6. Connect the black probe to the cathode end of the led, which is usually the shorter end or cut flat at its bottom. Cut the red probe to the anode end of the led.

5.6.5 Testing of wire

1. If the display screen reads voltage between 110 and 120 volts, the fixture is live.
2. If the display screen reads zero, then there is no voltage in the wire. In other words, there is no current flowing through the wire.

5.6.6 Testing of PCB

To test circuit board properly, touch the multimeter probes to the test points present on the board. Make sure while playing out this step you have your hands on the plastic portion of the probes. You can then go on to check either the voltage or resistance.

5.7 Soldering

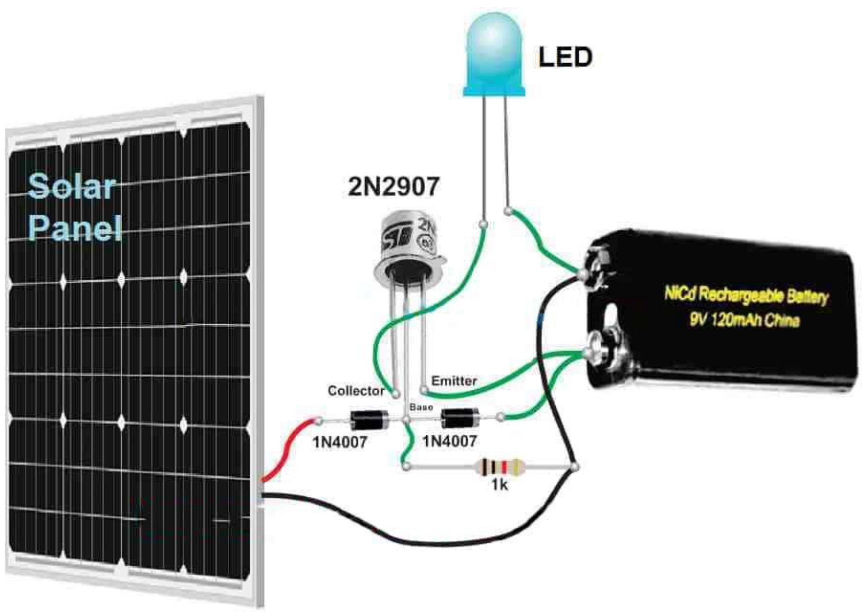
Soldering is a process in which two or more items are joined together by melting and putting a filler metal into the joint, the filler metal having a lower melting point than the adjoining metal. Unlike welding, soldering does not involve melting the work pieces.

Chapter 6: Projects

6.1 Project 1: Solar Light

6.1.1 What is Solar Light?

In scientific terms 'Solar Lights' are portable light fixtures which includes LED lamps, photo-voltaic solar panels and rechargeable batteries. In simple terms solar means the sun and lighting means to provide light. So, solar light is the light which is produced with the help of sun's energy.



6.1.2 Assembly of Solar Light

1. Fix the LED CAP casing to the Gooseneck using Tuff Bond (Glue)
2. Fix the BASE COVER (TOP) casing to the Gooseneck using Tuff Bond
3. Insert the LOAD WIRE (LED Connector) into the gooseneck from the opening inside the Bottom Blue
4. Solder the LED Connector inserted in the gooseneck to the LED PCB at the Top Blue
5. Fix the LED PCB with White Reflector using 2 x 6.5 PH screws

6. Fix the Top lens by attaching the White Reflector & transparent Glass to the Top Blue using 2 x 9.5 PH screw
7. Solder the 2.4V battery with Driver PCB
8. Properly align the Driver PCB with the Bottom Blue thereby checking the position of

   a. Switch,

   b. Bi-color LED and

   c. DC Socket
9. Fix the Driver PCB with the Bottom Blue using 2 x 6.5 PH screws
10. Check the Switch mobility by continuously pressing it 10-15 times
11. Connect the LED connector to its socket on the Driver PCB
12. Position the battery on the Bottom Black and align it with the Bottom Blue
13. Fix them using 2 x 13 CSK screws

6.1.3 Final packing and checking

Do the following checks before packaging

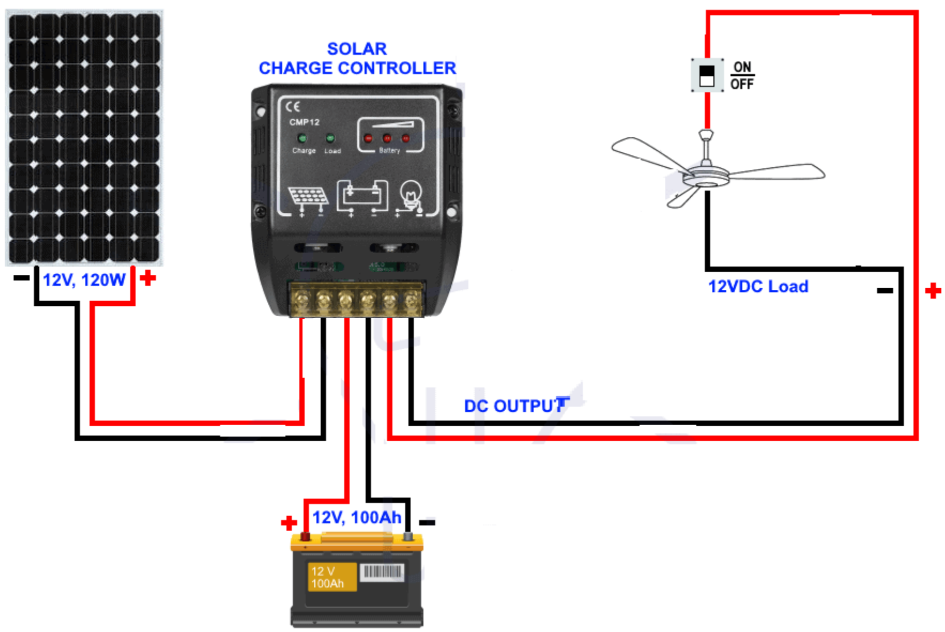
1. Switch **ON/OFF** the lamp multiple times, check if the switch is working properly or not.
2. Load LED is glowing in Low mode/High mode.
3. Check gooseneck joints with the LED cap and Base bottom is proper or not.
4. Attached solar panel and check for LED indicator, it is showing **RED color** or not. (for charging status) .
5. Check for screws, are the SoUL parts got properly fixed or not.

6.2 Project 2: Solar Fan

6.2.1 What is a Solar Fan?

Solar's fans run on solar energy instead of electricity. Similarly, to how solar lights works, a small solar fan is powered by a solar panel that is either mounted on the device or wired to a separate installation. Solar powered fans for homes do not usually require secondary power sources as long there is enough sunlight.

6.2.2 Assembly of a Solar Fan



Solar fan is can be easily bought from the market, it is a DC fan which can be used on the Solar energy. When Light Falls on the PV modules generate electricity (DC Current), Which can be directly used to run DC fan.

The Connection of the PV Module with the DC fan Can be done with the help of connecting wire and tape/Soldering through soldering iron.

This type fan can be used directly on solar PV modules as well, it can be used with the battery. Day time these systems are operated on the solar PV based energy and in night time it is operated on the battery charged through the solar energy.

6.2.3 Final packing and checking

Solar powered fan is assembled or connected with the solar PV modules of appropriate rating or connected through the battery. The user must ensure that the connection of the solar fan to PV module/battery is tighten properly or if soldered then it should be properly soldered.

Do the checks before packaging

6.3 Project 3: Solar Buddy

6.3.1 What is a Solar Buddy?

Solar Buddy is a combination of solar devices based on the major user requirements. The solar buddy is developed on the concept of the buddy/friend which helps in the rural and non-grid connected farmers/villagers.

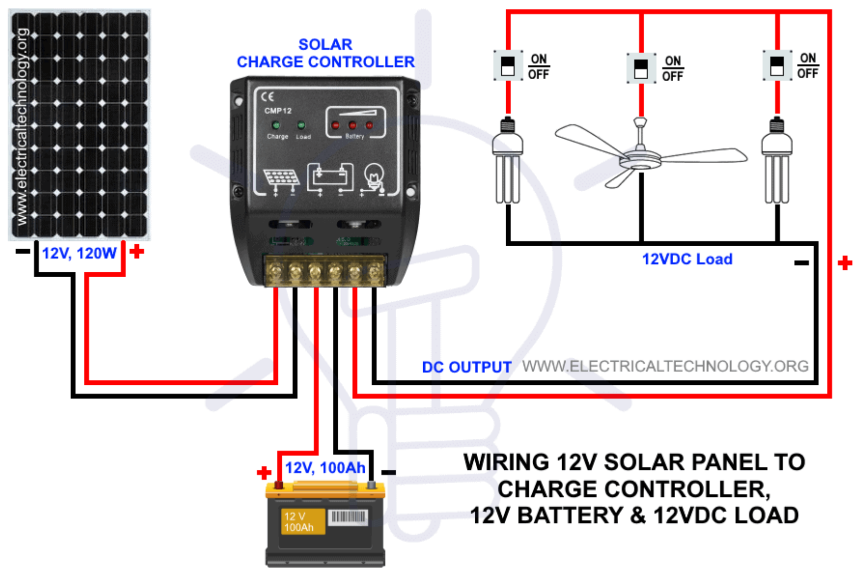
Solar buddy mainly containing solar PV module, Battery, Solar lamp (LED) for lightening and Solar powered fan. This system serves the necessary needs of lightening and cooling/ ventilation system which can be operated day/bight time as well. The system's battery gets charged during the day and can be used in the night as well.

6.3.2 Assembly of a Solar Buddy

The Solar buddy is assembled/ connected as per the circuit diagram described below.

The Solar PV plate of 12v, 120 Watt is connected to the solar charge controller and the battery. The load devices viz. LED lights and DC fan etc. are connected in parallel at the solar charge controller.

The solar charge controller takes care of the charging and discharging of the connected battery, when the generated solar current is below the required level it provide the current from the battery, and when the load is not connected to the solar charge controller, it charges the battery.



6.3.3 Final packing and checking

The connection of the wires should be tight and electric saftety tape should be wound properly. No connection should be left open.

Do the checks before packaging

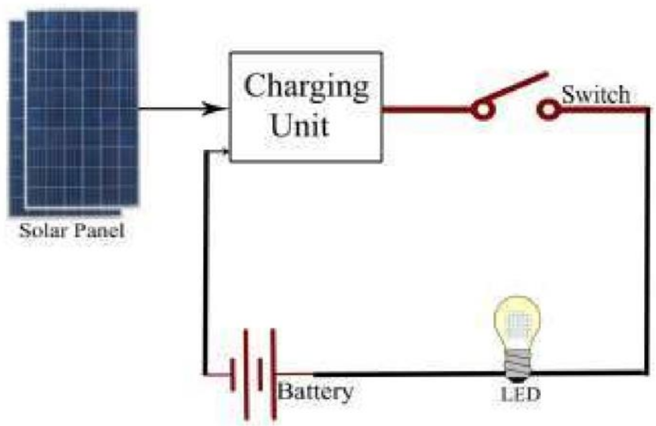
6.4 Project 4: Solar Insect Catcher

6.4.1 What is a Solar Insect Catcher?

Solar insect trap is a device for pest control. The device gets charged in day time using sunlight and automatically switches on at dawn and dusk to trap harmful insects. This type of insect catching devices are place in the agriculture crop fields. This device contains a solar PV system and a battery and a UV LED Lamp along with a plastic tub. The solar PV panel is used for charging the battery in the day time and in night the battery is used to glow the UV LED lamp, which radiates the short waves and attract the insects towards it. When insects come to the UV LED lamp, just below this lamp a plastic tub is filled with water and some oil/ shampoo is mixed into it. The insects fall in the water tub and will get trapped in it due to oil in the water.

6.4.2 Assembly of a Solar Insect Catcher

The electric circuit of the Solar Insect Catcher is as follows



The rest if the assembly looks as below figure

6.4.3 Final packing and checking

Do the checks before packaging

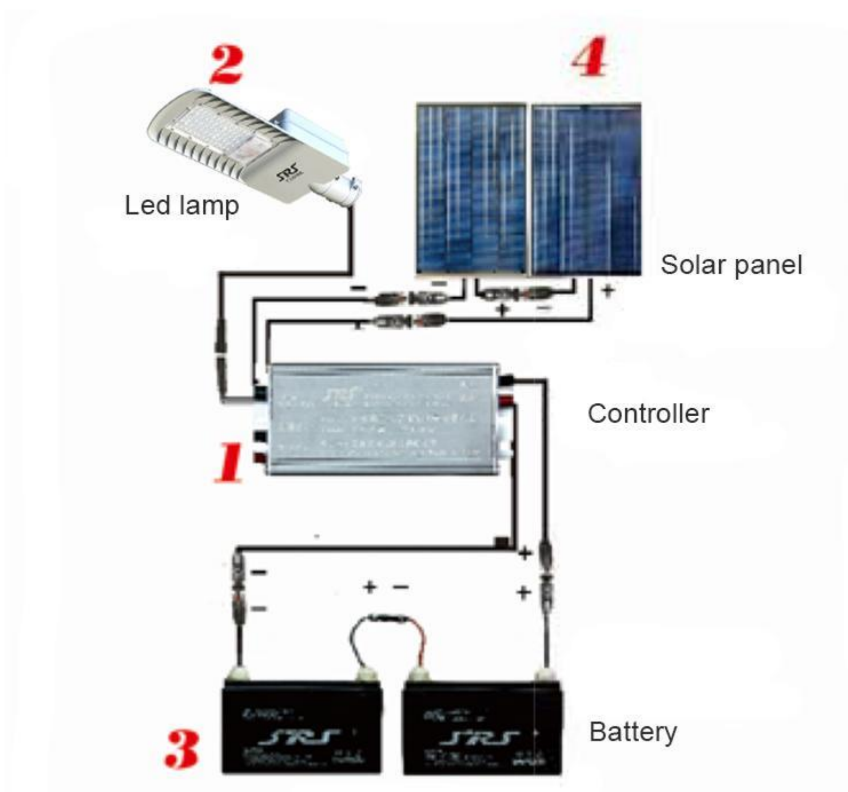
6.5 Project 5: Solar Street Light

6.5.1 What is a Solar Street Light?

A standalone solar photovoltaic street lighting system is an outdoor lighting unit used for illuminating a street or an open area. Recent advances in LED lighting have brought very promising opportunities for application in street lighting. Combining LED's low power, high illumination characteristics with current photovoltaic (PV) technology, PV powered street light utilizing LED has been used in many places.

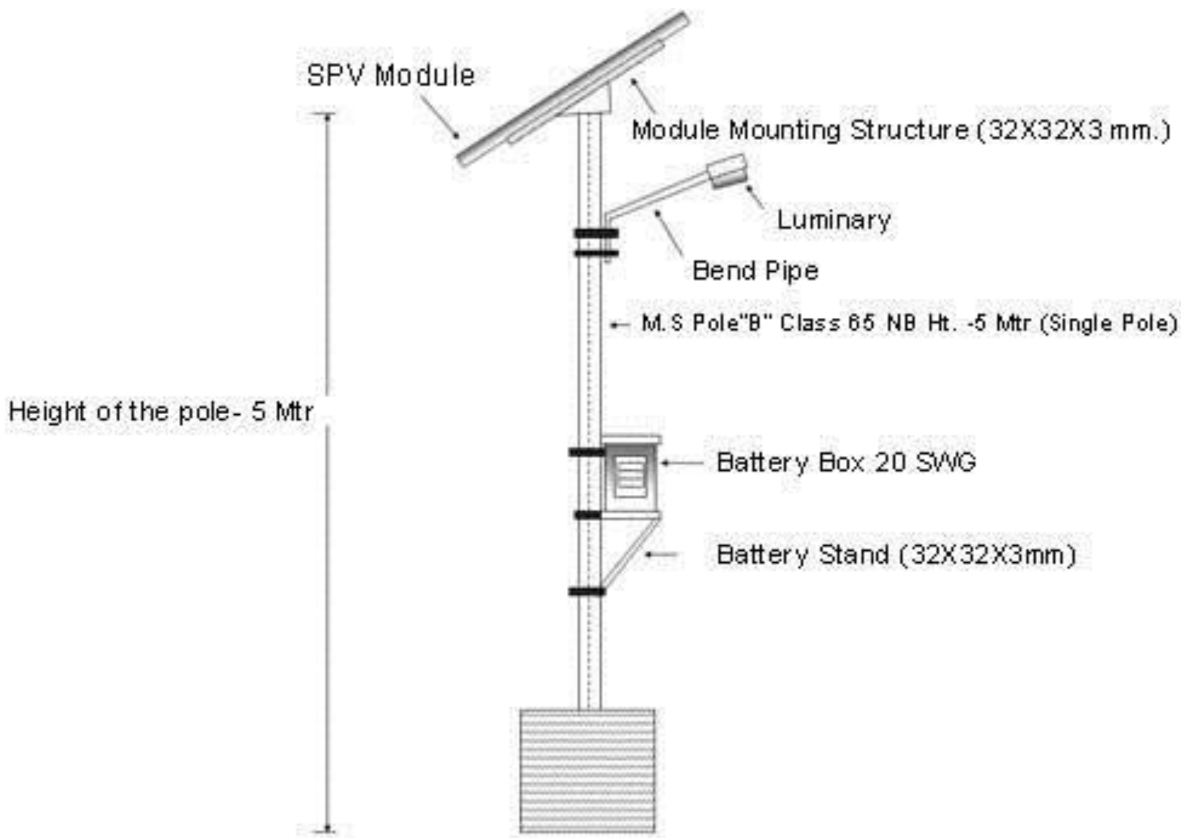
6.5.2 Assembly of a Street Light

Electric connection of the solar street light is as follows



The physically fitting of the electric circuit on the electric pole is as presented below figure of the solar street light. the complete setup is mounted on the pole of the specified height and the upper part containing the solar PV panel, below this the LED light of high lumines is installed and at the lower end a box is mounted. This box contains the solar charge controller and the battery.

The battery gets charged in the day time when solar radiation is available through the solar PV panel and in the discharge circuit, the switching is performed with the help of LDR, which makes LED/ Street light on during night and cutoff in the morning.



6.5.3 Final packing and checking

Do the checks before packaging