Solar PV System Installation and Maintenance

Level-II

Learning Guide -10

Unit of Competence	**Apply Principles of Photovoltaic system Operation**
Module Title	**Applying Principles of Photovoltaic system Operation**
LG Code	**EIS PIM2 M04 LO1 LG-10**
TTLM Code	**EIS PIM2TTLM 0819v1**

LO1:-Identify Renewable Energy Sources

Instruction Sheet	Learning Guide:-04

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics

- Basic electricity and electronics
- Identifying and describing types of renewable energy
- Basic working principles of renewable energy
- Applications of renewable energy
- Advantage and disadvantages of renewable energy sources
- Renewable energy plants

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to:-**

- Identify and describe types of renewable energy
- Identify basic working principles of renewable energy
- Identify the applications of renewable energy sources
- Identify advantage and disadvantages of renewable energy sources
- Identify components of renewable energy plants

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3, Sheet 4, Sheet 5 and Sheet 6 in pages3, 22, 27, 31 and 38 respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3, Self-check 4 Self-check 5 and Self-check 6 in pages 20, 26, 30, 37, 39 and 46 respectively
5. If you earned a satisfactory evaluation from the "Self-check" proceed to Operation Sheet 1in page 47.
6. Do the "LAP test" in page 48.

Information Sheet-1	Basic Electricity and Electronics

1.1. Introduction

Electricity is an apparent force in nature that exists whenever there is a net electrical charge between any two objects, and is put to use in industrial applications such as: electronics and electric power.

- **Electricity:**
  - ✓ **Dynamic** electricity is the flow of an electric charge through a conduction point. Dynamic electricity is often referred to as electric current. The biggest difference between dynamic electricity and static electricity is the movement of charges or currents.

- **Atom: - is the smallest particle of matter.**
  - It is made up of three parts known as:
  - ✓ Protons–positively charged particles
  - ✓ Neutrons–particles with no charge
  - ✓ Electrons–negatively charged particles

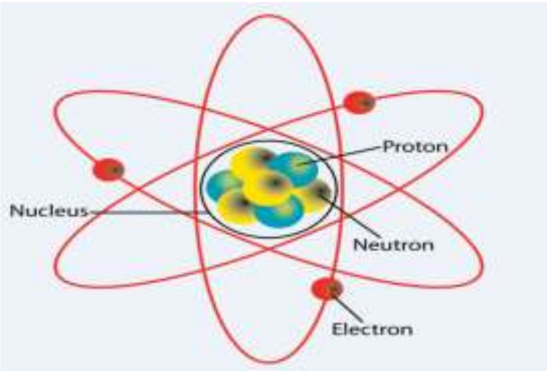

Figure 1:-Atom floating in an electric field

- **Conductors**
  - ✓ Allow the flow of electricity
  - ✓ Contain atoms with free electrons one to three electrons in the outer orbit
  - ✓ Free electrons are not locked in orbit around the nucleus
  - ✓ electrons can be forced to move from one atom to another
  - ✓ Copper, gold, and silver are good conductors

- **Insulators**
  - ✓ Resist the flow of electricity
  - ✓ Contain atoms with bound electrons five to eight electrons in the outer orbit
  - ✓ Bound electrons will not leave their orbit around the nucleus
  - ✓ Plastic, rubber, and ceramics are good insulators

- Three terms are used in the study of electricity:
  - ✓ Current
  - ✓ Voltage
  - ✓ Resistance

- **Current (I)**

  Current is a measure of the rate of electron flow through a material. Electrical current is measured in units of amperes or "Amps" or "A" for short. This flow of electrical current develops when electrons are forced from one atom to another. One amp is defined as 6.28×10^{18} electrons per second. When current flows in a conductor, heat is produced. This happens because every conductor offers some resistance to current flowing. That is why the amperage flow in a circuit is important, since the more amps flowing, the more heat is produced. Most people notice this heating effect when the cord of any appliance or electrical device heats up after the device has been running for an extended period. Recognizing this heat production is important in specifying wire sizes. When a wire carries more amps than it can handle without overheating, we say it is "overloaded". Overloaded wires can melt the insulation and create shocks or even fires(Source: REEPRO Level 1, 2009)

- Two theories are used to describe direction of current flow:
  - ✓ **Conventional current theory**:-states that current flows from positive to negative
  - ✓ **Electron theory**:-states that current flows from negative to positive

- **Voltage**

Voltage is the electrical force that causes free electrons to move from one atom to another. Just as water needs some pressure to force it through a pipe, electrical current needs some force to make it flows. "Volts" is the measure of "electrical pressure" that causes current flow. Voltage is sometimes referred to as the measure of a potential difference between two points along a conductor. Sometimes the symbol E is used for EMF (Electro motive force). (Source: REEPRO Level 1, 2009)

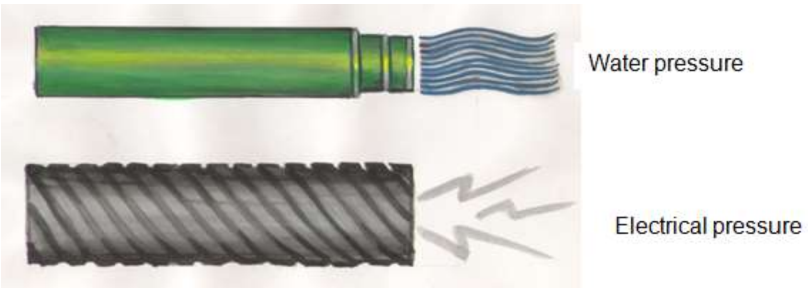

Figure 2: **Similarity of water pressure and Voltage**

- **Resistance**

Resistance is the opposition to current flow. Every medium has some resistance and the resistance of an object is determined by the nature of the substance, of which it is composed; the dimensions of the object and the temperature. This is known as resistivity. Resistivity is expressed in terms of the ohms resistance per cubic centimetre of the substance at 20° C (68°

F). As we know light bulbs, motors, electric heating elements and relay coils all have resistances even though they are just wires.

The electrical resistance of a material is measured in units called "ohms"(Ω). The lower the resistance of a material, the better the material acts as a conductor. For example, copper has a lower electrical resistance than aluminium, copper is a better conductor. We can use a water piping system as an analogy. The resistance in the water pipe to the flow of water comes mainly from the size of the pipe. Rust and corrosion inside the pipe, objects stuckinside the pipe, and the number of bends and fittings all add up to increase the resistance to theflow of water.
The same is true of current flow in an electric circuit. A number of factors determine the resistanceto current flow such as wire diameter, wire length and any impurities in the wire's makeup. Forexample, smaller wires have more resistance than larger diameter wires and longer wires havemore resistance than shorter wires.

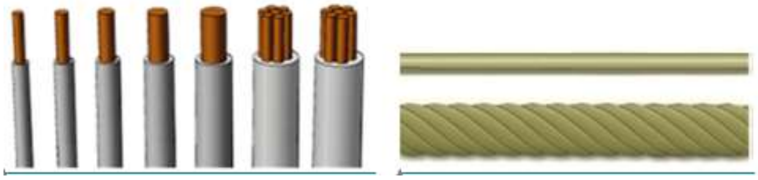

Figure 3: Types of wires/Cable

When electricity flows through any resistance, energy is dissipated in the form of heat. If the heat becomes intense enough, the conductor resistor may actually glow. This is exactly how an incandescent light bulbworks. The filament is made of a material that will resist the current enough to heat up and glow.

The scientific symbol for electrical resistance, which is measured in ohms, is the Greek letter Omega (Ω).Electricians and practical wiring books typically use an "R" to represent resistance.

- **Factors Affecting the Resistance of a conductor**
  - ✓ Kind of the material-the greatest the number of free electrons present in a substances, the lower the resistance. For example, copper has a lower electrical resistance than aluminium, copper is a better conductor
  - ✓ Length of the material-Directly proportional with resistance
  - ✓ Cross sectional area (thickness) -inversely proportional with resistance
  - ✓ Temperature-Metals generally offer higher resistance at high temperature. Non-metallic substance such as carbon offer lower resistance at high temperature

- **Ohm's law**

This is the most basic law of current flow, discovered by George Ohm. The law states that the amount of current flowing in a circuit made up of pure resistances is directly proportional to the electromotive force impressed on a circuit and is inversely proportional to the total resistance of the circuit. The relationship of Ohm's law is the behaviour of electric currents I, relating them to voltage V and resistance R.
$V = R \times I$

This is a linear relation. If you double the voltage (V) then for the same value of R you get twice the current. If you want to keep the current the same value after doubling V, you would have to double the resistance (R).

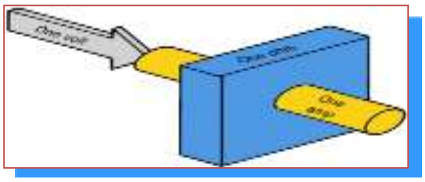

Figure 4 Relation between Voltage, Current and Resistance

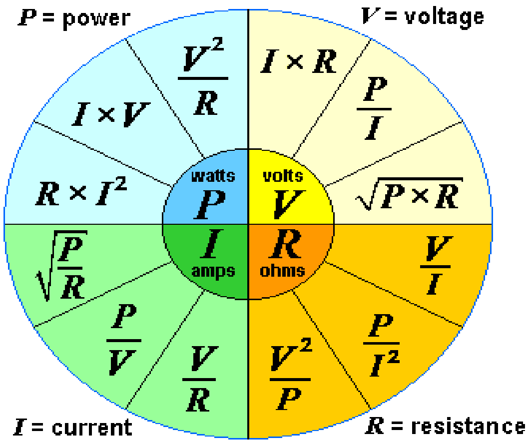

Figure 5 :Ohms law formulas

1.2. Electrical Circuits

An electrical circuit is a path or line through which an electrical current flows. The path may be closed (joined at both ends), making it a loop. A closed circuit makes electrical current flow possible. It may also be an open circuit where the electron flow is cut short because the path is broken. An open circuit does not allow electrical current to flow.

- **Alternating Current (AC) & Direct Current (DC)**

  The supply of current for electrical devices may come from a **direct current (DC)** source or an **alternating current (AC)** source. In a direct current circuit, electrons flow continuously in one direction from the source of power through a conductor to a load and back to the source of power. Voltage polarity for a direct current source remains constant. DC power sources include batteries and DC generators.

  By contrast, an AC generator makes electrons flow first in one direction then in another. In fact, an AC generator reverses its terminal polarities many times asecond, causing current to change direction with each reversal.

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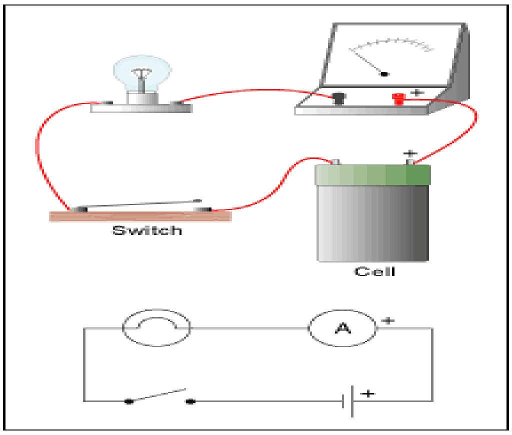


Figure 6: Simple circuit, Source: /www1.curriculum.edu.au

1.3. Types of Electrical Circuits

Based on the connection of loads, electrical circuits are classified in to three:

1.3.1 Series circuit

In series circuit, loads are connected end to end.

- The current is the same at any point in the circuit

$$I_1=I_2=I_3=...I_n$$

- The total resistance is the sum of the individual resistors

$$R_T=R_1+R_2+R_3...+R_N$$

- The applied voltage is equal to the sum of the voltage drops across all the resistors

$$V_T=V_1+V_2+V_3...+V_N$$

- **Advantage**:- Economical, less wire/cable is needed
- **Disadvantage**:- if one of the lamps is broken the whole circuit will be out of operation

1.3.2 Parallel circuit

In a parallel circuit the loads are arranged to allow all the positive terminals to be joined to a single conductor and all the negative one to another conductor so in effect the current travels through different parallel paths. The total resistance of a parallel circuit is the reciprocal of the sum of the reciprocals of each resistor.

- Loads are connected side by side or across the line voltage.
- has more than one electrical path
- Total current is the sum of all branch currents

$$I_T=I_1+I_2+I_3...+I_N$$

- equal voltage drops across each load

$$V_T=V_1=V_2=V_3........V_N$$

- Total resistance(R_T) is computed as:
  - ✓ Product over sum method

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

  - ✓ Reciprocal equation method

. $1/R_T = 1/R_1 + 1/R_2 + 1/R_3 + ..1/R_n$ =

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}..+\frac{1}{R_N}}$$

- ✓ For equal resistors connected in parallel:
- ✓ The value of one resistor is divided by number of branches/resistors
- ✓ Advantages **of parallel**: if one of the lamps is broken the other circuit part independently operate
- ✓ **Disadvantage**:-less-economical because more cables/wire are needed.

1.3.3 Series-parallel circuit

- **Loads are connected partly in series and partly in parallel**

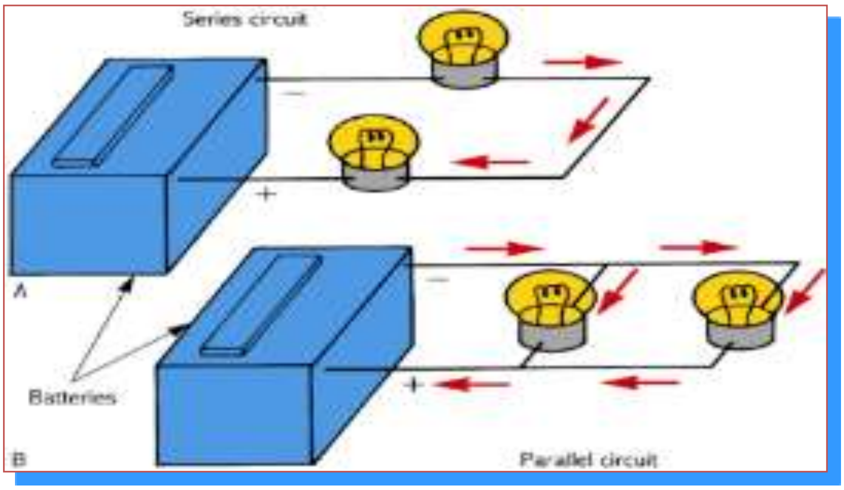
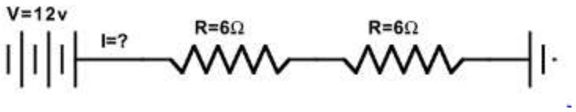


Figure 7: Series & Parallel Connection

- **Most important formulas**
  - ✓ **Voltage(** V) = I × R = P / I = √(P × R) in Volts V
  - ✓ **Current (I) = V / R = P / V = √(P / R) in Amperes**
  - ✓ **Resistance (R) = V / I = P / I2 = V2 / P in ohms Ω**
  - ✓ **Power (P)** = V × I = R × I^2 = V^2 / R in Watts W

EXAMPLE 1: calculate total current (I_T) in the following series connection



Given :

VT=12V, R1=6 Ω, R2=6 Ω

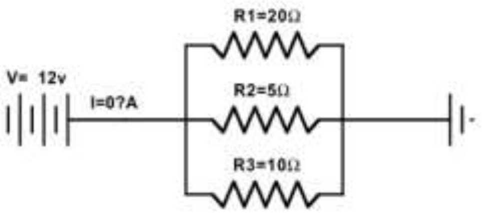
Find I?

SOLUTION: RT= R1+R2=6+6=12 Ω

then,

IT =VT/RT=12V/12 Ω=1A

EXAMPLE2: calculate total current in the following parallel connection



Given :-

VT=12V, R1=20 Ω, R2=5 ΩR3=10 Ω

Find IT:

SOLUTION**:**

$\frac{1}{Rt}=\frac{1}{R1}+\frac{1}{R2}+\frac{1}{R3}-=\frac{1}{20}+\frac{1}{5}+\frac{1}{10}$=0.05+0.2+0.1=0.35 (1/0.35Ω)

R_t=1/0.35 (1/Ω)=**2.86 Ω ,**

<u>**N.B.**</u> R_T is always less than even the smallest individual omhic value in the circuit.

Therefore $I_T=\frac{Vt}{Rt}$ = $\frac{12}{2.86}$ = **4.2A**

1.3 Components of Basic Electronic Devices

Electronic devices are simplified as components in which electrical conduction takes place by motions of electrons through them. Components of electronics are divided in to three as shown in the chart below

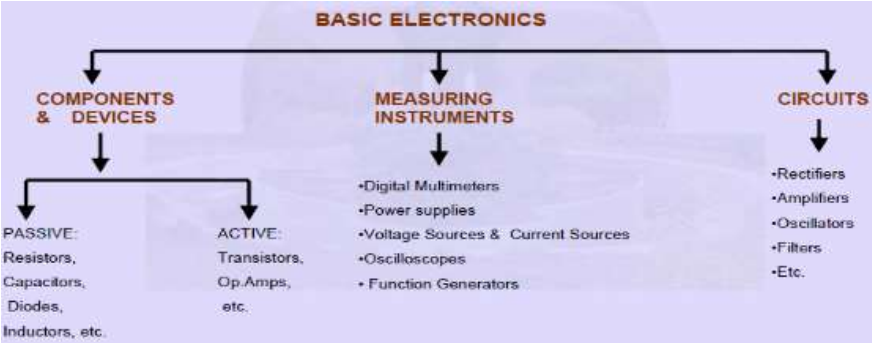


Figure 8: Components of electronics

.3.1 Passive Components

Typically, anything that doesn't require a bias voltage is a passive component. In other words, any component that isn't a semiconductor is passive. Passive components just have to be connected in the proper circuit pathway to function properly. Common examples of passive components are resistors, capacitors, inductors and transformers.

Are electronic devices that do not automatically amplify the signal or control the presence, flow, or direction of electrical current or voltage by means of an electrical control signal (current or voltage). There are many uses for *passive* electronic components, they are most commonly used in electronic engineering and control systems.

Electronic components carry all types of passive electronic component parts including resistors, capacitors, inductors, potentiometers, transformers, passive transducers, thermistors, thermostats, crystals, oscillators, resonators, fuses, batteries connectors, mechanical relays, switches, wire, and cable.

- **Resistor**

Resistors do exactly what the name sounds like they resist or oppose the flow of electric current through them, causing a voltage drop. Resistance is measured in Ohms and can be measured with an ohmmeter or a multimeter. Resistors are manufactured in various sizes, values and tolerances to meet a wide range of requirements for electronic circuits.

Figure 9: Resistor Symbol and a Resistor

- **Resistor Colour Code: -**An electronic colour code is used to indicate the values or ratings of electronic components, usually for resistors, but also for capacitors, inductors, diodes and others.

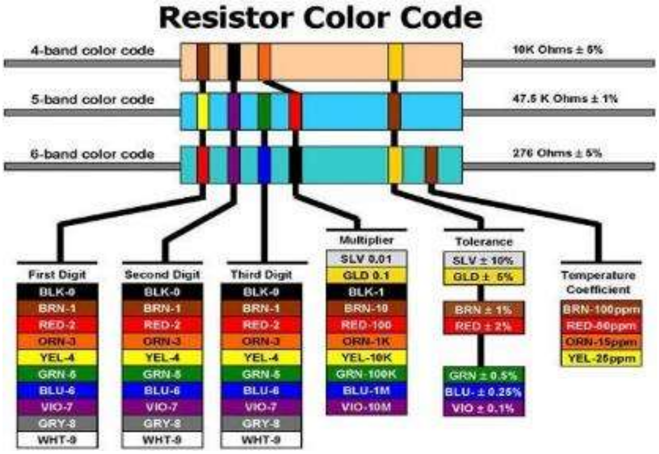


Figure 10: Colour Codes for Resistor

- **Capacitor**

Capacitors temporarily store electricity. How much electricity can be stored is measured in microfarads or uF. Capacitors are also manufactured as different types. Electrolytic capacitors can store a lot of electricity --- values of 470 uF are very common. Ceramic disk capacitors store a lot less electricity and a common value is .01 uF. Capacitors have two conductors separated by a non-conductive surface. Electrons build up on the surface of the conductors, resulting in a static charge. When a capacitor discharges, the electrons are released back into the circuit.

Figure 11: Electrolytic Capacitor and its Symbol

- **Inductor**

An inductor is a coil with or without a ferrous metal core. The inductor is also an electric current storage device, but it functions much differently than a capacitor and operates by storing energy in magnetic fields. Current passing through the coil creates a magnetic field within the coil, which in turn induces an opposing voltage to the current that created it in the first place.

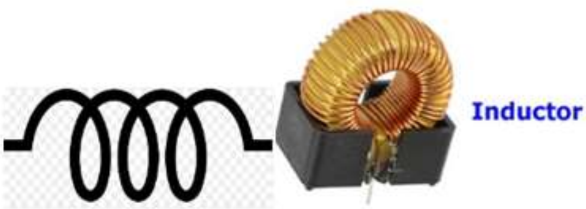


Figure 12: Inductor Symbol and an Inductor

- **Transformer**

Transformers operate only on alternating current and are used to change voltage from one value to another. Transformers are made from two inductors. The primary coil accepts the input voltage and induces a voltage in the secondary coil. The voltage level induced in the second coil is directly related to the number of turns of wire in both coils. Transformers find common use anywhere voltage changes are required such as battery chargers, power supplies, household electronics and power distribution grids.

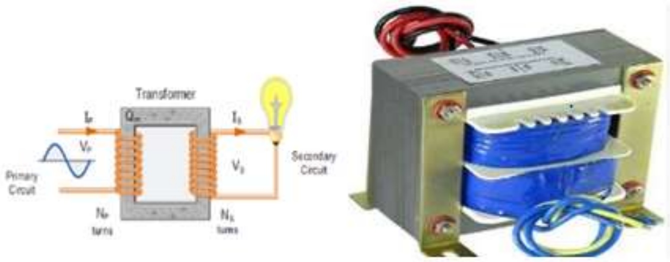


Figure 13: Transformer Symbol and a Transformer

1.3.2 Active Components

Active components require a separate power supply to turn the device on and function. Transistors, operational amplifiers and integrated circuits are examples of active components that require a power supply in order to work .

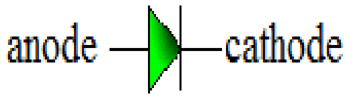
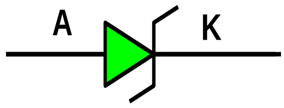
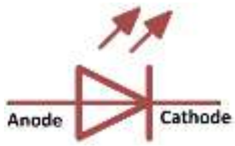
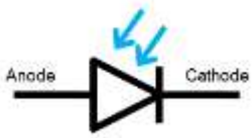
In general, active components require a bias voltage to break the internal barrier and turn them "on." Common examples are diodes, LEDs, transistors and integrated circuits, or chips. These components are sometimes referred to as "digital" components. In most circuits, passive components are combined with active to provide efficient and safe circuit operation.

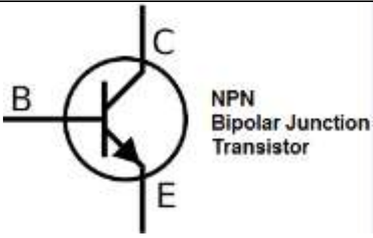
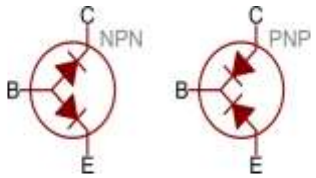
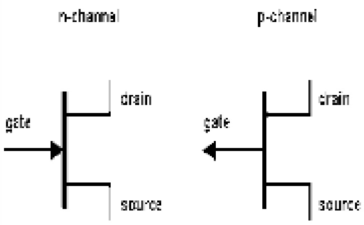
- **Semiconductor**

  Substances capable of acting as both a conductor and an insulator are called semiconductors. This enables semiconductor devices to control current without mechanical points.

- **Semiconductor devices include**
  - ✓ diodes
  - ✓ transistors
  - ✓ integrated circuits

Table 1: Describe Electronic Symbols

No.	Semiconductor Name	Description	Symbol
1.	Diode	An "electronic check valve" that allows current to flow in only one direction. • when a diode is forward biased, it acts as a conductor • when a diode is reverse biased, it acts as an insulator	
2.	Zener diode	Passes current in reverse direction to provide a constant voltage reference. Zener diode was designed for limiting the voltage across its terminals in reverse bias. This diode is intended to operate at that voltage, and so finds its greatest application as a voltage regulator or voltage reference, utilizing it's so called "reverse breakdown voltage rating." Recall the discussion of diode. Diode operates in forward bias but Zener diode, the normal operation is in reverse bias.	
3.	Light-emitting diode(LED)	A diode that emits light.	
4.	Photodiode	Are intended to sense light (photo detector) & Passes current in proportion to incident light. A photodiode can be used in solar cells, in photometry, or in optical communications.	

5.	Transistor	Allows the control of a high current circuit with a low current circuit and performs the same basic function as a relay. Acts as a remote switch or current amplifier. Operates more quickly than a mechanical device can Has no moving part to wear or deteriorate.	
6.	Bipolar Junction Transistor (BJT)	A semiconductor device constructed with three doped semiconductor regions collector, base and emitter separate by tow p-n junctions	
7.	Field-Effect Transistor (FET)	Electronic device which uses electric field to control the flow of current. FET has three terminals G = GATE, D =DRAIN and S= SOURCE	

The following videos show basic electricity and electronics components.

https://www.youtube.com/watch?v=mc979OhitAg

https://www.youtube.com/watch?v=WoN1nou5t1Q

1.4 Measuring Instruments

Table 2:-Electronic Measurement

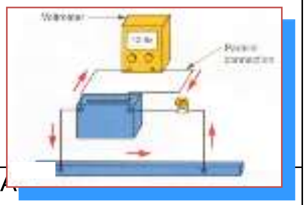
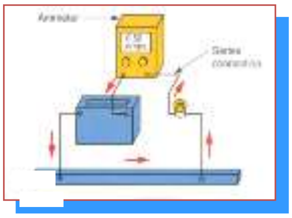
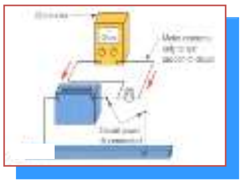
No.	Instrument	Description	Circuit Connection
1.	Multimeter /VOM	Combines an ohmmeter, ammeter, and voltmeter in one case.	
2.	Voltmeter	Used to measure the amount of voltage in a circuit Connected in parallel with the circuit Voltmeter reading can be compared to specifications to determine whether an electrical problem exists	Voltmeter Connections 
3.	Ammeter	Measures the amount of current in a circuit Connected in series with the circuit All the current in the circuit must pass through a conventional ammeter Inductive ammeters have a special pickup that is clamped around the wire uses the magnetic field around the wire to determine the amount of current in the wire	
4.	Ohmmeter	Measures the amount of resistance in ohms in a circuit or component Connected in parallel with the wire or component being tested Wire or component being tested must be disconnected from power Ohmmeter reading can be compared to specifications to determine if a part is defective	Ohmmeter Connections 

Table 3:- Standard basic electrical Units

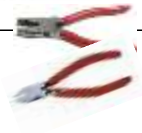
No	Electrical Parameter	Measuring Unit	Symbol	Description
1	Voltage	Volt	V or E	Electrical Potential **V = I × R**
2	Current	Ampere	I	Electrical Current **I = V ÷ R**
3	Resistance	Ohm(Ω)	R	DC Resistance **R = V ÷ I**

4	Conductance	Siemens (S) or seldomly Mho (℧)	G	Reciprocal of Resistance **G = 1 ÷ R**
5	Capacitance	Farad(F)	C	Capacitance **C = Q ÷ V**
6	Charge	Coulomb(C)	Q	Electrical Charge **Q = C × V**
7	Inductance	Henry(H)	L	Inductance $V_L = -L(di/dt)$
8	Power	Watts(W)	p	Power **P = V × I** or $I^2 \times R$
9	Impedance	Ohm(Ω)	Z	AC Resistance $Z^2 = R^2 + X^2$
10	Frequency	Hertz(Hz)	f	Frequency **ƒ = 1 ÷ T**

1.5 Necessary tools and equipment

The following tools and equipment are required to perform the tasks mentioned

Table 4:-Hand Tools

No.	Tool	Description	Picture
1.	**Screw drivers**	Used to remove or install screws Available in many shapes and sizes • Standard/Flat • Phillips	
2.	**Long nose/ Combination pliers**	Used to grip, cut, crimp, hold, and bend various parts	
3.	**Diagonal cutter**	Jaw shape allows these pliers to cut items flush with an adjacent surface	
4.	**Electrician knives**	This knife is needed to cut the insulation off of wiring. It is also used to open boxes and cut electrical tape when doing installation.	
5.	**Wire Crimpers**	This tool is used to cut wires, strips wires, and *crimps* lugs and connectors onto wires.	

1.6 OHS hazards and suitable PPE

Occupational health and safety:- is a cross-disciplinary area concerned with protecting the safety, health and welfare of people engaged in work or employment. The goal of all occupational health and safety programs is to foster a safe work environment. As a secondary effect, it may also protect co-workers, family members, employers, customers, suppliers, nearby communities, and other members of the public who are impacted by the workplace environment

- **Personal Protective Equipment (PPE)**

Table 5:-Safety Equipment

No.	equipment	Description	Picture
1	**Hard Hat**	used in workplace environments such as industrial or construction sites to protect the head from injury due to falling objects	
2	**Safety Shoe**	Protective, safety footwear is essential to ensure safe and healthy feet.	
3	**Glove**	It is important to wear gloves when working with hazardous chemicals and Electrical Shocks in working Area	
4	**Safety Belt/Harness**	A safety belt or harness has to be worn as a safety precaution by a person working at a great height. The safety harness has be worn correctly and fixed to an anchor point at the roof	
5	**Fire Extinguisher**	Are commonly sold at hardware stores for use in the kitchen or garage, are pressurized with nitrogen or carbon dioxide (CO_2) to propel a stream of fire-squelching agent to the fire. Fire extinguisher are also commonly used with water and powdered	

- **First Aid**
  - ✓ **First aid** is the first and immediate assistance given to any person suffering from either a minor or serious illness or injury.
  - ✓ **First aid** helps ensure that the right methods of administering medical assistance are provided. Knowing how to help a person is just as **important** in

emergency situations. It only takes six minutes for the human brain to expire due to lack of oxygen

- ✓ First aid is generally performed by someone with basic medical training..

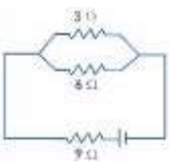
Figure 14: First aid Kit

Figure 15: First Aide procedure

Self-Check -1	Written Test

I. Choose the best option & circle the letter of your choice.

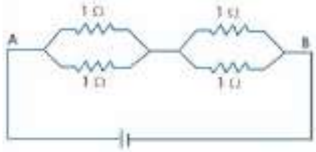
1. What is the name for the flow of electrons in an electric circuit?
A. Voltage B. Resistance C. Capacitance D. Current
2. Which of the following will remain the same in all parts of a series circuit?
(A) Voltage (B) Current (C) Power (D) Resistance
3. Which instrument would you use to measure resistance?
A. An ammeter B.A voltmeter C.An ohmmeter D. A wave meter
4. What does an electrical insulator do?
A. It lets electricity flow through it in one direction
B. It does not let electricity flow through it
C. It lets electricity flow through it when light shines on it
D. It lets electricity flow through it
5. A battery is a source of (A) DC voltage. (B) 1 φ AC voltage. (C) 3 φ AC voltage. (D) AC or DC voltage.
6. What is the basic unit of electric current?
A. The volt B. The watt C.The ampere D. The ohm
7. What is the name of the pressure that forces electrons to flow through a circuit?
A. Magneto motive force, or inductance B. Electromotive force, or voltage
C. Farad force, or capacitance D. Thermal force, or heat
8. Which instrument would you use to measure electric current?
A. An ohmmeter B. A wave meter
C. A voltmeter D. An ammeter
9. What is the basic unit of electromotive force (EMF)?
A. The volt B. The watt
C. The ampere D. The ohm
10. Which instrument would you use to measure electric potential or electromotive force?
A. An ammeter B. A voltmeter C. A wavemeter D. An ohmmeter
11. What limits the current that flows through a circuit for a particular applied DC voltage?
A. Reliance B. Reactance C. Saturation D. Resistance
12. What is the basic unit of resistance?
A. The volt B. The watt C.The ampere D. The ohm
13. What are three good electrical conductors?
A. Copper, gold, mica B. Gold, silver, wood
C. Gold, silver, aluminium D. Copper, aluminium, paper
14. What are four good electrical insulators?
A. Glass, air, plastic, porcelain B. Glass, wood, copper, porcelain
C. Paper, glass, air, aluminium D. Plastic, rubber, wood, carbon
15. in the figure,



A. 6 Ω , 3 Ω and 9 Ω are in series
B. 9 Ω and 6 Ω are in parallel and the combination is in series with 3 Ω
C. 3 Ω , 6 Ω and 9 Ω are in parallel

D. 3 Ω , 6 Ω are in parallel and 9 Ω is in series

16. The resistance across AB is



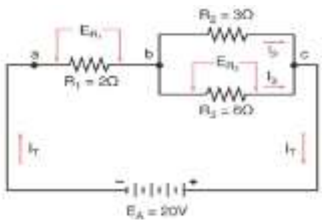
A. 4 Ohm B. 1 Ohm C. 2 Ohm D. 0.5 Ohm

17. Kilowatt-hour is the unit of

A. Potential difference B. Electric power C. Electrical energy D. Charge

18. What is the current through R3 (I3) in the image below?

A. 3.33 B. 1.67 C. 5 D. 6.66



Score = ___________
Rating: ____________

Short answer question

Note: **Satisfactory rating 10 and above points, Unsatisfactory - below 10 points**

Information Sheet-2	Identifying And Describing Types Of Renewable Energy

2.1 Introduction

- **Renewable energy:-**
  - ✓ is energy generated from natural resources
  - ✓ is energy that is generated from natural processes
  - ✓ Renewable resources are replenished naturally
  - ✓ They are found in unlimited supplies
  - ✓ They can never be depleted

  On the other hand resources that can be depleted such as petroleum and natural gas are called non-renewable resources

2.2 Identifying and describing types of Renewable Energy Sources

- **Solar energy**

  Humans have been harnessing solar energy for thousands of years—to grow crops, stay warm and dry foods. According to the National Renewable Energy Laboratory, "more energy from the sun falls on the earth in one hour than is used by everyone in the world in one year." Today, we use the sun's rays in many ways to heat homes and businesses, to warm water, or power devices. Photo voltaic panels shown in the pictures below convert solar radiation in to electricity

Figure 16: solar Installation

- **Hydro power**

  Hydropower relies on water typically fast-moving water in a large river or rapidly descending water from a high point and converts the force of that water into electricity by spinning a generator's turbine blades. Hydropower therefore requires good flow of water and good height difference (termed as head) between the water level and turbine. Hydropower is the main source of electricity in Ethiopia.

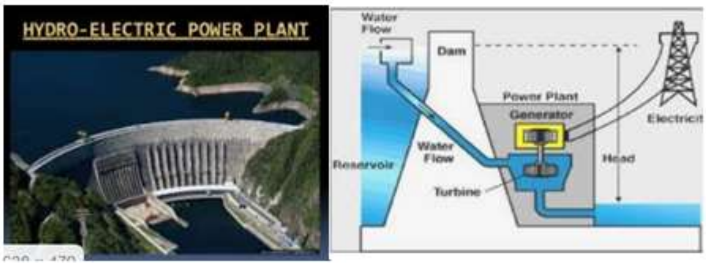


Figure 17: Hydro power Final work

- **Tidal energy**
  Tidal power, also called tidal energy, is a form of hydropower that converts the energy of tides into useful forms of power – mainly electricity. Although not yet widely used, tidal power has potential for future electricity generation. Tides are more predictable than wind energy and solar power.

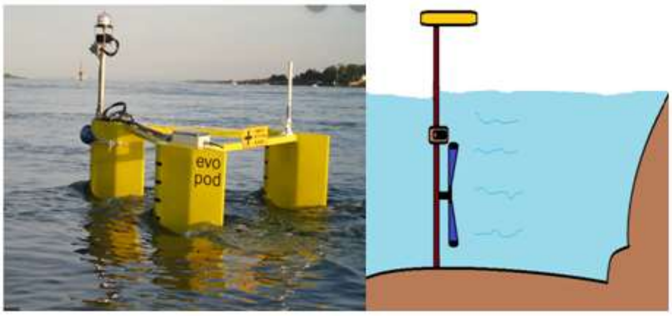


Figure 18: Tidal stream generator

- **Geothermal heat**
  If you've ever relaxed in a hot spring, you've used geothermal energy. The earth's core is about as hot as the sun's surface, due to the slow decay of radioactive particles in rocks at the centre of the planet. Drilling deep wells brings very hot underground water to the surface as a hydrothermal resource, which is then pumped through a turbine to create electricity.
  Geothermal plants typically have low emissions if they pump the steam and water they use back into the reservoir. There are ways to create geothermal plants where there are not underground reservoirs, but there are concerns that they may increase the risk of an earthquake in areas already considered geological hot spots.

Figure 19: Geothermal heat energy System

- **Bio mass energy:** is organic material that comes from plants and animals, and includes crops, waste wood, and trees. When biomass is burned, the chemical energy is released as heat and can generate electricity with a steam turbine.
  Examples of biomass and their uses for energy

- ✓ Wood and wood processing wastes—burned to heat buildings, to produce process heat in industry, and to generate electricity
- ✓ Agricultural crops and waste materials—burned as a fuel or converted to liquid bio fuels
- ✓ Food and wood waste in garbage—burned to generate electricity in power plants or converted to biogas in landfills
- ✓ Animal manure and human sewage—converted to biogas.

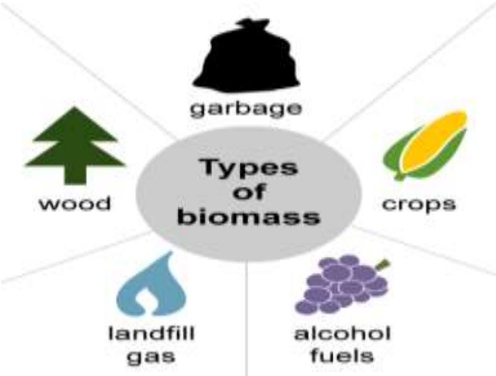


Figure 20: Types of Bio mass

- **Wind energy:**

Wind energy (or wind power) describes the process by which wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. Mechanical power can also be utilized directly for specific tasks such as pumping water Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity.

Figure 21: Wind Energy

Summary table for renewable energy sources with their respective symbols

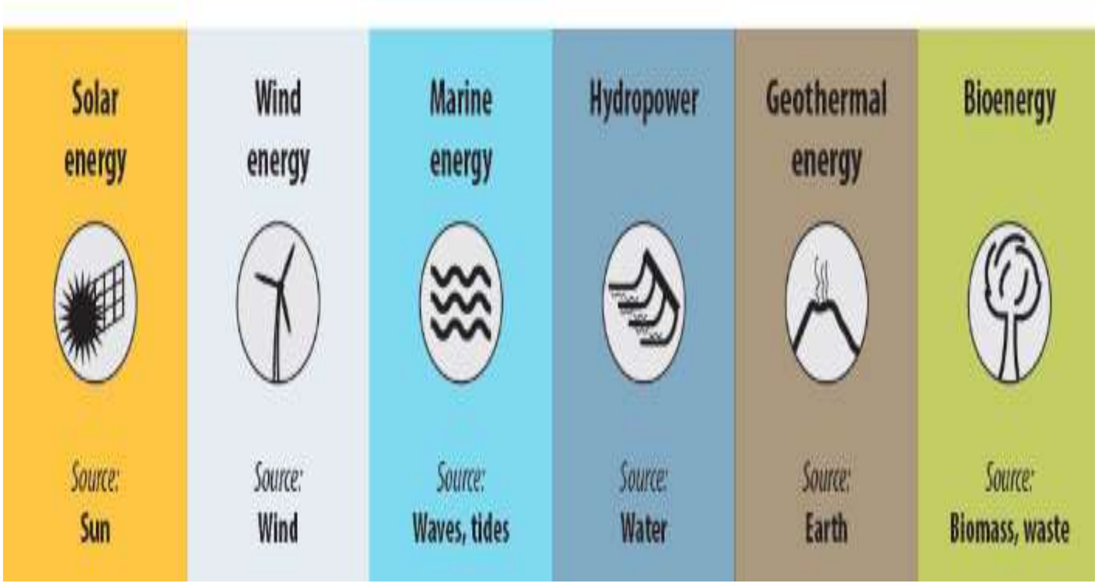


Figure 22: General description renewable Energy

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer for the following questions below

1. Which one of the following is a renewable resource:

a) Petroleum b) Natural gas c) Bio mass d) All

2. Energy from organic materials such as plants and animals is

a) Geothermal b) Natural gas c) Tidal d) None

3. Which one of the renewable resources is widely used to produce electricity in Ethiopia?

a) Wind energy b) Solar energy c) Hydropower d) Geothermal

4. The machines that convert kinetic energy in the flow air into mechanical power are called

a) Hydro turbines b) Wind turbines c) Pumps d) All

5. The heat that we use in hot springs comes from

a) Solar radiation b) Geothermal energy c) Natural gas d) All

***Note:* Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer questions

Information Sheet-3	Basic Working Principles of Renewable Energy

3.1 Principles of solar energy

Solar energy is created by light and heat which is emitted by the sun, in the form of electromagnetic radiation. With today's technology, we are able to capture this radiation and turn it into usable forms of solar energy - such as heating or electricity.

Solar energy is the sun's nuclear fusion reactions within the continuous energy generated. Earth's orbit, the average solar radiation intensity is 1,367 W/m^2. Circumference of the Earth's equator is 40,000km, thus we can calculate the energy the earth gets is up to 173,000 TW. At sea level on the standard peak intensity is 1 kW/m^2, a point on the earth's surface 24h of the annual average radiation intensity is 0.20 kW/m^2, or roughly 102,000 TW of energy. Humans rely on solar energy to survive, including all other forms of renewable energy (except for geothermal resources) Although the total amount of solar energy resources is ten thousand times of the energy used by humans, but the solar energy density is low, and it is influenced by location, season, which is a major problem of development and utilization of solar energy.

The technical feasibility and economic viability of using solar energy depends on the amount of available sunlight (solar radiation) in the area where you intend to place solar heaters or solar panels. This is sometimes referred to as the available solar resource. Every part of Earth is provided with sunlight during at least one part of the year.

"Part of the year" refers to the fact that the north and south polar caps are each in total darkness for a few months of the year. The amount of sunlight available is one factor to take into account when considering using solar energy.

There are a few other factors, however, which need to be looked at when determining the viability of solar energy in any given location. These are as follows:

- ✓ Geographic location
- ✓ Time of day
- ✓ Season
- ✓ Local landscape
- ✓ Local weather

3.2 Principles of wind energy

A windmill converts wind energy into rotational energy by means of its blades. The basic principle of every windmill is to convert kinetic energy of wind into mechanical energy which is used to rotate the turbine of electrical generator to produce electricity.

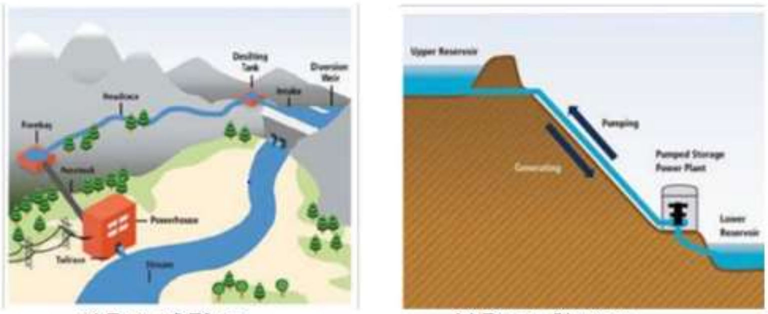
3.3 Principles of hydropower

Hydropower is probably the first form of automated power production which is not human / animal driven. Moving a grind stone for milling first, developed into the driving of an electrical generator. Next to steam it was for long the main power source for electricity. Continual availability does not require any power storage (unlike wind / solar power). It is mainly mechanical hardware. This makes it relative easy to understand and repair-/maintainable. In smaller units its environmental impact becomes neglect-able Head & Flow In order to create electricity from hydropower, two parameters are critical:

- **Flow**; or the minimum amount of water that is constantly available throughout the entire year
- **Head**; the difference in height

These specific conditions limit generalising and standardisation of "how to install hydropower plants". Choosing the right location and planning requires some specific knowledge. With knowledge of water flow and height difference the potential power can be estimated.

Head and flow are the two most important facts of a hydro site. This will determine everything about the hydro system - volume of civil constructions, pipeline size, turbine type and power output. Inaccurate measurements result in low efficiency, high cost and scarcity of power.



a) Run-of-River b) Pump Storage

Figure 23: Hydropower Plant

3.4 Principles of bio energy

Biomass can be converted into energy (heat or electricity) or energy carriers (charcoal, oil, or gas) using both thermo chemical and biochemical conversion technologies. Combustion is the most developed and most frequently applied process because of its low costs and high reliability. However, combustion technologies deserve continuous attention from developers in order to remain competitive with the other options.

3.5 Principles of tidal power

Tidal power harnesses the energy from the tidal force and wave action in order to generate electricity. Unlike other energy flows, it is a predictable source of energy because tides occur at expected time.

Tide or wave is periodic rise and fall of water level of the sea. Tides occur due to the attraction of sea water by the moon. Tides contain large amount of potential energy which is used for power generation. When the water is above the mean sea level, it is called flood tide. When the water level is below the mean level it is called ebb tide.

The arrangement of this system is shown in figure below. The ocean tides rise and fall and water can be stored during the rise period and it can be discharged during fall. A dam is constructed separating the tidal basin from the sea and a difference in water level is obtained between the basin and sea.

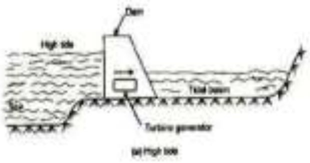


Figure 24: High of tidal power

During high tide period, water flows from the sea into the tidal basin through the water turbine. The height of tide is above that of tidal basin. Hence the turbine unit operates and generates power, as it is directly coupled to a generator.
During low tide period, water flows from tidal basin to sea, as the water level in the basin is more than that of the tide in the sea. During this period also, the flowing water rotates the turbine and generator power.

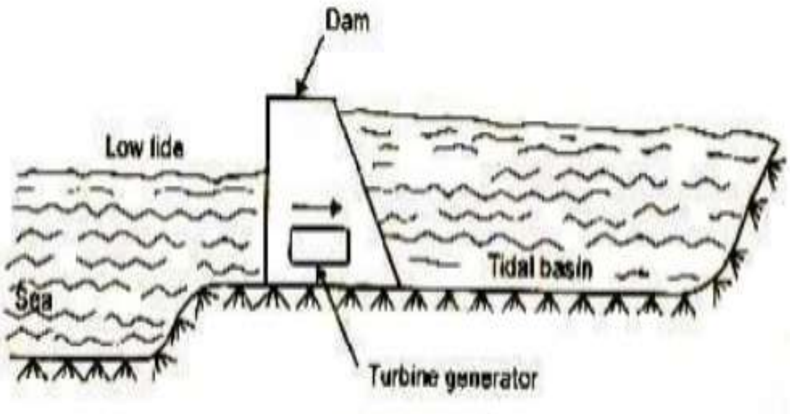


Figure 25: Low tidal power

The generation of power stops only when the sea level and the tidal basin level are equal. For the generation of power economically using this source of energy requires some minimum tide height and suitable site.

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Match Colum B to Column A

No	Column A	Column B
1	Geothermal Energy	A. Created by light and heat
2	Hydro power	B. Uses organic materials as source
3	Solar energy	C. uses heat as a prime mover
4	Wind energy	D. converts one kind of energy to rotational energy by its blades
5	Biomass	E. uses falling water

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: ________________

Short answer question

Information Sheet-4	Applications of Renewable Energy

4.1 Application of Solar Energy

Solar energy is utilized mainly in two ways: photovoltaic and thermal applications.

- **Photovoltaic application of solar energy**
  The photovoltaic effect (PV) is defined as the generation of electromotive force as a result of the absorption of ionizing radiation. Therefore, by using the photovoltaic effect, electricity can be generated directly from sunlight without going through a thermal process.. Devices that use the PV effect to generate a voltage when sunlight is the source of ionizing radiation are called solar cells.

An individual cell typically produces about 0.5V power with the current directly proportional to the cell's area. The Individual cells are connected in series – parallel combination o meet the voltage, power and reliability requirements of the particular application. . A series-connected set of **solar** cells or modules is called a "**string**".

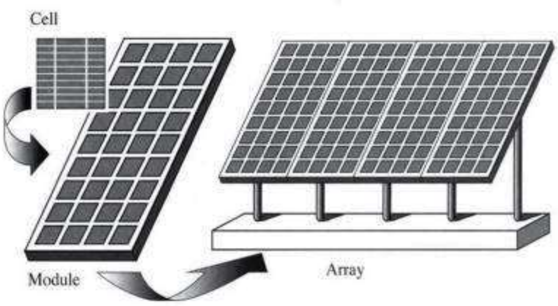


Figure 26: Solar cell, module and array

Some applications for PV systems are lighting for commercial buildings, outdoor (street) lighting, rural households and village lighting, rural small entertainment, health post lighting and vaccine storage, etc. Solar electric power systems can offer independence from the utility grid and offer protection during extended power failures. Solar PV systems are found to be economical especially in the hilly and far flung areas where conventional grid power supply is expensive and hard to reach.

PV tracking systems are alternatives to the fixed, stationary PV panels. PV tracking systems are mounted and provided with tracking mechanisms to follow the sun as it moves through the sky. These tracking systems run entirely on their own power and can increase output by 40%.

Backup systems are necessary since PV systems only generate electricity when the sun is shining. The two most common methods of backing up solar electric systems are connecting the system to the utility grid or storing excess electricity in batteries for use at night or on cloudy days.

- ***Thermal application of solar energy***

In solar thermal systems, solar energy can be converted into thermal energy with the help of solar collectors and receivers known as solar thermal devices. Solar energy is used for heating fluid, usually water or air, which can then be used for suitable applications.

The heating process is done by absorbing the solar radiation on an absorber plate and thus heating it. Then this heat is transferred to a circulating fluid for use elsewhere. If the surface area of the exposed sunlight is nearly equal to the surface used for absorbingsolar radiation, the device is said to be a non-concentrating type solar collector, for whichthe most common is the flat plate collector (FPC). An efficient solar collector traps the maximum solar radiation incident on its surface, and converts it to thermal energy for use with minimum losses.

Low-grade solar thermal devices are used in solar water heaters, air-heaters, solar cookers and solar dryers for domestic and industrial application solar water heater. Using the sun’s energy to heat water is not a new idea. More than one hundred years ago, black painted water tanks were used as simple solar water heaters in a number of countries. Solar water heating (SWH) technology has greatly improved during the past century. There are a number of service hot water applications. The most common application is the use of domestic hot water systems (DHWS), as depicted in the Figure below. An insulated storage tank holds the hot water. In case of systems that use fluids, heat is passed from the hot fluid to the water stored in the tank through a coil of tubes (heat exchanger)

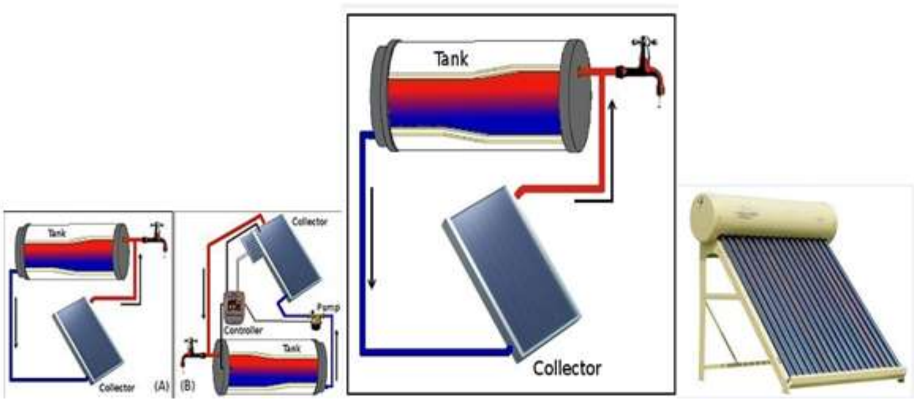


Figure 27: Solar water heater

Solar water heating systems can be either active or passive systems. The active systems, which are most common, rely on pumps to move the liquid between the collector and the storage tank. The passive systems rely on gravity and the tendency for water to naturally circulate as it is heated. Some industrial applications of solar water heaters are Hotels, Textiles, Breweries &Distilleries, etc.

- **Solar air heating**: hot air is needed for drying crops and for warming the area. Solar air heating is the same as for water heating where the fluid is heated while in contact with the surface of the radiation absorber. More specifically, the influence of the collector’ s orientation and the heat losses from the blowing of the wind, etc. for the two heating systems are very similar.

- **Passive heating system**

  The concept of passive heating systems is the selection of an absorber surface facing the sunlight as to capture an optimal amount of solar energy for a given construction building applications for solar air heating systems include both building ventilation air heating and process air heating.

  Systems used for ventilation heating vary depending on the type of building in which the system will be installed (e.g. industrial, commercial or residential).Large quantity of outdoor air is used for process air heating applications, such as for drying agricultural products. Solar systems can also serve as a pre-heater to (high temperature) industrial drying systems.

  Solar Cooker is a device, which uses solar energy for cooking, thus saving fossil fuels, fuel wood and electrical energy to a large extent. It is a simple cooking unit, ideal for domestic cooking throughout most of the year except during the monsoon season, cloudy days and winter months.
  The box type solar cookers, with a single reflecting mirror, are the most popular. These cookers have proved immensely popular in rural areas where women spend considerable time collecting firewood.

4.2 Application of Bioenergy

There are three fundamental forms of energy in terms of their utilization in our modern lives: heat, mechanical energy and electricity. The use of bioenergy can cover all of these forms of energy requirements.

- **Heat***:* is generated primarily in combustion systems. For stationary biomass systems that exist solely to generate heat, solid fuels predominate. Wood as a residue or raw material and production residues from farming can be used for heat production with low processing costs for cooking or drying.

- **Mechanical energy:** is required mainly by the transport industry. Bio resources can also be converted in to biofuels for use in cars and agricultural machinery.

- **Electricity***:* the generation of power (electricity) from bioenergy also makes use of the capabilities of heat and power generation. Systems that generate mechanical energy in combustion engines or in directly and indirectly fired turbines are coupled to electricity generators generated via heat and power-generating machines such as engines.

4.3 Application of Wind Energy

Most modern wind power is generated in the form of electricity by converting the rotation of turbine blades into electrical current by means of an electrical generator. Electricity generating wind turbines can be as small as having capacity in Watts to large scale turbines having capacity in Mega Watts.

In wind mills, wind energy is used to turn mechanical machinery to do physical work, such as crushing grain or pumping water. Recently, wind energy has also been used to desalinate water.

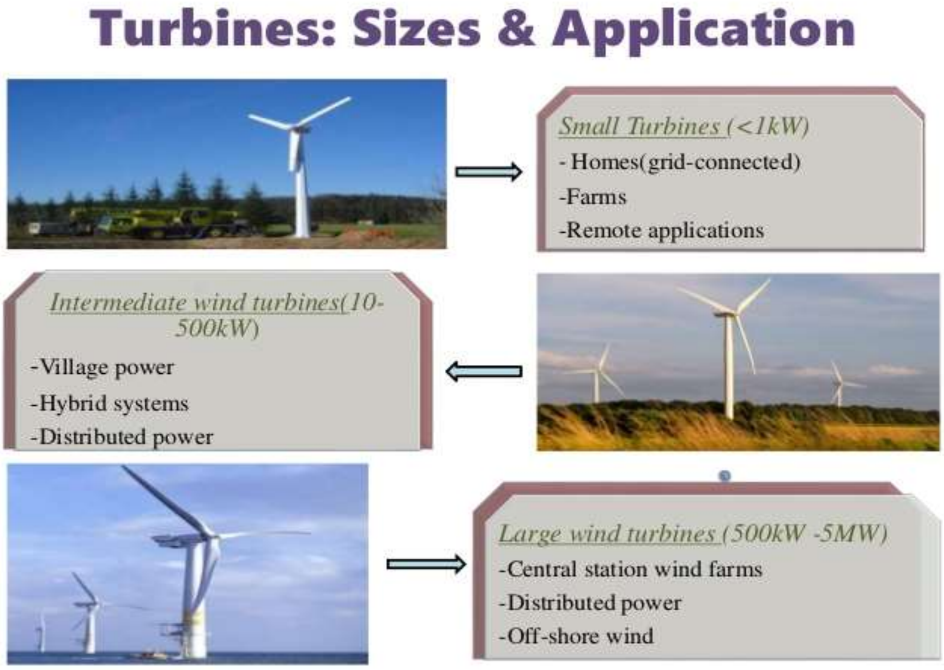


Figure 28: Application of wind energy

Self-Check -4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions

1. By using PV effect, electricity can be generated directly from sun light without going through thermal process
2. An individual cell in PV can typically produces above 0.5 V
3. Solar water heater is not used for household application
4. Wind energy can be used to desalinate water.
5. In PV system individual cells are connected in series, parallel combination to meet the voltage power and reliability requirement

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer questions

Information Sheet-5	Advantage and disadvantages of renewable energy sources

5.1 Advantages and disadvantages of renewable energy sources

- The use of renewable energies is the only possibility to electrify the southern hemisphere without destroying the world. The primary advantage of renewable energy resources is no or fewer potentially harmful emissions are released into the atmosphere.. The main disadvantage is that renewable energy sources are mostly volatile, that means they are not continuously available. But this problem can be solved by the use of appropriate storage systems e.g. thermal storage, hydro power plants with pumped storage, battery storage, ice storage and power to gas technology. The following outlines the general advantages and disadvantages of renewable energy resources
- **Advantages of Renewable Energy**
  - ✓ Pollution free and causes no greenhouse gases to be emitted after installation.
  - ✓ Reducing dependence on imported fuels
  - ✓ Creating economic development and jobs in manufacturing and installation
  - ✓ Renewable clean power is available in different forms: solar, wind, hydropower, bioenergy, tidal power etc.
  - ✓ sustainable energy supply for the future of the country & the next generation
- **Disadvantages of Renewable Energy**
  - ✓ Most of the renewable energy sources relatively need large investment
  - ✓ Many forms of renewable energy are location specific
  - ✓ Some forms of renewable energy require large space for their application
  - ✓ Some forms of renewable energy technologies are still under development and are not commercially available

5.2 Advantages and disadvantages of solar energy

- **Advantages:**
  - ✓ Solar energy causes no pollution
  - ✓ Solar energy can be produced free of charge ,no cost for fuel.
  - ✓ Almost no or low maintenance is required on solar technology is installed
  - ✓ Solar energy can be used in different forms: thermal or electricity
- **Disadvantages:**
  - ✓ Cost: the initial cost of purchasing a solar system is fairly high
  - ✓ Weather dependent: although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops
  - ✓ Solar energy storage is expensive
  - ✓ Uses a lot of space

.

Self-Check -5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer for the following questions.

1. The main disadvantage of renewable energy resources is
a. Pollution b. Cost c. Space d. Technology development
2. The advantage of solar energy can be
a. Produced free of charge b. Low maintenance c. Pollution free d. All of the above
3. Most of the renewable energy resources are location specific.
a. False b. True
4. One of the disadvantages of solar energy is expensive energy storage.
a. True b. False
5. Employing renewable energy resources reduces dependence on fuels
a. True b. False

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer question

Information Sheet-6	Renewable Energy Plants

6.1 Geothermal power plant

Geothermal is a thermal power plant, but the steam required for power generation is available naturally in some part of the earth below the earth surface. According to various theories earth has a molten core. The fact that volcanic action taken place in many places on the surface of earth supports these theories.

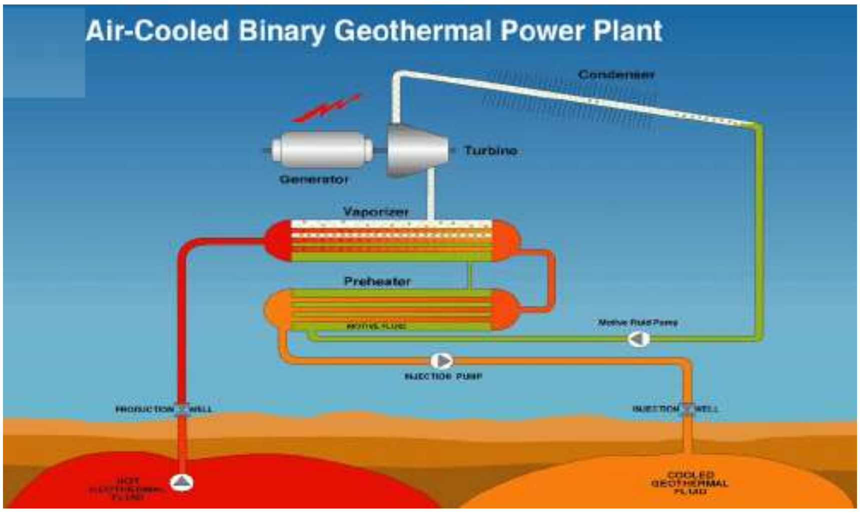


Figure 29: Schematic drawing of Geothermal power plant

- **Steam well**

  Pipes are embedded at places of fresh volcanic action called steam wells, where the molten internal mass of earth vents to the atmosphere with very high temperatures. By sending water through embedded pipes, steam is raised from the underground steam storage wells to the ground level.

- **Separator**

  The steam is then passed through the separator where most of the dirt and sand carried by the steam are removed.

- **Turbine**

  The steam from the separator is passed through steam drum and is used to run the turbine which in turn drives the generator. The exhaust steam from the turbine is condensed. The condensate is pumped into the earth to absorb the ground heat again and to get converted into steam.Location of the plant, installation of equipment like control unit etc., within the source of heat and the cost of drilling deep wells as deep as 15,000 metres are some of the difficulties commonly encountered.

6.2 Tidal power plants

The tidal power plants are generally classified on the basis of the number of basins used for the power generation. They are further subdivided as one-way or two-way system as per the cycle of operation for power generation.

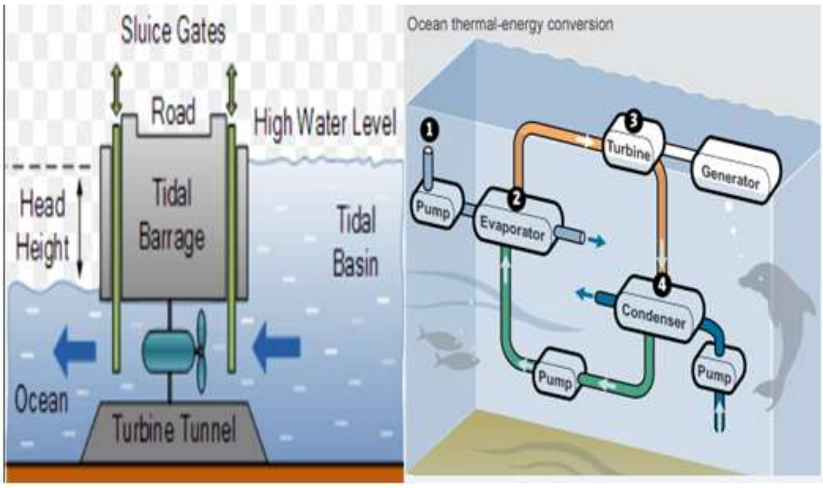


Figure 30: Tidal power plants

6.3. Working principles of different tidal power plants

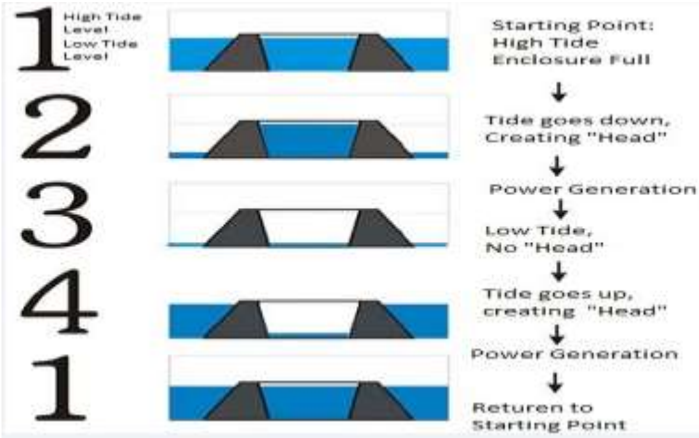


Figure 31: How Tidal Lagoon Works

- **Single basin-one-way cycle**

  This is the simplest form of tidal power plant. In this system a basin is allowed to get filled during flood tide and during the ebb tide, the water flows from the basin to the sea passing through the turbine and generates power. The power is available for a short duration ebb tide.

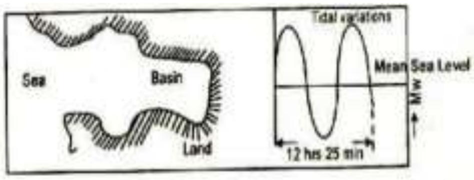


Figure: (a) Tidal region before construction of the power plant and tidal variation

FIGUR

- **Single-basin two-way cycle**

  In this arrangement, power is generated both during flood tide as well as ebb tide also. The power generation is also intermittent but generation period is increased compared with one-way cycle. However, the peak obtained is less than the one-way cycle. The arrangement of the basin and the power cycle is shown in figure.

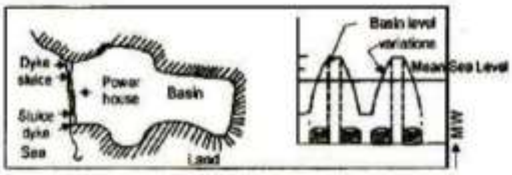
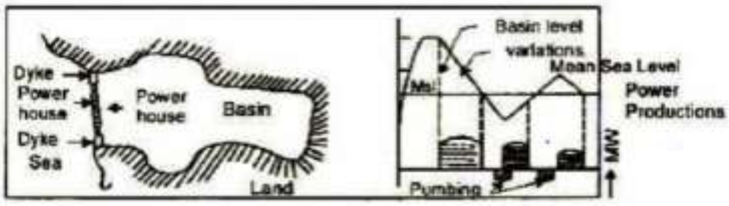


Figure: Single –basin two-way tidal power plant

  The main difficulty with this arrangement, the same turbine must be used as prime mover as ebb and tide flows pass through the turbine in opposite directions. Variable pitch turbine and dual rotation generator are used of such scheme.

- **Single –basin two-way cycle with pump storage**

  In this system, power is generated both during flood and ebb tides. Complex machines capable of generating power and pumping the water in either direction are used. A part of the energy produced is used for introducing the difference in the water levels between the basin and sea at any time of the tide and this is done by pumping water into the basin up or down. The period of power production with this system is much longer than the other two described earlier. The cycle of operation is shown in figure.



- **Double basin type**

  In this arrangement, the turbine is set up between the basins as shown in figure. One basin is intermittently filled tide and other is intermittently drained by the ebb tide. Therefore, a small capacity but continuous power is made available with this system as shown in figure. The main disadvantages of this system are that 50% of the potential energy is sacrificed in introducing the variation in the water levels of the two basins.

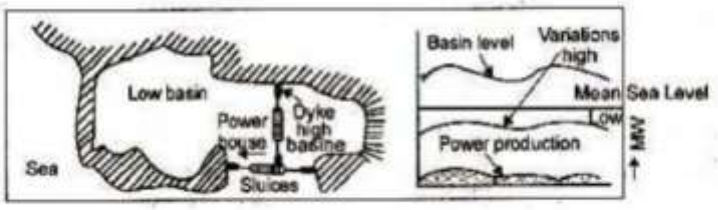


Figure: Double basin, one-way tidal plant.

- **Barrages**

The Tidal barrages are designed to utilize the potential energy created due to the difference in the level (height) of the tidal waves.

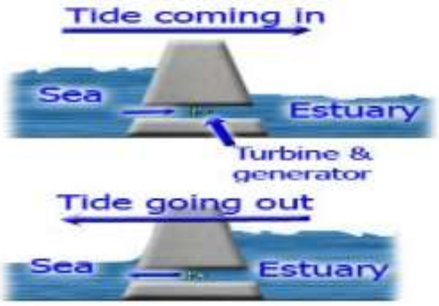


Figure 32:- How Tidal Barrage works

6.3 Wind-Electric Generating power plant

Figure shows the various parts of a wind-electric generating power plant. These are:

- ✓ Turbine rotor and hub
- ✓ Nacelle: it houses drive train and generator. Drive train includes shafts, gear box, clutch, brake etc. Generator converts the mechanical energy in the rotating shaft into electricity.

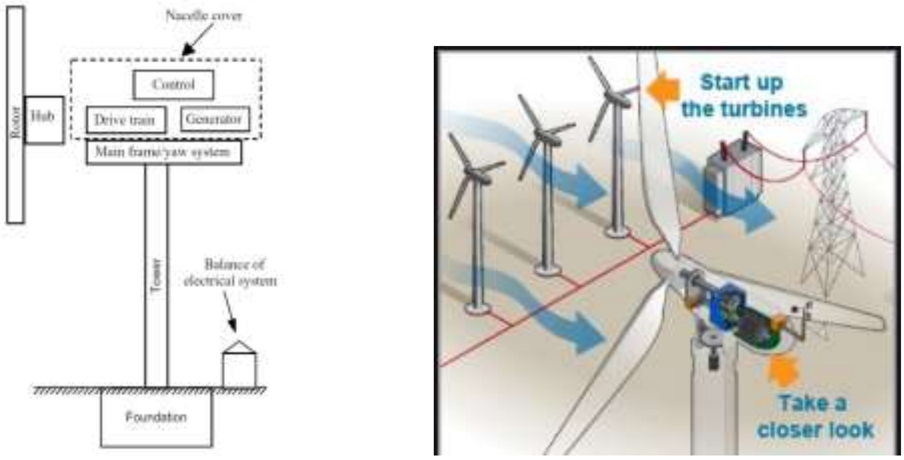


Figure 33:-Supporting tower and its foundation

The most important component is the **rotor**. For an effective utilization, all components should be properly designed and matched with the rest of the components.

The Nacelle performs the following functions:

- ✓ It houses the drive train components and generator.
- ✓ It also houses any control mechanism incorporated like changing the pitch of the blades and yawing of the turbine to orient the rotor to face the wind.Yawingis facilitated by mounting it on the top of the supporting structure on suitable bearings.

The turbine rotor may be located either upwind or downwind of the tower. In the upwind location the wind encounters the rotor before reaching the tower. In downwind rotors the wind reaches the rotor after reaching the tower. Generally upwind turbines are preferred especially for the large aero generators.

The supporting structure is designed to withstand the wind load during gusts. Its type and height is related to cost and transmission system incorporated. Horizontal axis wind turbines are mounted on towers so as to be above the level of turbulence and other ground related effects.

- **Types of Wind Machines**

  Wind turbines (sometimes called aero generators) are generally classified as follows:
  - ✓ Horizontal axis wind turbines (HAWT).
  - ✓ Vertical axis wind turbines (VAWT).
- **Horizontal axis wind turbines.** Figure shows a schematic arrangement of horizontal axis turbine. Although the common wind turbine with horizontal axis is simple in principle yet the design of a complete system, especially a large one that would produce electric power economically, is complex. It is of paramount importance that the components like rotor, transmission, generator and tower should not only be as efficient as possible but they must also function effectively in combination.

Figure 34:- Horizontal Axis Wind Turbines

- **Vertical axis wind turbines.** Figure shows vertical axis type wind turbine. One of the main advantages of vertical axis rotors is that they do not have to be turned into the wind stream as the wind direction changes. Because their operation is independent of wind direction, vertical axis machine are called panemones.

Figure 35:- Vertical Axis Wind Turbines

6.4 Hydroelectric power plants

Convert the hydraulic potential energy from water into electrical energy. Such plants are suitable where water with suitable ***head*** is available. The layout covered in this article is just a simple one and only cover the important parts of hydroelectric plant.

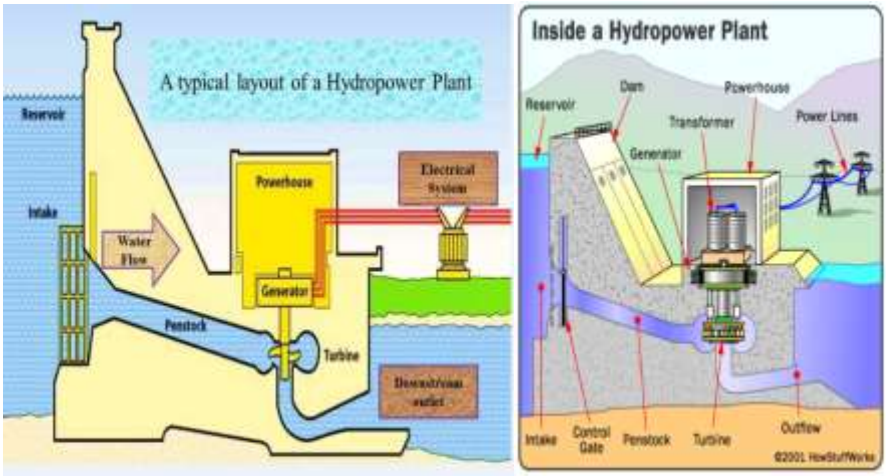


Figure 36:-Typical lay out of Hydropower Plant

- **Dam**
  Dams are structures built over rivers to stop the water flow and form a reservoir. The reservoir stores the water flowing down the river. This water is diverted to turbines in power stations. The dams collect water during the rainy season and store it, thus allowing for a steady flow through the turbines throughout the year. Dams are also used for controlling floods and irrigation. The dams should be water-tight and should be able to withstand the pressure exerted by the water on it. There are different types of dams such as arch dams, gravity dams and buttress dams. The height of water in the dam is called *head race*.
- **Spillway**

A spillway as the name suggests could be called as a way for spilling of water from dams. It is used to provide for the release of flood water from a dam. It is used to prevent over toping of the dams which could result in damage or failure of dams. Spillways could be controlled type or uncontrolled type. The uncontrolled types start releasing water upon water rising above a particular level. But in case of the controlled type, regulation of flow is possible.

- **Penstock and Tunnels**

Penstocks are pipes which carry water from the reservoir to the turbines inside power station. They are usually made of steel and are equipped with gate systems. Water under high pressure flows through the penstock. A tunnel serves the same purpose as a penstock. It is used when an obstruction is present between the dam and power station such as a mountain.

- **Surge Tank**

Surge tanks are tanks connected to the water conductor system. It serves the purpose of reducing water hammering in pipes which can cause damage to pipes. The sudden surges of water in penstock are taken by the surge tank, and when the water requirements increase, it supplies the collected water thereby regulating water flow and pressure inside the penstock.

- **Power Station**

Power station contains a turbine coupled to a generator. The water brought to the power station rotates the vanes of the turbine producing torque and rotation of turbine shaft. This rotational torque is transferred to the generator and is converted into electricity.
The used water is released through the *tail race*. The difference between head race and tail race is called gross head and by subtracting the frictional losses we get the net head available to the turbine for generation of electricity.

6.5 Biomass power plants

Biomass power plants range from small biogas plants to large scale electricity generating plants. Biogas plants convert organic materials into biogas through bacteria digestion. While large scale biomass power plants burn the organic materials or waste and generate heat which can drive steam turbines to produce electricity.

- **Biogas plant**

A typical biogas plant consists of the following parts:

- ✓ Mixing tank with inlet pipe: this where the organic material is mixed with water and flows into the digester
- ✓ Digester: is the main part of the plant where the mixed organic material is digested by bacteria to create the biogas
- ✓ Compensating and removal tank: this a tank where the digested material is removed as a slurry
- ✓ Gasholder: this is the part of the plant where the biogas is stored
- ✓ Gas pipe: the biogas is extracted through the gas pipe for use

- ✓ Entry hatch: this is an opening where it is closed in normal operation but may be opened for inspection and maintenance.

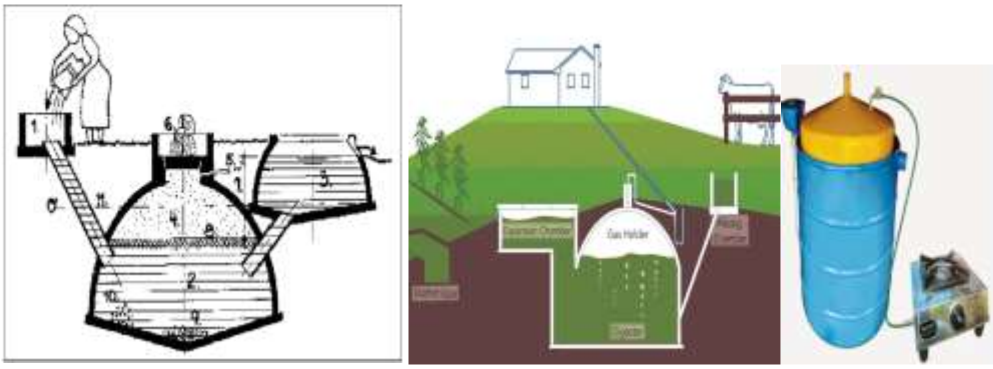


Figure 37:- Fixed Dom Biogas Plant and Biogas stove

The biogas can be then used to:

- ✓ Produce electricity and heat by burning it in a combustion engine
- ✓ Use it as biofuel e.g. for cars
- ✓ Use it for cooking or heating
- ✓ Use it as energy storage

Self-Check – 6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Match the components in column A to their respective power plants in column B

Column A	Column B
____ 1. Penstock	A. Tidal power plant
____ 2. Separator	B. Wind power plant
____ 3. Basin	C. Hydropower plant
____ 4. Rotor	D. Biogas plant
____ 5. Digester	E. Geothermal power plant

Note: **Satisfactory rating - 3 points** **Unsatisfactory - below 3 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer question

Operation Sheet 1	Basic electricity

Operation Title: Procedure to measure current, voltage and resistance in a circuit

Step -1.Wear appropriate personal protective equipment

Step -2. Prepare and plan work place

Step -3 Select appropriate equipment and tools

Step -4 Perform the given project accurately

Step -5 Switches “ON” the multimeter and point selector switch in “Ω” section.

Step -6. Connect the red lead to “V/Ω” and black lead to “COM”

Step -7. Read the given colour code value indicated in Schematic symbol correctly

Step -8. Select the Ohm-scale within the range and turn off the power source

Step -9. Place the black probe of the multi-meter in one terminal of the resistor.

Step -10. Place the red probe of the multi-meter in the other terminal of the resistor.

Step -11 Measure the value each resistor

Step -12 Point selector switch in “V” section.

Step -13 Connect the leads appropriately to the right polarity

Step -14 Measures the voltage drop across each resister by giving voltage source

Step -15 Point selector switch in “A” section and change the lead position properly

Step -16 connect the leads to the right polarity

Step -17Measure current by disconnecting one leg of a resistor inserting the ammeter in series with resistors

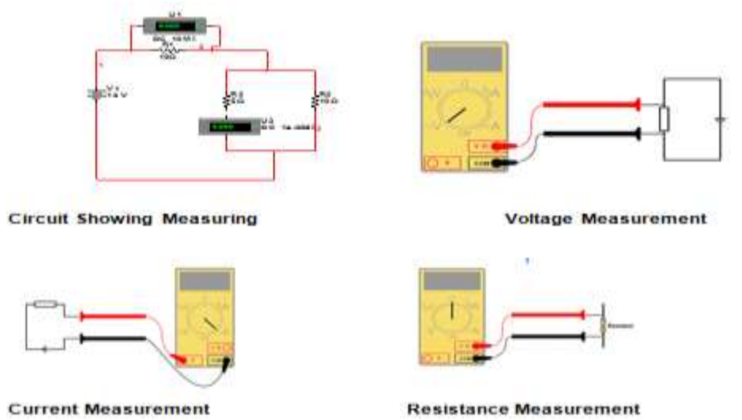


Figure 38:-Ohms Law Circuit Measurement

LAP Test	Practical Demonstration

Name: _____________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task 1. Measure the current, voltage & resister in the circuit.

List of Reference Materials

1. Jan Kai Dobelmann and Antje Klauss-Vorreiter, *Promotion of the Efficient Use of*
2. *Renewable Energies in Developing Countries, Level 2 Technician Training Manual,* DGS REEPRO, 2009.
3. Bhatia,S.C., &Gupta,R.K., Textbook of Renewable Energy,Woodhead Publishing India, 2018.
4. https://www.youtube.com/watch?v=mc979OhitAg
5. https://www.youtube.com/watch?v=WoN1nou5t1Q
6. https://vittana.org/11-advantages-and-disadvantages-of-renewable-energy
7. https://venturesolar.com/the-major-advantages-and-disadvantages-of-solar-energy-2/
8. http://www.susana.org/_resources/documents/default/2-1799-biogasplants.pdf
9. https://www.pinterest.com/pin/831054937461949360/

Solar PV System Installation and Maintenance

Level-II

Learning Guide -11

Unit of Competence	**Apply Principles of Photovoltaic system Operation**
Module Title	**Applying Principles of Photovoltaic system Operation**
LG Code	EIS PIM2 M04 LO2**LG-11**
TTLM Code	EIS PIM2 **TTLM 0819v1**

LO2: Explain the basics of photovoltaic (PV) technology

Instruction Sheet	Learning Guide:-11

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics

- Basic terms of PV technology
- Conversion of sunlight into electric current
- Different types of photovoltaic cells
- Identifying different PV configurations

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to:-**

- state and describe basic terms of PV technology
- Describe conversion of sunlight into electric current
- Describe different types of photovoltaic cells
- describe different PV configurations

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3 and Sheet 4 in page 52, 62, 65 & 68respectively.
4. Accomplish the Self-check 1, Self-check 2, Self-check 3 and Self-check 4 in page 61, 64,67 & 74 respectively
5. If you earned a satisfactory evaluation from the Self-check proceed to Operation Sheet 1 in page 75.
6. Do the LAP test in page 76.

Information Sheet-1	Basic terms of PV technology

1.1. Definition: Photo voltaic, the term photo voltaic (PV) is drive from Greek word meaning:

- ✓ Photo... light and
- ✓ Voltaic ….. Electricity.

- **Photovoltaic (PV) Technology:** is a process of generating electrical energy from the Energy of solar radiation. The principle of conversion of solar energy into electrical Energy is based on the effect called photovoltaic effect. The smallest part of the device that converts solar energy into electrical energy is called solar cell. Solar cells are in fact large area semiconductor diodes, which are made by combining silicon material with different impurities. The sand, a base material for semiconductor, is the most abundantly available raw material in the world. The ordinary sand (SiO_2) is the raw form of silicone.

  The solar energy can be considered as a bunch of light particles called photons. At Incidence of photon stream onto solar cell the electrons are released and become free. The newly freed electrons with higher energy level become source of electrical energy. Once these electrons pass through the load, they release the additional energy gained during collision and fall into their original atomic position ready for next cycle of electricity generation. This process of releasing free electrons (generation) and then falling into original atomic position (recombination) is a continuous process as long as there is the stream of photons (solar energy) falling onto the solar cell surface.

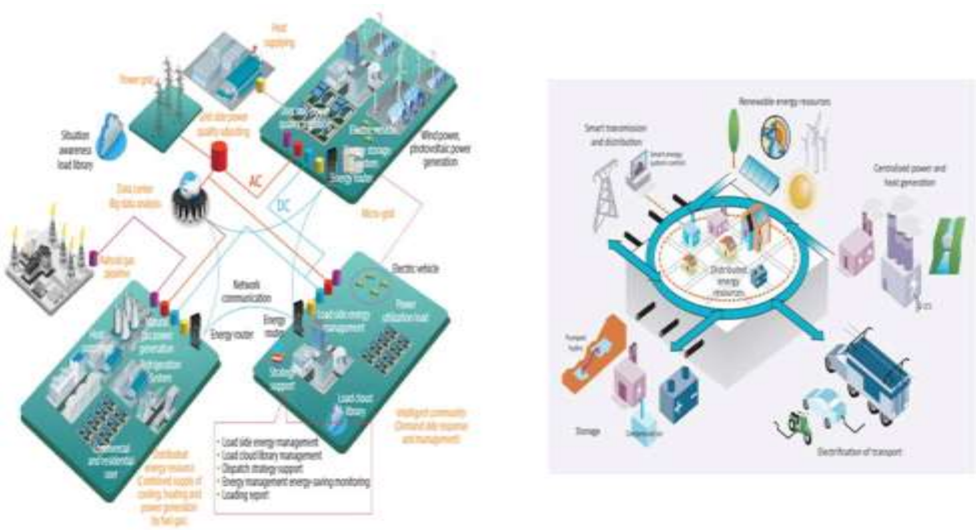


Figure 39: Build up of a solar cell

1.2. Types of Photovoltaic (PV) Cells

Crystalline silicon (c-Si) is the crystalline forms of silicon, either multicrystalline silicon (multi-Si) consisting of small crystals, or monocrystalline silicon (mono-Si), a continuous crystal. Crystalline silicon is the dominant semiconducting material used in photovoltaic technology for the production of solar cells.

Solar cells made of crystalline silicon are often called conventional, traditional, or first generation solar cells, as they were developed in the 1950s and remained the most common type up to the present time.

Solar cells made from c-Si are single-junction cells and are generally more efficient than their rival technologies, which are the second-generation thin film solar cells, the most important being CdTe, CIGS, and amorphous silicon (a-Si).

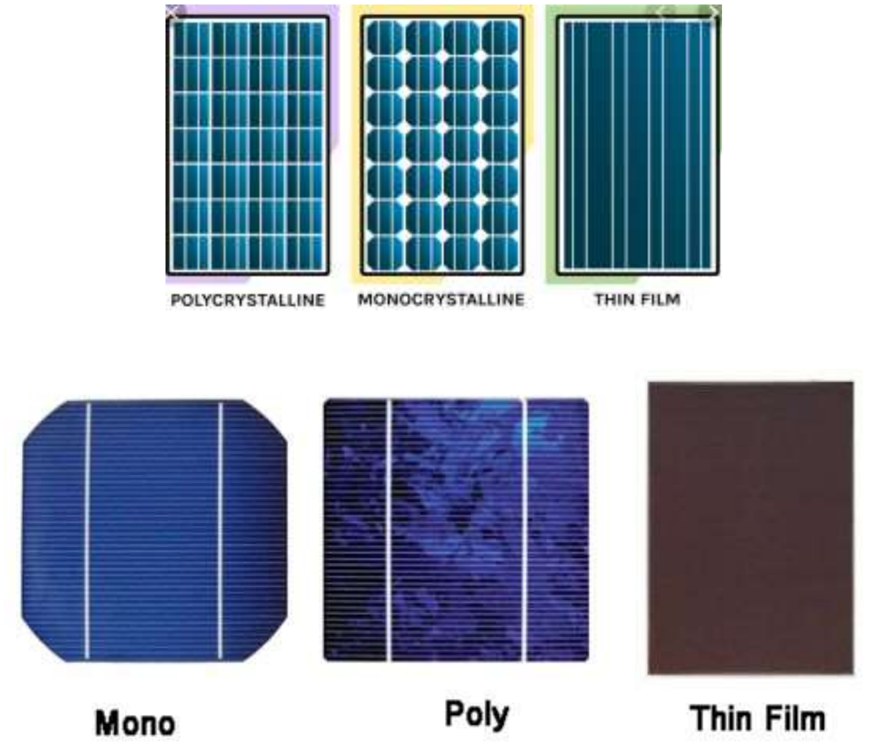


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Figure 40:- Types of PV cells

- **Mono crystalline silicon PV Cells**

  These are made slicing cells from a single cylindrical crystal of silicon. This is the most efficient photovoltaic technology, with cells typically converting around 23% of the sun's energy into electricity. The manufacturing process required to produce mono-crystalline silicon is complicated, resulting in slightly higher costs than other technologies.

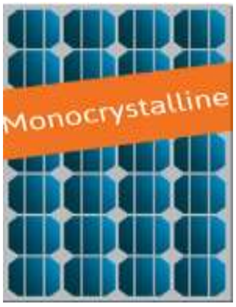


Figure 41:-Mono-Crystalline cells

- **Polycrystalline silicon PVCells**

  Also sometimes known as multi crystalline cells, polycrystalline silicon cells are made from cells cut from an ingot of melted and re-crystallized silicon. The ingots are then saw-cut into very thin wafers and assembled into complete cells. They are generally cheaper to produce than monocrystalline cells, due to the simpler manufacturing process, but they tend to be slightly less efficient, with average efficiencies of around 12%.

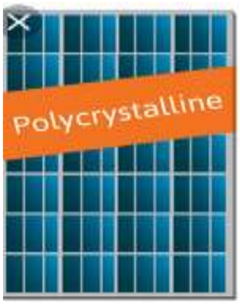


Figure 42:-Poly Crystalline cells

Figure 43:-Steps of production of crystalline PV cells

- **Thin-film PV cells**

  A thin-film solar cell is a second generation solar cell that is made by depositing one or more thin layers, or thin film (TF) of photovoltaic material on a substrate, such as glass, plastic or metal. Thin-film solar cells are commercially used in several technologies, including cadmium telluride (CdTe), copper indium gallium diselenide (CIGS), and amorphous thin-film silicon (a-Si, TF-Si).

Figure 44:-Thin film

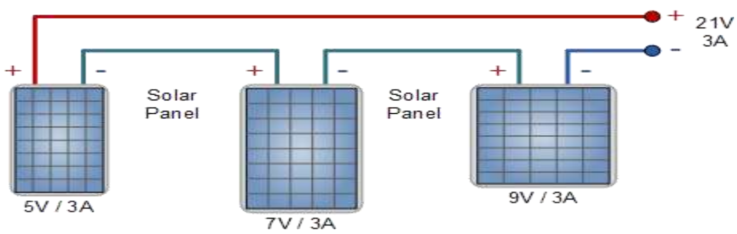
Amorphous silicon can be deposited on a wide range of substrates, both rigid and flexible. Amorphous silicon is an allotropic variant of silicon, and amorphous means "without shape" to describe its non-crystalline form.

Figure 45:-Amorphous

1.3. PV connection

A bulk silicon PV module consists of multiple individual solar cells connected, nearly always in series, to increase the power and voltage above that from a single solar cell.There are two main types of connecting solar panels

- **In series: -** In series connection when two cells are connected, voltages are added while the current remains same. You connect solar panels in series when you want to get a higher voltage



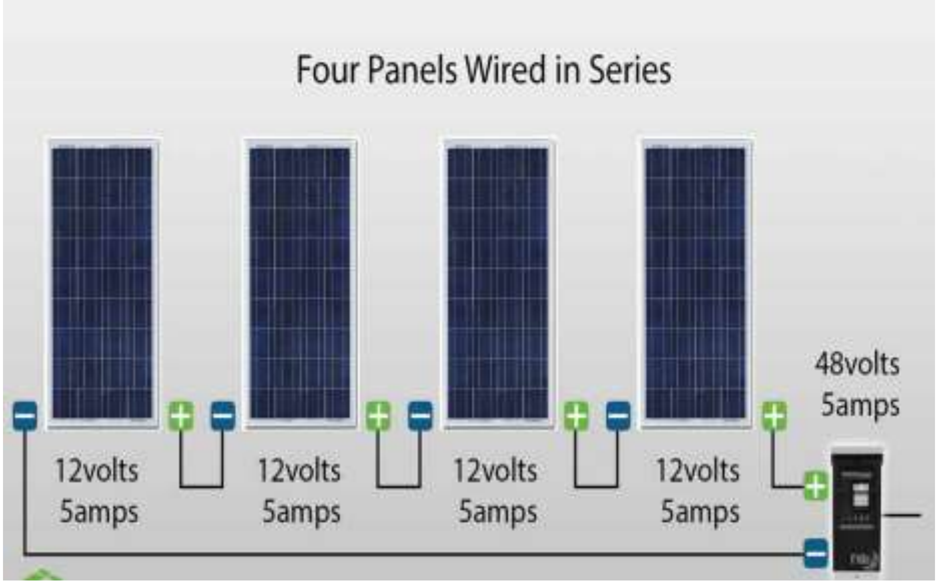
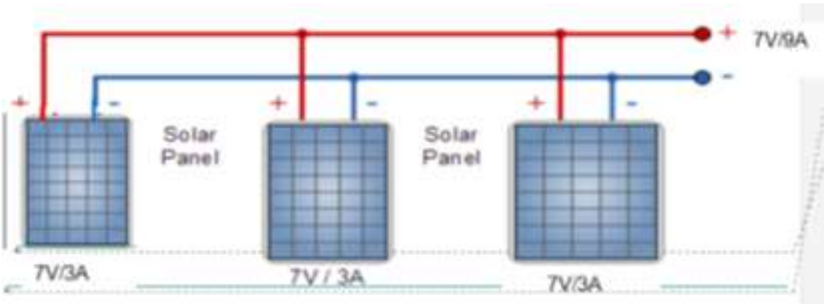


Figure 46:-Series Connection

The following videos show about series, parallel & combination connections
https://www.coursera.org/lecture/solar-cells/series-and-parallel-connections-XwXbe

- **In parallel connection: -**in parallel connection voltage remains same and the amperage adds up. If you need to get higher current, you should connect your panels in parallel.
  Strictly parallel connections are mostly utilized in smaller, more basic systems, and usually with PWM Controllers, although they are exceptions. Connecting your panels in parallel will increase the amps and keep the voltage the same. This is often used in 12V systems with multiple panels as wiring 12V panels in parallel allows you to keep your charging capabilities 12V.



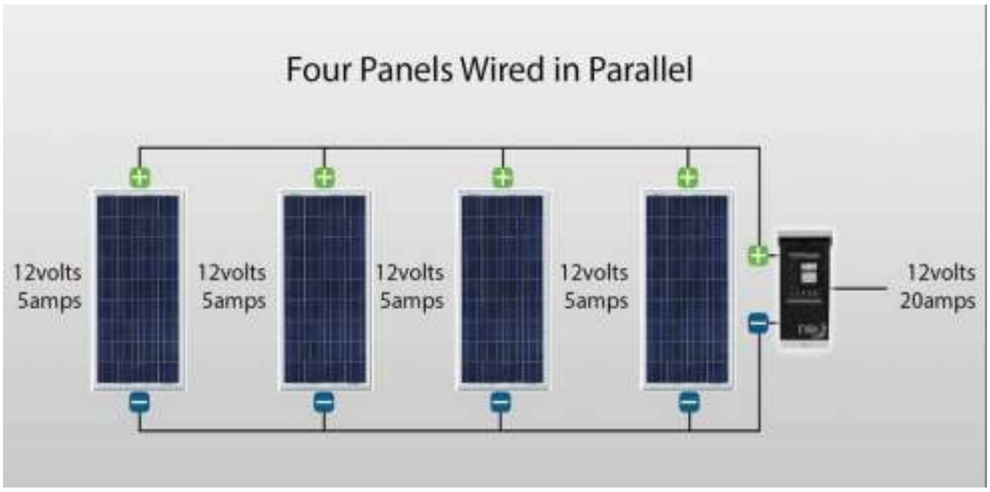


Figure 47:-Parallel Connection

https://www.coursera.org/lecture/solar-cells/series-and-parallel-connections-XwXbe

- **Series parallel PV connection: -**When connecting multiple solar panels in a 12-48 volt off-grid system, you have a few options: parallel, series, or a combination of the two Solar Panel arrays are usually limited by one factor, the charge controller. Charge controllers are only designed to accept a certain amount of amperage and voltage. Often times for larger systems, in order to stay within those parameters of amperage and voltage, we have to be creative and utilize a series parallel connection. For this connection, a string is created by 2 or more panels in series. Then, an equal string needs to be created and paralleled.

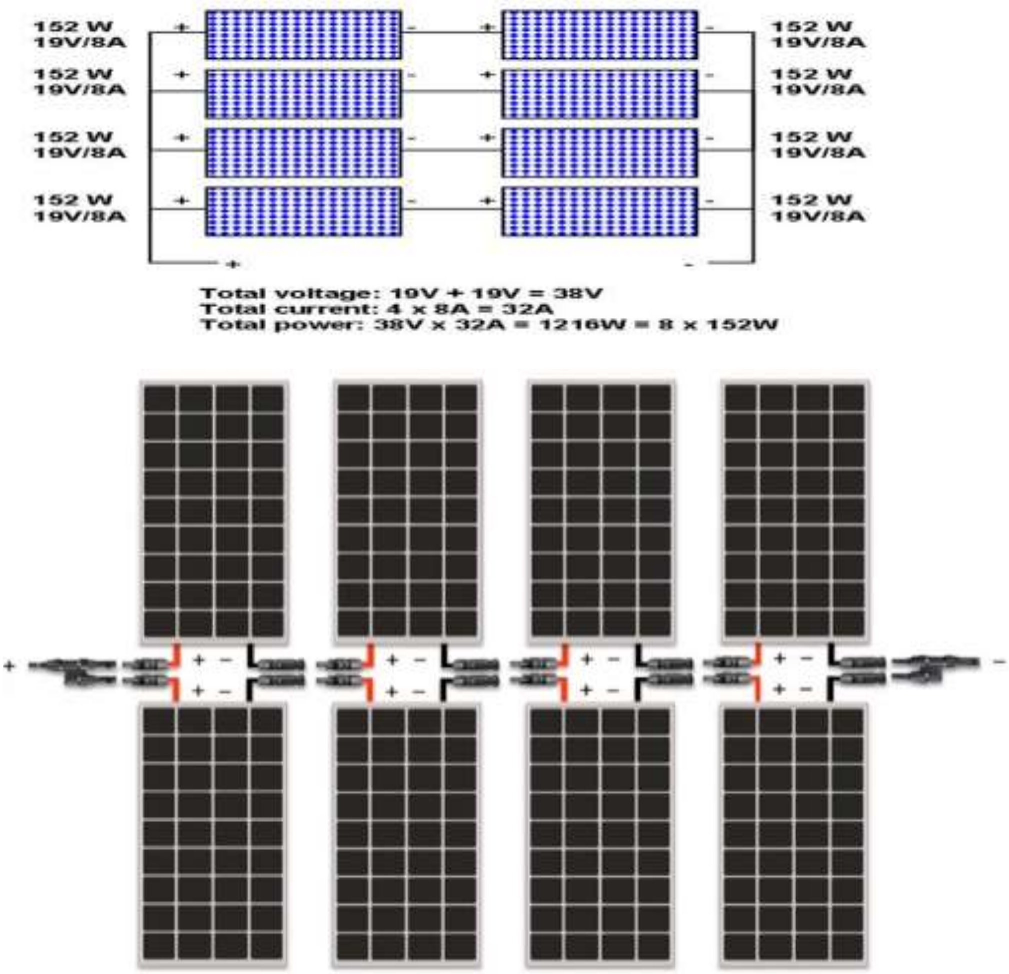


Figure 48:-Series Parallel Connection
https://www.youtube.com/watch?v=O8GgRIIB1Yc

1.4. Application of PV Power

Photovoltaic (PV) cells are one of the ways to harness solar energy. PV cells convert sunlight directly to electricity and can be influential in meeting the world's energy demand. PV systems are being used in a variety of applications.

Table 6: Application of PV power

No.	Application	Description	Symbol
1	**Mobile Banking**	**Mobile banking** refers to the use of a smartphone or other cellular device to perform online **banking** tasks. Remote access is possible using power from PV systems.	
2	**Residential Homes**	Homes in rural and Urban areas use PV systems to power electrical appliance	
3	**Holiday Properties**	Remote holiday properties employ PV power systems	
4	**Telecom**	The telecommunication sector uses PV systems to power Remote antennas and masts	
5	**Street Sale Light**	Movable street sell carts use PV panels. Street lights may also be powered from PV systems directly installed on the street light poles.	
6	**Health**	In health centres PV systems are used to power refrigerators to preserve medicine and vaccination	

7	**Cell Phone Charging**	The average solar-powered charger takes between 6 and 10 hours to charge an electronic device, such as a cell phone.	
8	**Water pumping**	Solar water pumping employs PV systems to power motor driven pumps	

1.5. Advantages of the PV technology:

- ✓ Environmental friendly it does not produce the greenhouse gases CFC
- ✓ It is limitless supply and in abundance
- ✓ Because of the sun solar energy founds every where
- ✓ Economic viability for future
- ✓ Low maintenance & operating cost
- ✓ Solar PVs do not produce noise when in operation
- ✓ Does not have mechanical moving parts that can fail or break.
- ✓ No fuel/running cost
- ✓ The technology is save & reliable
- ✓ Energy independence from the national grid
- ✓ Independence of import from foreign nation (save of currency)

1.6. Disadvantages of Solar Energy

- ✓ Cost. The initial cost of purchasing a solar system is fairly high
- ✓ Weather Dependent. Although solar energy can still be collected during cloudy and rainy days, the efficiency of the solar system drops
- ✓ Solar Energy Storage Is Expensive
- ✓ Uses a Lot of Space
- ✓ Needs to be recycled at the end of lifetime, especially battery waste needs to be collected to not harm the environment

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions below

1. The term photo voltaic (PV) is derived from England word
2. Photovoltaic (PV) Technology is a process of generating electrical energy from the Energy of solar radiation.
3. The solar energy can be considered as a bunch of light particles
4. There are six types of photo voltaic cells
5. Mon crystalline silicon PV panels are a multi crystalline cells

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer question

Information Sheet-2	Conversion of sunlight into electric current

2.1 Definition of photovoltaic conversion

Photovoltaic cells, or solar cells, convert solar radiation into electricity using a process known as the “photovoltaic effect.” During this process, the materials in the solar cell produce electrons when exposed to the photons in sunlight.
Solar-powered photovoltaic (PV) panels convert the sun's rays into electricity by exciting electrons in silicon cells using the photons of light from the sun. This electricity can then be used to supply renewable energy to your home or business.

Photovoltaic energy is the conversion of sunlight into electricity. A photovoltaic cell, commonly called a solar cell or PV, is the technology used to convert solar energy directly into electrical power. A photovoltaic cell is a non-mechanical device usually made from silicon alloys.

The ultimate efficiency of a silicon photovoltaic cell in converting sunlight to electrical energy is around 20 per cent, and large areas of solar cells are needed to produce useful amounts of power.

When photons (light energy) strike the surface of the semiconducting material electrons are let loose. The delocalization of electron creates a flow of charge which produces electricity. Thus, it is the semiconductor present in a photovoltaic cell which is responsible for converting light to electricity
Simply put, a solar panel works by allowing photons, or particles of light, to knock electrons free from atoms, generating a flow of electricity. Solar panels actually comprise many, smaller units called photovoltaic cells. (Photovoltaic simply means they convert sunlight into electricity.)

Solar PV cells generate electricity by absorbing sunlight and using that light energy to create an electrical current. There are many photovoltaic cells within a single solar panel, and the current created by all of the cells together adds up to enough electricity to help power your home.
Solar photovoltaic are made with a number of parts, the most important of which are silicon cells. The manufacturing process involves cutting individual wafers of silicon that can be affixed onto a solar panel. Mono-crystalline silicon cells are more efficient than polycrystalline or amorphous solar cells.

Conversion of light energy in electrical energy is based on a phenomenon called photovoltaic effect. When semiconductor materials are exposed to light, the some of the photons of light ray are absorbed by the semiconductor crystal which causes a significant number of free electrons in the crystal.
Everybody know that the solar cells or the photovoltaic cells are the electrical devices that converts the energy of sunlight into the electricity by the photovoltaic effect which is the ability of matter to emit the electrons when a light is shone on it .

2.2 Main components of a solar photovoltaic system.

- ✓ Photovoltaic Array: this is the core of the system, composed of several solar modules which are in turn composed of solar cells.
- ✓ Battery Bank
- ✓ Charge Controller
- ✓ DC And Ac Disconnect
- ✓ Inverter
- ✓ Oprional: Electric Meter

.

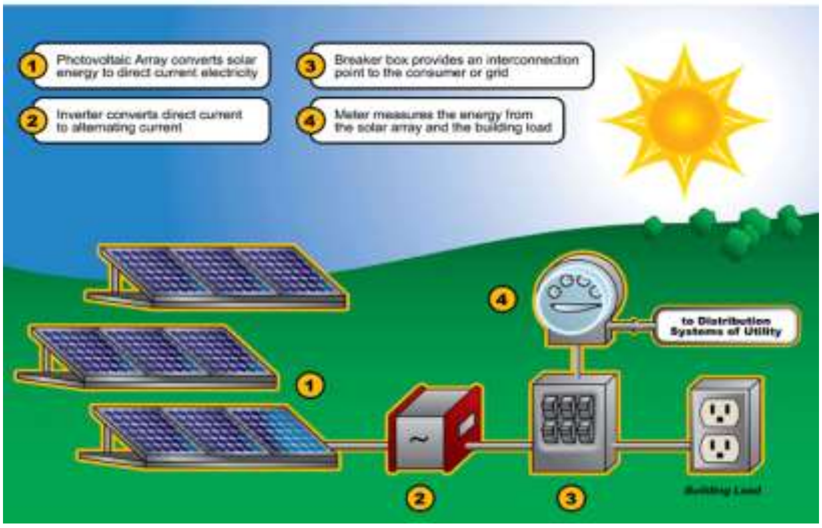


Figure 49:- solar radiation converted into electricity

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions below

1. Solar cells, also called photovoltaic (PV) cells by scientists, convert sunlight indirectly into electricity
2. Photovoltaic cells, or solar cells, convert solar radiation into electricity using a process known as the photovoltaic effect.
3. Solar-powered photovoltaic (PV) panels convert the sun's rays into fuel energy by exciting electrons in silicon cells using the photons of light from the sun.
4. A photovoltaic cell is a mechanical device usually made from silicon alloys.
5. Photovoltaic Array is the core of the system, composed of several solar modules which are in turn composed of solar cells.

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: _______________

Short answer question

Information Sheet-3	Different types of photovoltaic cells

3.1 **Definitions of photovoltaic cells:** A photovoltaic cell (PV cell) is a specialized semiconductor diode that converts visible light into direct current (DC). Some PV cells can also convert infrared (IR) or ultraviolet (UV) radiation into DC electricity. Large sets of PV cells can be connected together to form solar modules, arrays, or panels.

3.2 Different types of photovoltaic cells

There are three types of PV cell technologies that dominate the world market: monocrystalline silicon, polycrystalline silicon, and thin film.

For Further Reading

- ✓ Photovoltaic cell.
- ✓ Solar panel.
- ✓ P-n junction.
- ✓ Semiconductor.
- ✓ Concentrated photovoltaic.

The Two Types of Solar Energy, Photovoltaic and Thermal. Photovoltaic technology directly converts sunlight into electricity. Solar thermal technology harnesses its heat. These different technologies both tap the Sun's energy, locally and in large-scale solar farms.

Solar panels have the highest efficiency rates since they are made out of the highest-grade silicon. The efficiency rates of monocrystalline solar panels are typically 15-20%. SunPower produces the highest efficiency solar panels on the U.S. market today.

3.3 **Solar PV Principle:**

Photovoltaic (PV) effect is the conversion of sunlight energy into electricity. In a PV system, the PV cells exercise this effect. Semi-conducting materials in the PV cell are doped to form P-N structure as an internal electric field.

Photo voltaic directly convert solar energy into electricity. They work on the principle of the photovoltaic effect. When certain materials are exposed to light, they absorb photons and release free electrons. This phenomenon is called as the photoelectric effect.

3.4. Photovoltaic cells:

Photovoltaic cells are based on a related phenomenon called the photovoltaic effect, and they convert light directly into electricity. Let’s look at how.

Most photovoltaic cells are made of silicon, an element that is at the heart of all modern electronics. Silicon is special because of the arrangement of its electrons—it has four out of the possible eight electrons in its outermost shell. This means that it makes perfect covalent bonds with four other silicon atoms, forming a lattice structure.

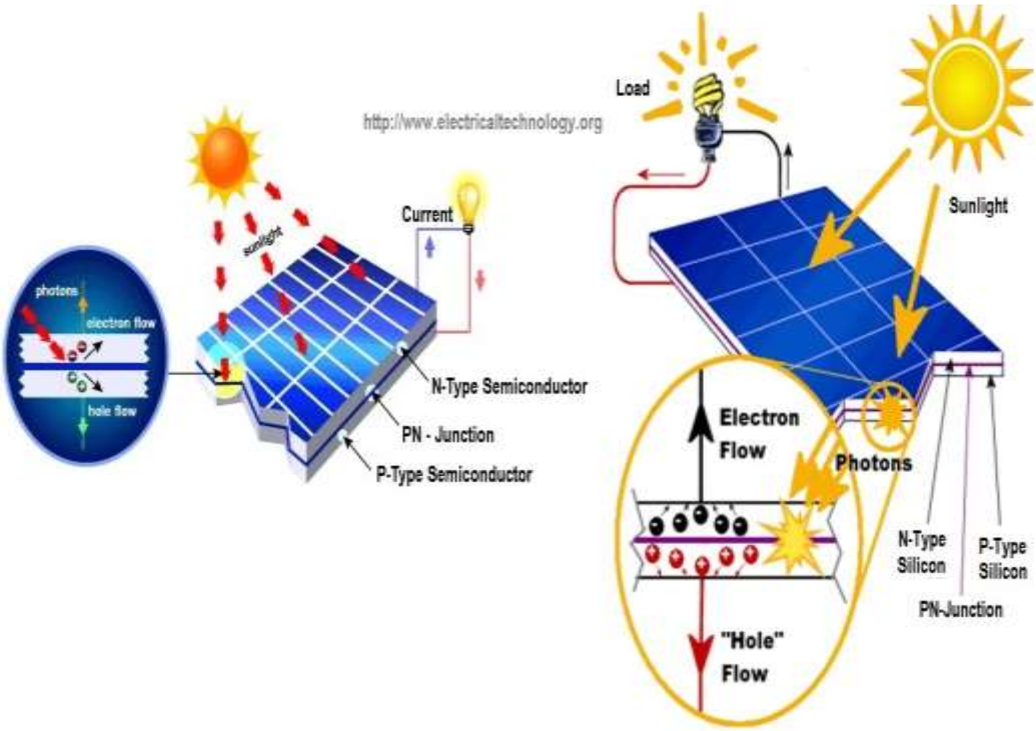


Figure 50:-Basic operating Principle of solar Cell

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer for the following questions below

1. All are components of photo voltaic cell except one
   A. Photovoltaic cell.
   B. Solar panel.
   C. P-n junction.
   D. Semiconductor.
   E. Concentrated photovoltaic.
   F. Voltmeter
2. Identify the one which is not types of photovoltaic cell
   A. mono crystalline silicon
   B. polycrystalline silicon
   C. Thin film.
   D. Tetra crystalline cupper

***Note:* Satisfactory rating – 1.5 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ___________

Rating:

Name: ___________________________ Date: ________________

Short answer question

Information Sheet-4	Describing different PV configurations

4.1 Define PV configurations

Solar modules can be used for many different application. Depending on the purpose different system configurations are being used. Solar modules can be used in very simple systems with only a few components (e.g. solar lamps or pico systems) or can be combined in more complex systems to supply more power (e.g. Solar Home Systems). Solar energy can even be used on a utility scale to produce power for the public grid.

In the following paragraphs some system configurations or types of PV systems are introduced.

- **Solar lamps**

A **solar lamp** also known as solar light or solar lantern, is a lighting system composed of an LED lamp, solar panels, battery, charge controller and there may also be an inverter. The lamp operates on electricity from batteries, charged through the use of solar photovoltaic panel.

Solar-powered household lighting can replace other light sources like candles or kerosene lamps. Solar lamps have a lower operating cost than kerosene lamps because renewable energy from the sun is free, unlike fuel. In addition, solar lamps produce no indoor air pollution unlike kerosene lamps. However, solar lamps generally have a higher initial cost, and are weather dependent.

Figure 51:-solar lamp

Figure 52: solar Lantern

- **Pico solar systems**

  We have all seen large photovoltaic solar panels on top of roofs or in array fields generating many kilowatts of free electricity. But there is another form of solar energy that has started to emerge called Pico solar or Pico pv, that uses small compact and light weight solar photovoltaic panels to generate just a few watts of power in a wide range of small and portable applications.

Pico Solar Systems are becoming more common place with us using Pico solar cells in our daily lives without even knowing it. Pico solar systems are much smaller and cheaper than traditional solar systems but have the potential to provide useful amounts of electrical power to charge the increasing number of low power gadgets such as calculators, toys, cameras, mp3 players, cell phones, tablets, and other portable electronic devices etc., as well as a variety of chargers all use Pico solar cells to charge batteries

Figure 53:-Pico Light

A typical Pico solar system generates relatively small and safe amounts of electricity of about 5 volts, affectionately called “Pico power”, which means that the amount of electricity generated by a Pico Solar Charger is low but can still be incredibly useful for people travelling or without access to a mains powered charger. Pico solar systems come in a range of shapes and sizes, with a typical system being made up of the following components:

- ✓ A Pico PV solar module usually less than 20 watts-peak to capture the sun’s light to generate the electricity.
- ✓ Rechargeable dry-cell battery or batteries of less than 12 volts to store the solar power for use when needed.

The following videos show about the use of Pico PV solar

https://www.youtube.com/watch?v=WTzV8kahpNU

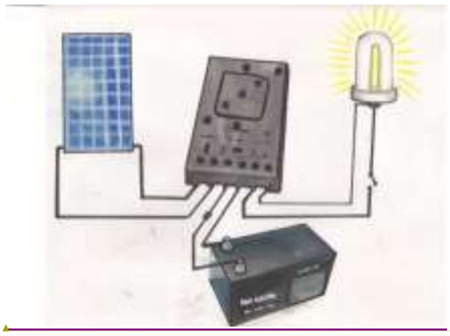
https://www.youtube.com/watch?v=Sc8bX4sNje0

https://www.youtube.com/watch?v=W6gKoLrHuAU

- **DC coupled Solar Home System (DC only):-**

  A simple 12 volt DC system provides lighting for small houses. Low wattage (<150W) solar panels are connected to a simple charge controller which charges the battery. The lamps and other 12 volt DC appliances are connected to the charge controller as shown in below figure. There is only DC power available and the amount is limited to the battery capacity and the PV production. Available appliances are limited for 12 volt DC power, because wire resistance limits power to a few hundred watts. This system is not connected to AC power lines and is considered to be “off the grid”.

  If 2, 3 or 4 batteries are connected in series the system can also be a 24V, 36V or 46V system. The number of PV modules should also be increased to be able to charge the batteries.



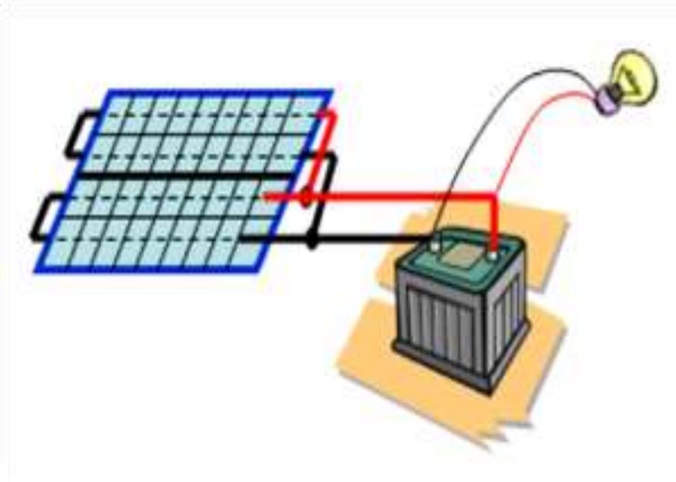
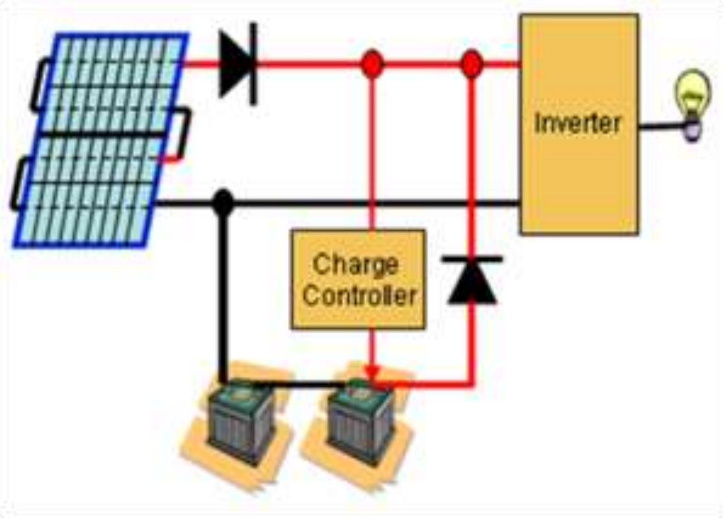


Figure 54:-DC-coupled Solar Home System (DC only)

- **Solar Home Systems:** Like in the DC only Solar Home System, PV modules are connected to a charge controller which charges the battery and provides a DC power outlet. Additionally, there is an inverter connected to the battery which converts the DC power into AC. Conventional AC appliances like AC fridges or TVs can be connected to the inverter - under the condition that the consumption of the appliances matches the size of the PV system!

These systems typically have PV generators in the range of 100W – 5000W.

If a public grid is available. DC coupled solar home systems can also be connected to the grid. To connect them, an inverter charger is needed instead of the simple inverter. It must be able to connected to the grid and create an island grid in case of power failure. This type of system is often used when the available grid is rather unstable.



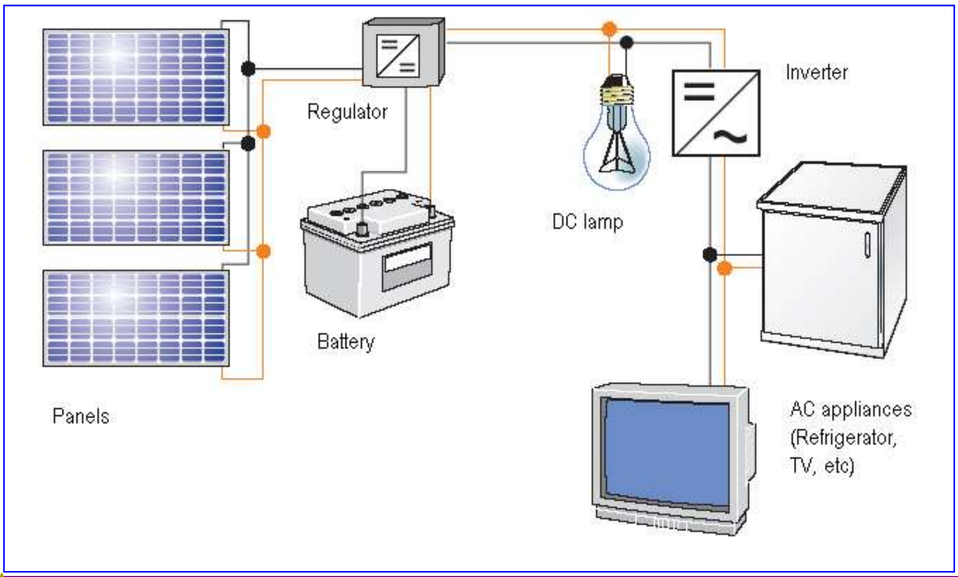


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Figure 55:-**Solar Home System (with AC outlet)**

Grid connected PV Systems: The solar modules are connected to a grid-tied inverter which converts the DC solar electricity directly to 220V AC. This system is connected to AC power lines (i.e., connected to the grid) as shown in Figure 54.

The customer can use the solar electricity during daytime. Depending on the legal situation, excess electricity can be sold to the power company during the day. During the night the client buys power from the power company.

In this setup no batteries are used which reduces the costs of the systems but on the other hand, there will not be any power failure when there is a power failure in the grid. This kind of PV system cannot operate without the grid and switches off during power failure.

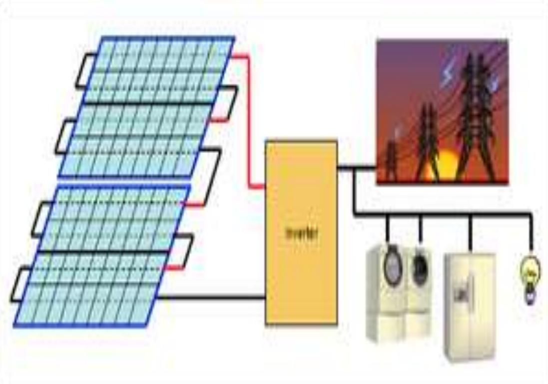


Figure 56:-Grid-connected Solar System

It is possible to use a PV system as backup system or uninterrupted power supply system (UPS). Then batteries and a control unit for the batteries, an inverter-charger are added to the system. The inverter charger not only charges the batteries but can also supply an island grid which enables the system to supply power during power failures of the public grid. This system configuration is called AC-coupled backup system.

4.2 The major parts of a DC-coupled Solar Home System

- ✓ PV modules (which together form a PV array) with racking.
- ✓ A battery-based inverter
- ✓ A combiner box (for systems with more than 2 strings)
- ✓ A charge controller.
- ✓ A battery bank.
- ✓ DC over current protection.
- ✓ AC disconnects (for stationary SHS).

4.3. Necessary tools and Equipment you need to install solar panels

Fortunately, most of the tools needed for a PV install are commonly used and easily found.

Table 7:- Solar tools and Equipment

Basic Tools Needed for Installation			
No		No	
1	Angle finder	14	Wire strippers
2	Torpedo level	15	Crimpers
3	Fish tape	16	Needle-nose pliers
4	Chalk line	17	Lineman's pliers
5	Cordless drill (14.4V or greater), multiple catteries	18	Slip-joint pliers
6	Unibit and multiple drill bits (wood, metal, masonry)	19	Small cable cutters
7	Hole saw	20	Large cable cutters
8	Hole punch	21	AC/DC multimeter
9	Torque wrench with deep sockets	22	Hacksaw
10	Nut drivers (most common PV sizes are 7/16”, ½”, 9/16”)	23	Wire strippers
11	Tape measure	24	Caulking gun

12	Blanket, cardboard or black plastic to keep modules from going “live” during installation	25	Fuse Pullers
13	Heavy duty extension cords	26	Screwdriver (flat and Philips)

Self-Check -4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.Say true or false for the following questions below

1. In urban Home System a simple 12 volt DC system provides lighting.
2. In Log Cabin System larger panels providing 200- 400 volts are connected
3. In country Home System panels providing 24- 96 volts are connected
4. Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels.
5. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems.

***Note:* Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ____________________________ Date: _________________

Short answer questions

Operation Sheet 1	Identify PV Components

Operation Title: Procedure to identify PV components
Given the PV system components

Step-1Plan and prepare work place
Step-2Use appropriate tools and Instruments
Step-3Identify and record models of the given PV components
Step- 4. Identify the capacity/ratings of each component (in terms of power, voltage, current ratings etc.)
Step-5.For the given PV module identify the type of solar cells used (Monocrystalline, polycrystalline, thin film)
Step-6.For the given charge controller identify the connections for the PV module, Battery and Load

LAP Test	Practical Demonstration

Name: ____________________________ Date: _______________

Time started: _______________________ Time finished: _______________

Instructions: Given necessary materials, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task 1.Describe each components of Photovoltaic (PV) system

List of Reference Materials

1. KhamphoneNanthavong, *Promotion of the Efficient Use of Renewable Energies in Developing Countries: Photovoltaic,* DGS REEPRO, 2008.
2. ChristofBuam, *Solar Photovoltaic: Basic in Solar Photovoltaic Systems,* 2nd edition, Don Bosco, Addis Ababa, 2008.
3. SNV, *Solar PV Training and Refferal Manual,* Developed by SNV for the Rural Solar Market Development, 2015.
4. SNV, *Solar PV Standardized Training Manual,* Developed by SNV for the Rural Solar Market Development, 2015.
5. David Tan and AngKianSeng, *Handbook for Solar Photovoltaic (PV) Systems,* Energy Market Authority and Building and Construction Authority, 2019.
6. Mark Hankins, *Stand-Alone Solar Electric Systems: the Earthscan Expert Handbookfor Planning, Design and Installation,*Earthscan, 2010.
7. Jan Kai Dobelmann and Antje Klauss-Vorreiter, *Promotion of the Efficient Use ofRenewable Energies in Developing Countries, Level 2 Technician Training Manual,* DGS REEPRO, 2009.

8. CLEAN (Clean Energy Access Network), *Installation, Operation and Maintenance of Solar PV Microgrid Systems: A hand book for trainers,* GSES Indian Sustainable Energy, 2016.
9. https://www.youtube.com/watch?v=WTzV8kahpNU
10. https://www.youtube.com/watch?v=Sc8bX4sNje0
11. https://www.youtube.com/watch?v=W6gKoLrHuAU
12. https://www.coursera.org/lecture/solar-cells/series-and-parallel-connections-XwXbe
    https://www.youtube.com/watch?v=O8GgRIIB1Yc

Solar PV System Installation and Maintenance

Level-II

Learning Guide -12

Unit of Competence	**Apply Principles of Photovoltaic system Operation**
Module Title	**Applying Principles of Photovoltaic system Operation**
LG Code	**EIS PIM2 M04 Lo3LG-12**
TTLM Code:	**EIS PIM2 M01 TTLM 0819v1**

LO3: Describe PV components

Instruction Sheet	Learning Guide 12

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics

- PV components
- Explaining PV components
- Characteristics of PV components
- Limitations of the various PV components
- Strengths and weaknesses of different PV system components

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, **you will be able to:-**

- List PV components
- List and explain uses of PV components
- Explain characteristics of PV components
- Explain limitations of the various PV components
- Explain strengths and weaknesses of the different PV system components

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1, Sheet 2, Sheet 3,Sheet 4& Sheet 5 in page 80, 82, 90, 96 & 98 respectively.
4. Accomplish the Self-check 1, Self-check t 2, Self-check 3, Self-check 4 & Self-check 5 **in** page 81, 89, 95, 97 & 99 respectively
5. If you earned a satisfactory evaluation from the Self-check proceed to Operation Sheet 1, in page 100
6. Do the LAP test in page 101

Information Sheet-1	PV components

1.1 Photovoltaic systems consist of some or all of the following components:

- ✓ PV modules (groups of PV cells), which are commonly called PV panels;
- ✓ One or more batteries;
- ✓ A charge regulator or controller for a stand-alone system;
- ✓ An inverter when alternating current (ac) rather than direct current (dc) is required and inverter-charger for a utility-grid-connected system;
- ✓ Wiring; and
- ✓ Mounting hardware or a framework.

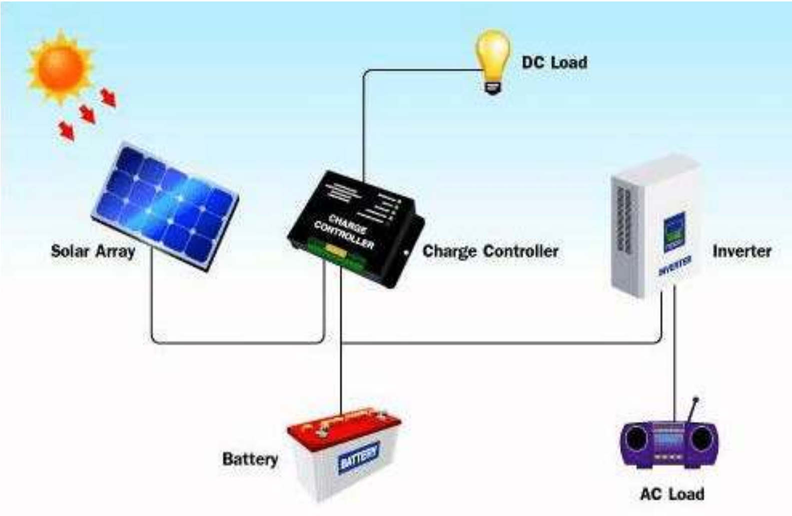


Figure 57:-Components

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.Choose the best answer from the following question below

1. All are PV components except
   - A. PV modules
   - B. Solar batteries;
   - C. A charge controller
   - D. An inverter
   - E. Wind energy

Note: **Satisfactory rating - 1 points** **Unsatisfactory - below 1 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer questions

Information Sheet-2	Explaining PV components

2.1 definitions of PV components

- **Solar Panel - Converts sunlight to electricity**

  Solar Panel (Solar Module) The solar panel produces electricity when there is sunlight by converting it into DC (direct current) electricity.. Photovoltaic (PV) or solar cells are the building blocks of solar panels. Solar panels come in different sizes and power ratings. For off-grid applications often modules with 60 solar cells are used, in grid-connected PV systems 72 cells modules are more common. There is also a variety of smaller modules available that are made especially for solar home systems and pico solar systems. Those modules have between 5 and 150 W.

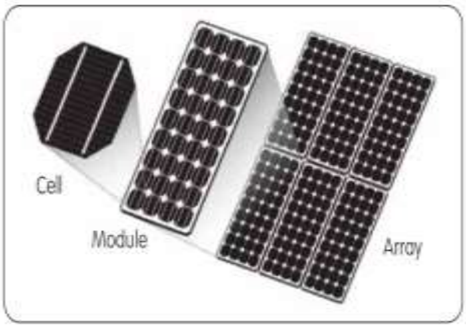


Figure 58:-Different solar panel

- ✓ Every solar panel has a rated power output.
- ✓ The rated output of the panel is determined by the voltage and current that the solar panel can produce.
- ✓ The amount of current and voltage the solar panel produces determines the amount of power the solar panel produces.

The power output of solar panels is rated at “Standard test conditions”, short STC. Because the power production of solar panels depends among others on temperature and irradiation, the rating of solar panels is tested under STCs to be able to compare power ratings of different modules. STC are 25°C module temperature, 1000 W/m² solar irradiation and 1 m/s wind speed. So in reality, a module rated 120W at STC can produce more electricity when e.g. the irradiation is higher than 1000W/m² or less electricity when there is less light or when it is hotter than 25°C.

- **Charge Controller:** Manages the flow of electricity between the solar panel and the batteries. It converts the solar electricity to the right voltage level so that the battery can be charged. Its main job is to keep the batteries from overcharging and deep discharging.

When DC loads are used, they are connected to the DC output of the charge controller. The charge controller then provides the appliances with power and shuts down when the battery is almost empty.

Sometimes also inverters are connected to charge controllers but this configuration is only recommended when the charge controller has a much higher amperage than the inverter, otherwise it will damage the charge controller.

Figure 59:- Charge Controller

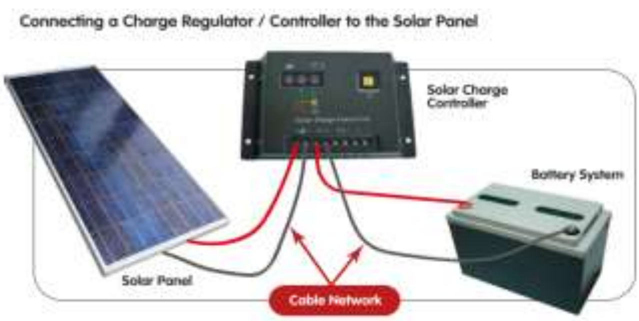


Figure 60: Charge Controller Connection

- **The following videos show charge controller operation** https://www.youtube.com/watch?v=3LsLGr2qjOY

2.2. Purposes:

- Protection of the battery from:
    - ✓ Overvoltage
    - ✓ deep discharge
    - ✓ Overcharging
- Increase the battery's lifetime by optimal treatment
- Increase the system efficiency by intelligent management
- Increase usability of the produced energy
- Reduce system costs by intelligent management
- Give system information
- Facilitate maintenance

2.3 EXAMPLES OF CHARGE CONTROLLER

There are various charge controllers available in the market. Depending on the functions and technology used the prices differ. In the following some manufacturers and models are listed:

- Steca:
- ✓ Solsum F (6A, 8A, 10A)
- ✓ Solarix PRS (10A, 15A, 20A, 30A)
- ✓ Solsum 2525/4040 (25A, 40A)
- ✓ Solarix MPPT (10A, 20A) MPPT-**Maximum power point tracking**.this most frequently concerns programming of a nightlight function.
    - Morningstar
    - Victron
    - Phocos

- **Solar Batteries**

The battery stores electricity produced by the solar panel for later use. It is an important part of solar systems that need to have electricity at night when the solar panel is not producing power.

The battery is one of the most expensive parts of the solar system. It also has the shortest life and is the part most easily damaged by poor maintenance or improper use. The most important thing a PV technician can learn is how to take care of batteries and how to tell if the people using a PV system are causing battery damage through improper use.

Figure 61:- Solar Battery

- **Connecting a Battery to a Solar System**
  - ✓ Before you begin the process of connecting, please ensure that the panel is shaded/covered (no sunshine reaching the collector) to avoid a sudden raise of voltage that damages the inverter.
  - ✓ Always connect the battery bank first. Most charge controller automatically detect the voltage level of the system.
  - ✓ To protect the battery a fuse should be put between the charge controller and battery. The fuse is mounted as close as possible to the positive battery terminal
  - ✓ Fit the cable to the positive terminal of the charge controller and to the positive terminal of the battery.
  - ✓ Fit the cable to the negative terminal of the charge controller and to the negative terminal of the batterycharacteristics.
  - ✓ Insert the fuse

- **Inverter:** Used when there are AC loads to be used in the solar system it converts DC from the batteries to AC.

Figure 62:-Inverter

Connecting the Inverter

- ✓ The inverter is connected directly to the solar battery. One should make sure that the inverter has a deep discharge protection function to avoid damaging the battery.
- ✓ Sometimes, in small applications the inverter is connected to the charge controller at the terminals indicated in the image below (+) and (-). In this case the charge controller must provide a significantly higher amperage than the inverter consumes.

✓ The terminals are loosened and the cable from the inverteris fitted with the same polarity:

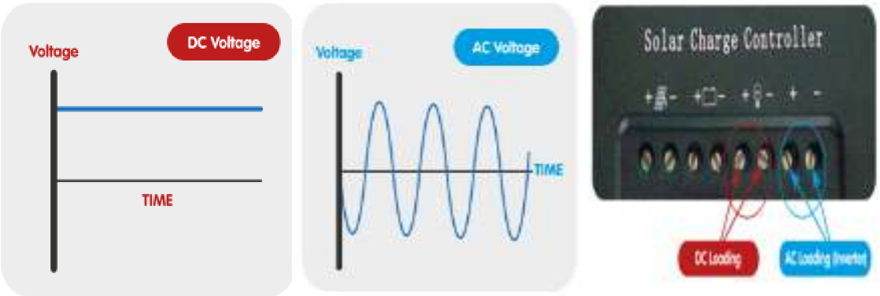


Figure 63:- Wave Form

➢ **The following videos show about the wave forms of inverter**

https://www.youtube.com/watch?v=ln9VZIL8rVs

- **Load** - Application for electricity, e.g. lights, computer, radio, TV

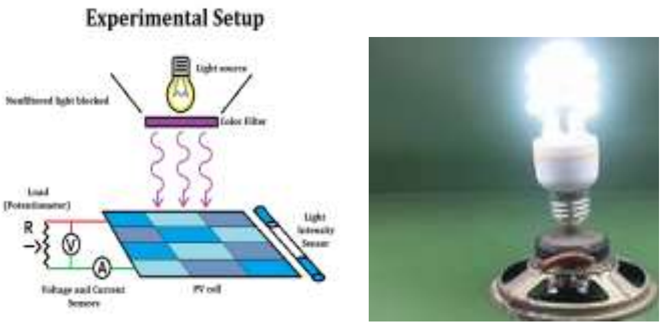


Figure 64:- Output Load

- **Wires** - Connect the other various components together. Solar cables have a double insulation and better UV protection because they must resist the sunlight on the roof.

Figure 65:-Wire

2.4 General Description of PV Solar Configuration:

- ✓ **The solar panel are connected to the Charge controller and the Controller control the power that receives from the solar panel and battery and that distributes to solar load.**

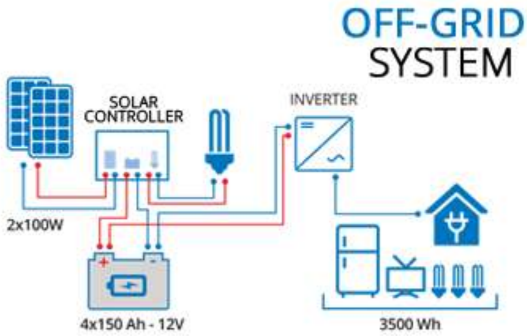


Figure 66:-General Installation

- **The following videos show general installations of PV solar components** [**https://www.youtube.com/watch?v=xKxrkht7CpY**](https://www.youtube.com/watch?v=xKxrkht7CpY)

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I.MATCH COLUMN B TO COLUMN A

A	B
1. Converts sun light to electricity	A. inverter
2. Converts DC power to AC	B. battery
3. Stores electricity	C. solar panel
4. Manages the flow of electricity B/n the solar panel & load	D. charge controller
5. Produced by PV modules & Stored in batteries	E. AC
	F. DC

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date: _______________

Short answer question

3.1. Characteristic PV

- **Charge Controller**

There exist different types of charge controllers, the four main types are series, shunt, PWM and MPPT charge controllers. Shunt and series controllers use very simple technology which limits the functions but reduces the price. PWM charge controllers and MPPT charge controllers are electronically more sophisticated and are therefore more precise when charging and discharging the battery. For all types of charge controllers, except MPPT controllers, the voltage of the PV array must be matched to the battery voltage. MPPT controllers allow to also connect bigger modules with a higher voltage therefore MPPT charge controllers are often the preferred technology.

- **Solar batteries**

The most common battery type is the lead-acid battery. For solar applications, special solar batteries are used which have thicker lead plates than conventional car batteries.
Of all the parts of a solar system, the battery requires the most care.

Lead acid battery

The type of battery usually used in a solar system is a *Lead- Acid* battery. That is its name because the main material it is made of is lead and the battery contains Sulphuric Acid.
Lead-Acid batteries are made up of cells. Each cell produces about 2 Volts. A 12 Volt battery has six 2 Volt cells connected in series (figure 67).

Figure 67Wet Lead Acid battery

Wet batteries

This battery type has removable caps on top so you can test the cells and add water when it is needed. They are called ***open cell*** or***flooded cell*** or***wet batteries*** (67, a). It must be checked regularly to be sure the liquid level is correct and purified water added if the cells are low.

Gel battery

A more advanced version of the ordinary wet lead-acid battery with grid plates is the lead-gel battery. In these, the sulphuric acid is immobilized-that is, thickened into a gel by mean of additives.
These batteries are sealed and cannot be maintained except at the factory. They are called ***maintenance free***or ***sealed*** or ***gel batteries*** (figure 67, b). That type of battery has a smooth top and no filler caps.

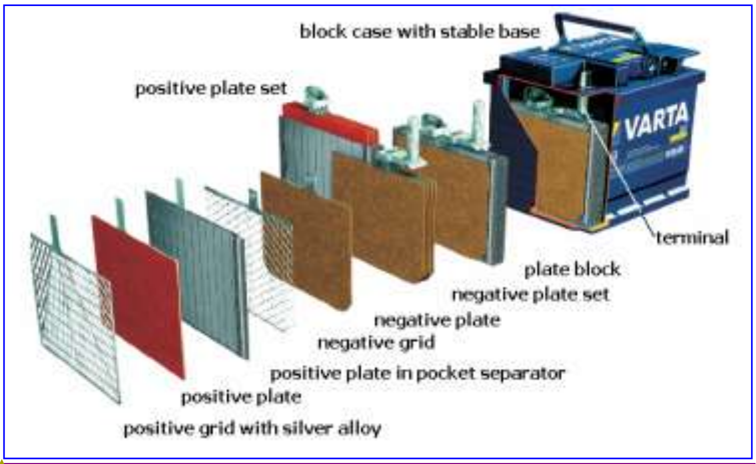


Figure 68:- Solar Battery

Although the solar battery may look like the battery used in automobiles, inside it is very different. Batteries used for vehicles are designed to provide large amounts of power for a short time while solar batteries are designed to provide a small amount of power continuously for many hours.

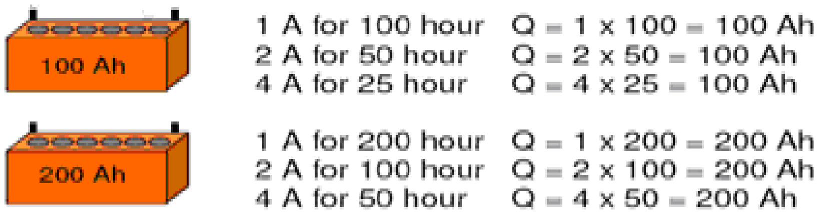
Note. If an automobile battery is used in a solar system it will not last nearly as long as the battery made especially for solar systems. You should ***never*** allow a solar system battery to be used for any other purpose.

The type battery best suited for most solar systems is called a **deep discharge battery**. It is called that because it is especially designed to deliver a high percentage of its power without any damage. You can regularly use 80% of the power stored in a deep discharge battery without damage (comparing to allowable rate 10% for a car battery). Therefore use of deep cycle battery would necessitate a correspondingly much smaller battery capacity. In order to have an optimal lifetime it is recommended to only discharge a solar battery up to 50%. So the battery should always have double the capacity you need .

If you regularly use more than 20% to 30% of the power stored in a starting battery, it will not last long. Though a starting type battery is cheaper than the same size of deep discharge battery, it will not last as long when used in a PV system and with its more frequent replacement, and therefore maybe more expensive in the long run.

Batteries are rated according to how much electricity they can store. The measure used is the Ampere-Hour (Ah). If a battery delivers one Ampere of current continuously for 100 hours it has provided 100 Ampere-hours. If a battery delivers 10 Amperes continuously for 10 hours, it is also delivering 100 Ampere hours.

Q (Battery Capacity, in Ah) = Charging/Discharging current (A) x time (h)
Example



- **Solar inverters**

Stand-alone inverters typically operate at 12, 24, 48 volts DC input and creates 110 or 220 volts AC at 50/60 Hertz. The selection of the inverter input voltage is an important decision because it often dictates the system dc voltage; the shape of the output waveform is an important parameter. Inverters are often categorized according to the type of waveform produced;

- ✓ Square wave
- ✓ Modified sine wave
- ✓ Sine wave

The output waveform depends on the conversion method and the filtering used on the output waveform to eliminate spikes and unwanted frequencies that result when the switching occurs. Square wave inverters are relatively inexpensive, have efficiencies above 90%, high harmonic frequency content, and little output voltage regulation. They are suitable for resistive loads and incandescent lamps. Some sensitive electric devices can be damaged by square waves. Modified sine wave inverters offer improved voltage regulation by varying the duration of the pulse width in their output. Efficiencies can reach 90 %. This type of inverter can be used to operate a wider variety of loads including lights, electronic equipment, and most motors. However, these inverters will not operate a motor as efficiently as a sine wave inverter because the energy in the additional harmonics is dissipated in the motor windings. Sine wave inverters produce an ac waveform as good as that from most electric utilities.

- ✓ Power Conversion Efficiency
- ✓ Rated Power
- ✓ Duty Rating
- ✓ Input Voltage

- Surge Capacity - Most inverters can exceed their rated power for limited periods of time (seconds). Surge requirements of specific loads should be determined or measured. Some transformers and ac motors require starting currents several times their operating level for several seconds.
  - ✓ Standby Current
  - ✓ Voltage Regulation
  - ✓ Voltage Protection
  - ✓ Frequency
  - ✓ Modularity
  - ✓ Power Factor

Electrical Characteristics

Maximum power (Pmax)	50W
Voltage at Pmax (Vmp)	17.5V
Current at Pmax (Imp)	2.9A
Warranted minimum Pmax	45W
Short-circuit current (Isc)	3.2A
Open-circuit voltage (Voc)	21.8V

50W Module Specification

Solar inverters are available in various sizes and categories. The smallest are between 200W and 1000W. They are for simple solar home systems and often have a power outlet right at the device. They are easy to set up and have basic funtions. More complex inverters for Solar Home Systems are in the range of 1- 5 kW. These inverters can be programmed according the used battery type and enable system monitoring.

Figure 69:-Sample Electrical Characteristics of a module

Nowadays also hybrid inverter and charge controllers are available where the inverter and charge controller is combined in one device

.

3.2Typical applications of PV

- ✓ Stand-alone power systems for cottages and remote residences,
- ✓ Remote telecommunication sites for utilities and the military,
- ✓ Water pumping for farmers,
- ✓ Emergency call boxes for highways and college campuses,
- ✓ Street Lighting
- ✓ Grid Connected supply of Electricity
- ✓ Navigational aids for the Coast Guard

3.4 Advantages and disadvantages of using photovoltaic systems

- **Advantages**
  - ✓ **Reliability-**Even in harsh climates, photovoltaic systems have proven their reliability. Often, photovoltaic systems are chosen for systems that must remain operational at all times. Photovoltaic systems may prevent costly or dangerous power failures in situation where continuous operation is critical
  - ✓ **Low Maintenance Cost** on a commercial building roof or field, solar power products can be deployed in many sizes and configurations and can be installed quickly and almost anywhere in the world.
  - ✓ **Universal Applications-** Solar PV is the only renewable energy technology that can be installed on a truly global scale because of its versatility and because it generates power under virtually all conditions, i.e. even in overcast light condition
  - ✓ **Peak Shaving-** The output of solar systems typically correlates with periods of high electricity demand where air conditioning systems create peak demands during hot sunny days.
  - ✓ **Reliability**
  - ✓ **Dual use-** Solar panels are expected to increasingly serve as both a power generator and the skin of the building.
  - ✓ **Environmentally safe-** Solar power systems produce no air or water emissions or greenhouse gases and produce no noise.
- **Disadvantages**
  - ✓ **Cost-** Photovoltaic systems have a high initial cost. Each installation must be evaluated from an economic perspective and compared to existing alternatives.

- ✓ **Variability of Available Solar Radiation**- Weather can adversely affect the power output of any PV system. If there is no sunshine there is no power.
- ✓ **Energy Storage-** Some photovoltaic systems use batteries for storing energy which will be used at a later time. The battery increases the system's size and cost can make the system more complex.
- ✓ **Lack of awareness-** Photovoltaic systems use a new technology with which many people are unfamiliar. Few people understand its applicability. This lack of information slows market and technological growth.

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer for the following questions below

1. which one of the following is a wave types of inverter
   - A. Square wave
   - B. Modified sine wave
   - C. triangular wave
   - D. A& B
   - E. B& C
   - F. None

2. Typical applications of PV
   - A. Stand-alone power systems for cottages and remote residences,
   - B. Remote telecommunication sites for utilities and the military,
   - C. Water pumping for farmers,
   - D. Emergency call boxes for highways and college campuses,
   - E. Street Lighting
   - F. all

Note: **Satisfactory rating – 1 and above points**

Unsatisfactory - below 1 points

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer question

Information Sheet-4	Limitations of the various PV components

4.1 Limitations of PV modules

- Hot spots are places on the panels which are overloaded and therefore become warm. Hotspots on panels are mainly caused by badly-soldered connections, or are a result of a structural defect in the solar cells. Planning and construction errors can also lead to hotspot development when a cell is constantly shaded
- Delamination is the detachment of the laminated components. Delamination – but also incorrectly fitted module trim, for example – can cause moisture to penetrate or bubbles to occur. Moisture leads to corrosion
- PID stands for 'Potential Induced Degradation'. This problem can arise when a voltage difference occurs between the panel and the earthling. For safety reasons, the solar panel is earthed, which can cause a harmful potential difference between the earthing and the voltage generated by the panel.
- One phenomenon regularly encountered are 'micro-cracks' in crystalline PV panels. These are virtually imperceptible microscopic tears in the solar cells. Micro-cracks can occur during PV modules production, but also during shipping or due to careless handling practice during installation.

4.2 Limitations of Batteries

- Batteries make up the largest component cost over the lifetime of a solar system. Good batteries are expensive, but worth the investment. The right type of battery for should be chosen for the PV system.
- Batteries wear out. No matter the type, batteries eventually wear out and need to be replaced. Planning for the replacement of batteries is necessary.
- Some batteries need to be maintained. The acid/electrolyte levels have to be topped up regularly.
- Lead-acid batteries contain corrosive sulphuric acid. If spilled, sulphuric acid will burn the skin or eyes (and potentially cause blindness). It will burn holes through clothes and furniture and it will damage cement floors. Gloves an goggles needed when handling batteries!
- Batteries give off explosive hydrogen gas when they are being charged. This gas must be vented away from the battery to prevent explosions.
- Working on large battery banks and in battery rooms is extremely hazardous and should only be carried out by appropriately trained persons.

Self-Check -4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer for the following questions below

1. Which one of the following is not limitation of PV modules
   a. Micro cracks b. Delamination c. corrosive sulphuric acid d. Hot spots
2. Which one of the following is not limitation of batteries in solar application
   a. High cost b. Energy storage c. Potential for explosion
   d. Need for maintenance

Note: **Satisfactory rating - 1 points** **Unsatisfactory - below 1 point**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer Question

Information Sheet-5	Strengths and weaknesses of different PV system components

5.1 Strengths and weaknesses of different PV system

Table 8:- Strengths and weaknesses of PV

No	Strength	Weakness
1	Plenty of sun shine	Lack of technical support for remote locations
2	Carbon Credits	Poor program and project design
3	Wide application in rural community	High initial cost

5.2 Advantages and disadvantages of solar photovoltaic

- **Advantages:-**
  - ✓ Free resource and enormous potential distributed on the planet
  - ✓ Decentralized means of production, autonomy
  - ✓ Great reliability and little maintenance (no moving parts)
  - ✓ No pollution during the use on site
  - ✓ Great flexibility of production, from kilowatt to Megawatts

- **Disadvantages:-**
  - ✓ High investment cost, need for subsidies, dependence on political decisions and policies
  - ✓ Intermittent availability (auxiliary electrical network or storage needed)
  - ✓ Diffused source, large surface of sensors, difficulty of integration (building/landscape)
  - ✓ High-end manufacturing technology, energy intensive, use of chemical products
  - ✓ Difficulty to recycle components that must resist more than 20 years even in bad weather conditions

Self-Check -5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Say true or false for the following questions below

1. Plenty of sun shine is the one of the weakness of PV system component.
2. High investment cost, need for subsidies, dependence on political decisions and Policies are the disadvantages of the solar photo voltaic.
3. Poor program and project design is one of the strength of PV system component.
4. Free resource and enormous potential distributed on the planet is one of the advantages of solar photovoltaic.
5. Solar Photo voltaic is friendly to the environment.

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer questions

Operation Sheet 1	Identify PV Components

Operation Title: Procedure to connect PV components
Given PV system components: PV module, charge controller, battery, inverter and light bulb

Step-1.Prepare appropriate working space for the PV system components
Step-2.Use appropriate tools and measuring instruments
Step-3.Identify the capacity/ratings of each component
Step-4.Make sure the components are compatible to each other
Step-5.Connect the PV module to the charge controller appropriately. Cover the PV module with cloth or carton to avoid the danger of electric shock.
Step-6.Connect the charge controller to the battery to the correct polarity
Step-7.DC loads: check that appliance is appropriate for the DC voltage level.
Step-8. Connect the DC appliance to the charge controller on the load side terminal.
Step-9. AC loads: connect the inverter DC connection to the charge controller on the load side terminals with the correct polarities.
Step-10.Connect the AC light bulb to the inverter correctly on the AC connection

LAP Test	Practical Demonstration

Name: _____________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary components of PV system, tools and measuring instruments you are required to perform the following tasks within 1 hour.

Task-1 Connect the PV components appropriately & Measure voltage and current in the PV circuit

List of Reference Materials

1. KhamphoneNanthavong, *Promotion of the Efficient Use of Renewable Energies in Developing Countries: Photovoltaic,* DGS REEPRO, 2008.
2. ChristofBuam, *Solar Photovoltaic: Basic in Solar Photovoltaic Systems,* 2nd edition, Don Bosco, Addis Ababa, 2008.
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5. David Tan and AngKianSeng, *Handbook for Solar Photovoltaic (PV) Systems,* Energy Market Authority and Building and Construction Authority, 2019.
6. Mark Hankins, *Stand-Alone Solar Electric Systems: the Earthscan Expert Handbookfor Planning, Design and Installation,*Earthscan, 2010.
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8. CLEAN (Clean Energy Access Network), *Installation, Operation and Maintenance of Solar PV Microgrid Systems: A hand book for trainers,* GSES Indian Sustainable Energy, 2016.
9. https://www.youtube.com/watch?v=3LsLGr2qjOY
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11. https://www.youtube.com/watch?v=xKxrkht7CpY

Solar PV System Installation and Maintenance

Level-II

Learning Guide -13

Unit of Competence	**Apply Principles of Photovoltaic system Operation**
Module Title	**Applying Principles of Photovoltaic system Operation**
LG Code	EIS PIM2 M01 Lo4**LG-13**
TTLM Code	EIS PIM2 **TTLM 0819v1**

LO4: Distinguish DC and AC appliances

Instruction Sheet	Learning Guide:-04

This learning guide is developed to provide you the necessary information regarding the following **content coverage** and topics

- Differences between DC and AC appliances are discussed
- Voltage, current and power ratings of AC and DC appliances is explained.

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to:-

- Discuss differences between DC and AC appliances
- Explain voltage, current and power ratings of AC and DC appliances

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below 3 to 6.
3. Read the information written in the information Sheet 1 & Sheet 2 in page 105& 111 respectively.
4. Accomplish the Self-check 1 & Self-check 2 in page 110 & 113 respectively

Information Sheet-1	Discussing differences between DC and AC appliances

1.1 Concepts of DC & AC appliance

- **Air conditioning**

Air conditioning (often referred to as **AC**, **A/C**, or **air con**)is the process of removing heat and moisture from the interior of an occupied space to improve the comfort of occupants. Air conditioning can be used in both domestic and commercial environments. This process is most commonly used to achieve a more comfortable interior environment, typically for humans and other animals; however, air conditioning is also used to cool and dehumidify rooms filled with heat-producing electronic devices, such as computer servers, power amplifiers, and to display and store some delicate products, such as artwork.

Air conditioners often use a fan to distribute the conditioned air to an occupied space such as a building or a car to improve thermal comfort and indoor air quality. Electric refrigerant-based AC units range from small units that can cool a small bedroom, which can be carried by a single adult, to massive units installed on the roof of office towers that can cool an entire building. The cooling is typically achieved through a refrigeration cycle, but sometimes evaporation or free cooling is used.

Figure 70:- Air conditioning units outside a building

- **Electric water boiler**

An **electric water boiler**, also called a **thermo pot**, is a consumer electronics small appliance used for boiling water and maintaining it at a constant temperature. It is typically used to provide an immediate source of hot water for making tea, hot chocolate, coffee,instant noodles, or baby formula, or for any other household use where clean hot water is required. They are a common component of Japanese kitchens and the kitchens of many East Asian countries but are found in varying use globally. Some thermo pots are designed with a feature that can purify water.

Figure 71:-Boiler

- **Tea kettle**

  A **kettle**, sometimes called a **tea kettle** or **teakettle**, is a type of pot, specialized for boiling water, with a lid, spout, and handle, or a small kitchen appliance of similar shape that functions in a self-contained manner. Kettles can be heated either by placing on a stove, or by their own internal electric heating element in the appliance versions.

Figure 72:- A stainless steel kettle with handle

- **Refrigerator**

  A **refrigerator** (colloquially **fridge**) consists of a thermally insulated compartment and a heat pump (mechanical, electronic or chemical) that transfers heat from the inside of the fridge to its external environment so that the inside of the fridge is cooled to a temperature below the ambient temperature of the room. Refrigeration is an essential food storage technique in developed countries.

  The lower temperature lowers the reproduction rate of bacteria, so the refrigerator reduces the rate of spoilage. A refrigerator maintains a temperature a few degrees above the freezing point of water. Optimum temperature range for perishable food storage is 3 to 5 °C (37 to 41 °F). A similar device that maintains a temperature below the freezing point of water is called a **freezer**. The refrigerator replaced the icebox, which had been a common household appliance for almost a century and a half.

Food in a refrigerator with its door open

Figure 73:- Refrigerator

- **Washing machine**

  A **washing machine** (**laundry machine**, **clothes washer**, or **washer**) is a home appliance used to wash laundry. The term is mostly applied to machines that use water as opposed to dry cleaning (which uses alternative cleaning fluids, and is performed by specialist businesses) or ultrasonic cleaners. The user adds laundry detergent, which is sold in liquid or powder form, to the wash water.

Figure 74:- A typical front-loader washing machine

- **Dishwasher**

  A is a machine for cleaning dishware and cutlery automatically. Unlike manual dishwashing, which relies largely on physical scrubbing to remove soiling, the mechanical dishwasher cleans by spraying hot water, typically between 45 and 75 °C (110 and 170 °F), at the dishes, with lower temperatures used for delicate items.

Figure 75:- Dish washer

- **Microwave oven**
  (Also commonly referred to as a microwave) is an electric oven that heats and cooks food by exposing it to electromagnetic radiation in the microwave frequency range. This induces polar molecules in the food to rotate and produce thermal energy in a process known as dielectric heating. Microwave ovens heat foods quickly and efficiently because excitation is fairly uniform in the outer 25–38 mm(1–1.5 inches) of a homogeneous, high water content food item.

A modern microwave oven (2016)

Figure 76:-Oven

1.2 Differences between DC and AC appliances

Current (DC), the electric charge (current) only flows in one direction. Electric charge in alternating current (AC), on the other hand, changes direction periodically. The voltage in AC circuits also periodically reverses because the current changes direction.

Table 9:-Comparisme of AC &DC

Different between AC and DC Generator	
AC	**DC**
In our Home we use AC current to provide power to all the appliance such TV,Fridge, Light etc.	DC current is often used in charging the batteries and in all electronics system as the source of power supply

	

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Matching from column B to column A

A

1. Refrigerator
2. Tea kettle
3. Electric water boiler
4. Air conditioning
5. Washing machine

B

A. home appliance used to wash laundries
B. a device which is used to transfers heat from the inside to its external environment
C. a small kitchen appliance
D. thermo pot
E. used to cool the air and to remove a moisture

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer question

Information Sheet-2	Identifying voltage, current and power ratings of AC and DC appliances

2.1 Energy savings

Estimated percept energy savings from switching from the standard appliance to the most efficient DC compatible appliance run on AC, and from avoided AC-DC conversion losses in the DC-appliance.

Table 10:-Energy savings AC & DC

Appliance	(A) Energy savings from switching to DC-compatible run on AC	(B) Energy Savings from avoided AC-DC power conversion losses
Lighting-Incandescent	73%	18%
Lighting-Reflector	71%	18%
Lighting-Torchiere	69%	18%
Refrigerators	53%	13%
Freezers	53%	13%
Dishwashers	51%	12%
Electric Water Heaters	50%	12%
Electric Space Heaters other than Heat Pumps	50%	12%
Spas	50%	12%
Central Air Conditioners	47%	11%
Electric Clothes Dryers	45%	11%
Room Air Conditioners	34%	11%
Furnace Fans and Boiler Circulation Pumps	30%	13%
Clothes Washers	30%	13%
Ceiling Fans	30%	13%
Electric Cooking Equipments	12%	12%
Lighting-Fluorescent	1%	18%
Home Audio	0%	21%
Personal Computers and Related	0%	20%
Rechargeable Electronics	0%	20%
DVDs/VCRs	0%	31%
Security Systems	0%	17%
Color TVs and Set-Top Boxes	0%	15%
Coffee Makers	0%	13%
Electric Other	0%	13%

2.2 Comparison Voltage between AC & DC appliance

Table 11:-Voltage Comparison AC & DC

No	Item description	AC appliance	DC appliances
1	Air conditioning	220-240v	12V, 24V,48v,
2	Electric water boiler	220-240v	12V, 24V,48v,
3	Tea kettle	220-240v	12V, 24V
4	Refrigerator	220-240v	12V, 24V
5	Washing machine	220-240v	12V, 24V,48v,
6	Dishwasher	220-240v	12V, 24V,48v,
7	Microwave oven	220-240v	24V,48v,
8	Light	220-240v	6,12V, 24V,48v,

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Matching from column B to column

Appliance		**Energy saving from switching DC compatible run on AC**
NO	**A**	**B**
1.	Freezers	A. 50%
2.	Washing machine	B. 34%
3.	Florescent lamp	C. 1%
4.	Room air conditioner	D. 30%
5.	Electric water heater	E. 53%

Note: **Satisfactory rating - 5 points** **Unsatisfactory - below 5 points**

Answer Sheet

Score = ___________

Rating: ____________

Name: _________________________ Date: _______________

Short answer questions

List of Reference Materials

1. KhamphoneNanthavong, *Promotion of the Efficient Use of Renewable Energies in Developing Countries: Photovoltaic,* DGS REEPRO, 2008.
2. ChristofBuam, *Solar Photovoltaic: Basic in Solar Photovoltaic Systems,* 2nd edition, Don Bosco, Addis Ababa, 2008.
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