Solar Home System
Basic Maintenance & Repair
Training Workbook

RIDS-Nepal

Rural Integrated Development Services Nepal

www.rids-nepal.org

2009

Published by

RIDS-Nepal (Rural Integrated Development Services – Nepal)

www.rids-nepal.org

G.P.O. Box: 8975,

E.P.C. No: 2704, Everest Postal Care,

Kathmandu,

NEPAL

ACKNOWLEDGEMENTS

Thank you to all the staff at RIDS-Nepal. Especially:

Haripal Nepali

Sher Bahadur Budha

Paras Karki

Govinda Nepali

Muni Raj Upadhyaya

Alex Zahnd

This book is based on a solar photovoltaic course as taught by Haripal Nepali and Sher Bahadur Budha in April 2009.

Thank you to Dr Herbert Wade for comments on the book. Parts of the text and graphics are reproduced with kind permission from:

Dr Herbert Wade (2009), *Training Manual for Solar Home System in Bhutan*: *provided to the participants of the JICA training "Training of Photovoltaic Trainers"*, January 25-30 2009, Begana, Bhutan.

Bushlight, *Training Course: Remote Area Power Supply Systems Basic Maintenance and Troubleshooting – Student Handbook*, Centre for Appropriate Technology, Alice Springs, Australia.

Alternative Energy Promotion Centre/ Energy Sector Assistance Program (2008) , *Training Manual for Engineers on Solar PV System*, Ministry of Environment, Science and Technology, Government of Nepal, Kathmandu, Nepal.

Special thanks to Engineers Without Borders Australia for providing funding and support for Long Seng To to write this book on secondment.

TABLE OF CONTENTS

DAY 1: INTRODUCTION TO ELECTRICITY, CIRCUITS & TOOLS

INTRODUCTION TO ELECTRICITY

TYPES OF ENERGY

There are many sources of energy and different ways of converting it into useful forms. Here are some examples, try to match each source with the converting equipment and use:

Sources	Equipment	Used for…
Wood	Solar panel	Cooking
River	Smokeless metal stove	Light
Sun	Water mill	Grinding grain

ELECTRICITY

Which piece of equipment above makes electricity? (circle it)

Electricity is a type of energy. We cannot see electricity, but it works in a similar way to water. We can better understand electrical systems by thinking of water flowing through a water mill. There are 4 characteristics of electricity.

VOLTAGE

Voltage is electrical pressure. It is like water pressure. The higher the water pressure, the faster the water mill spins. So the higher the voltage, the more work can be done. Voltage is measured in Volts (V).

CURRENT

Current is the flow of electricity. It is like the current of water flowing. The higher the rate of flow, the faster the water mill spins. So the higher the current, the higher the volume of flow and the more work that can be done. Electrical current is measured in Amperes (A).

RESISTANCE

Resistance obstructs electrical flow. Resistance can be compared to water flowing through a hole in the bottom of a water container. The rock stops some of the water flow. The smaller the hole, the less the flow because the small hole resists the flow of water more than a large one. So a material with a high electrical resistance, is like a small hole in a water container, it resists the flow, and causes less electricity to flow. A material with a low resistance allows electricity to flow easily as would a large hole in a water container.

A stone, plastic and dry wood have high resistivity – that is why they do not let electricity flow through them. Metals have low resistivity, so the electricity can pass through them easily. Metals are called good conductors of electricity. Different metals have different resistivity. For example: Copper has low resistivity thus lets electricity flow easily with very low obstruction and iron has high resistivity and obstructs on the flow. Thus the copper wire is used in the wiring cables. The unit for measuring resistivity is Ohms and it is written Ω.

POWER

Power is the ability to do work. If we think of a stream of water, power increases with both increased water flow and pressure. The same is true for electrical power. It is measured in Watts. This can be written as:

Power (W) = Current (A) x Voltage (V)

Now match the following:

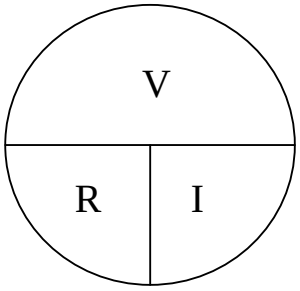
Characteristic	Unit	Symbol	Similar to…
Voltage	Ohms	I	Water pressure
Resistance	Volts	W	Speed of water flow
Current	Watts	Ω	A hole in a container
Power	Amperes	V	Ability to do work

HOW ARE V, I AND R RELATED?

Electricity flowing through a wire is similar to water flowing through a pipe. If wire length (resistance) is doubled and the Voltage (electrical pressure) kept the same, the Amperes flowing (electrical flow rate) are cut in half. If the Voltage is kept the same and the wire length doubled we can have the same current only by cutting the wire resistance in half. This can be done by doubling up the wire with another one of the same size or by replacing the old small wire with one having twice the cross sectional area or the thickness of the first one. This can be written in a formula:

V = I x R	which is the same as	I = V / R	which is the same as	R = V / I

This means that if we know two of the values for voltage (V), current (I) and resistance (R), then we can find the third. An easy way to remember the formula is:



Now try the following exercises.

Question 1

A Voltage of 12 Volts forces a current of 4 Amperes through an unknown resistance. What is the resistance in Ohms?

R = V / I

R = 12V / 4A

R = 3 Ω

Question 2

A resistance of 6 ohms is placed across a voltage of 24 Volts. What current flows?

I = V / R

I = 24V / 6 Ω

I = 4A

Question 3

A resistance of 3 ohms is measured to have a current of 2 Amperes flowing through it. What voltage is there across the resistance?

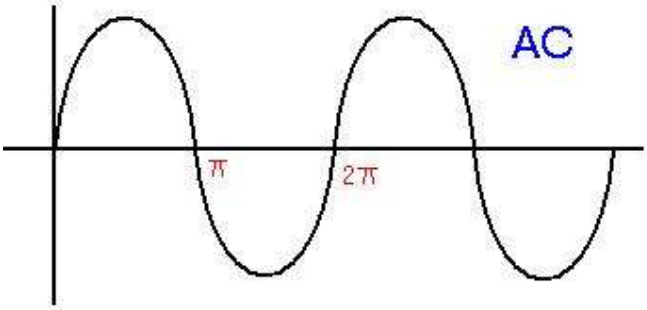
V = R x I

V = 3Ω x 2A

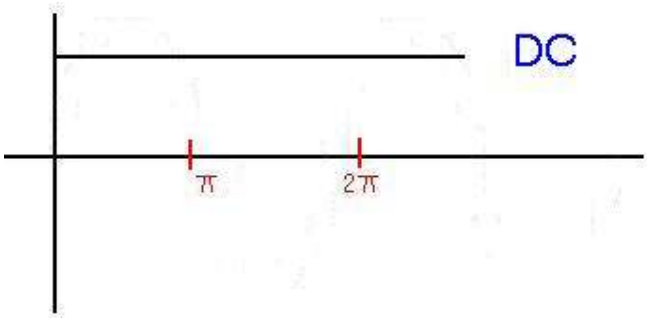
V = 6V

Alternating Current and Direct Current

There are two types of electricity – alternating current (AC) and direct current (DC). With AC, current flows in one direction for a short time before changing direction to flow in the other direction for a short time. The voltage for AC changes all the time. DC flows in one direction only and the voltage stays constant. The grid line distributed by Nepal Electricity Authority produces AC.

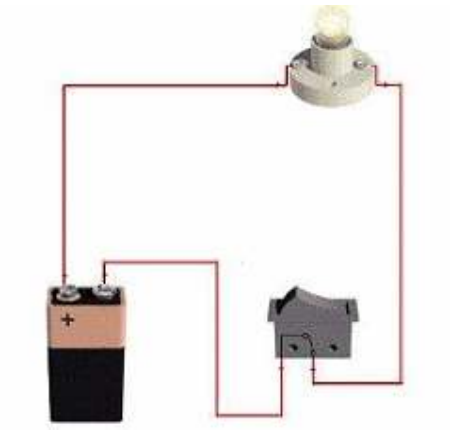


Solar home systems run on DC. You can change this DC into AC with the help of an inverter.



Basic Circuits

An electric circuit is an unbroken connection which allows electricity to flow through it. In the example below, the electricity flows along the wire out of the negative terminal of the battery, through the light, through the switch and back into the positive terminal of the battery.



Source: http://www.geocities.com/thesciencefiles/electric/circuits.html

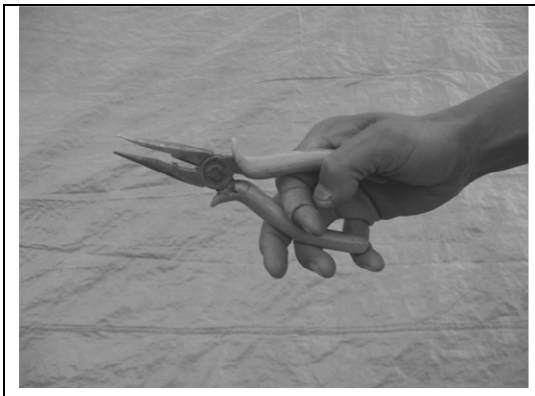
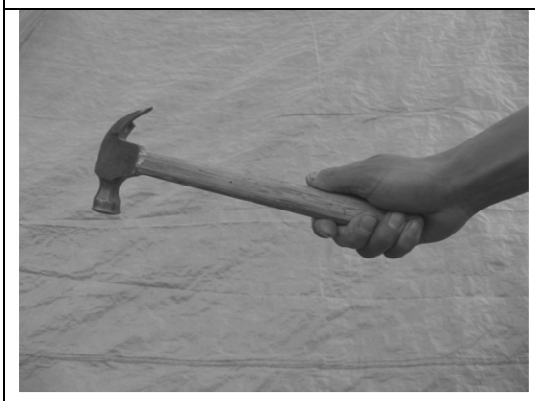
If the switch in the example above was put in the off position, the circuit would be broken and no electricity would flow. In other words, it would be an open circuit.

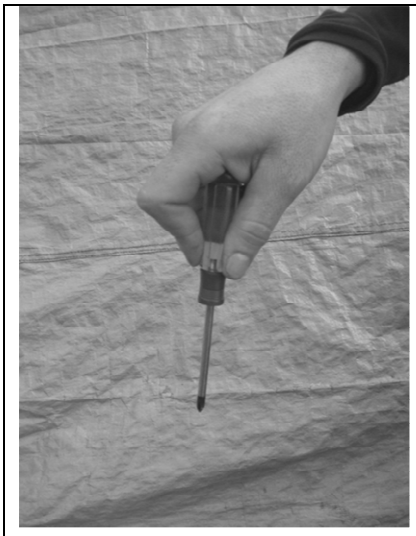
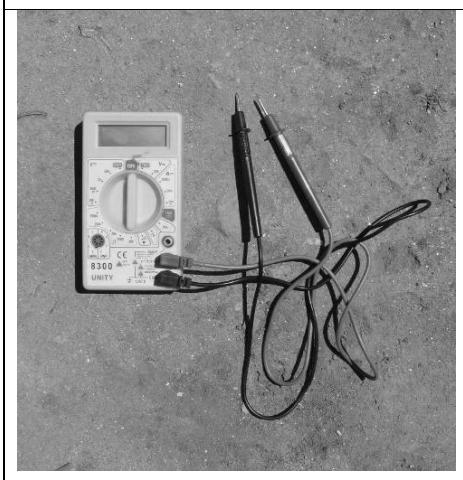
Safety Around Solar PV Lighting Systems

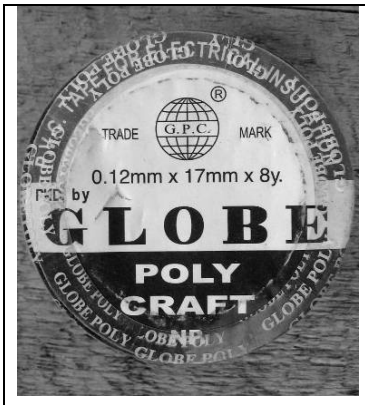
Electricity can be dangerous. It can give you an electric shock or burn you.

- Do not smoke or make a fire near the system.
- Keep the batteries and charge controller dry.
- Don't keep oil, kerosene or chemicals near the system.
- Always use insulated tools.
- Make sure hands are dry before working with electricity.
- Keep the system away from children.

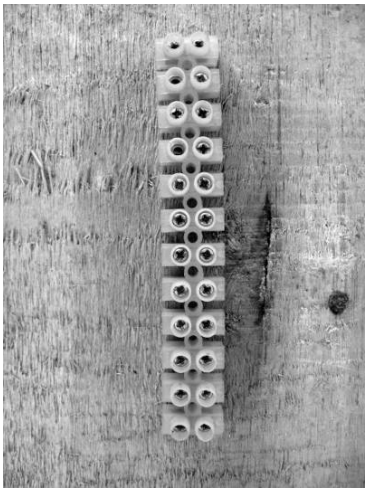
TOOLS

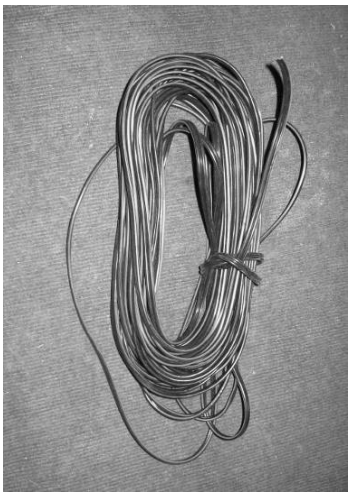
	Name of tool: Used for:
	Name of tool: Used for:
	Name of tool: Used for:

	Name of tool: Used for:
	Name of tool: Used for:
	Name of tool: Used for:

	Name of tool: Used for:

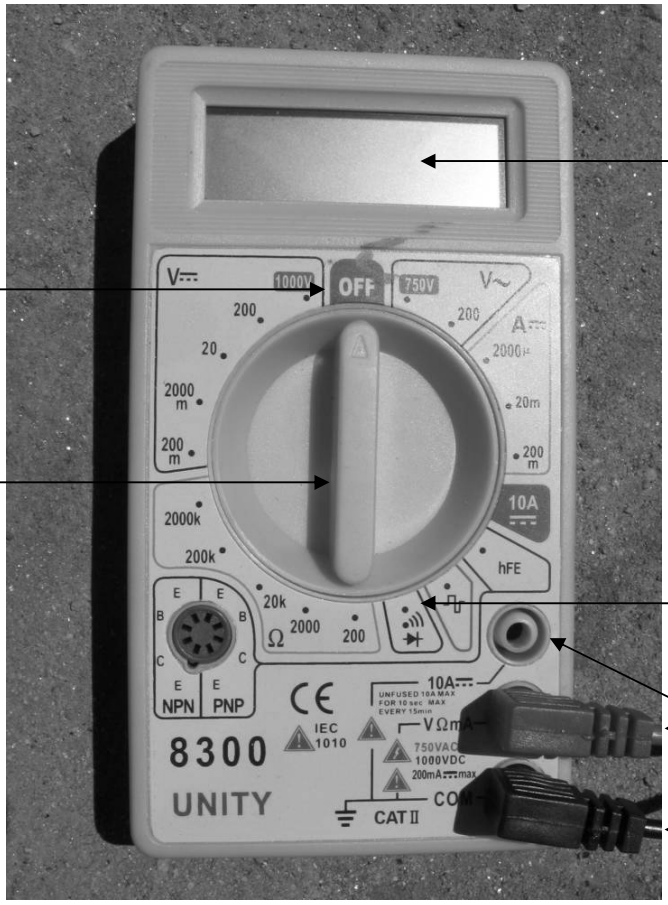
Which tool would you use for the following items?





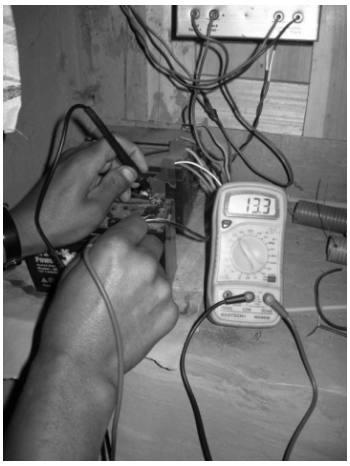
…… …… ……

How to use a multimeter



Procedure for taking measurements

1. Plug in the black negative probe into the 'COM' hole
2. Plug the red positive probe into 10ADC hole on the left for current measurements or the VΩmA hole on the right for voltage measurements.
3. Switch the dial to the measurement you wish to take. You will only be using the 20VDC, 200VDC, 10A and short circuit detection settings.
4. Place the black negative probe on the negative terminal or wire that you wish to measure and the red positive probe on the positive terminal or wire.
5. If the display reads '0', try removing the probes, switching the dial to a lower setting and replacing the probe.



Safety tip: Safety tip: Do not measure the battery terminals with the red probe plugged into the 10ADC hole or the meter knob set to measure in the Am range. This is dangerous and will break the multimeter.

After doing a measurement of Amperes, always remove the wire from the 10ADC hole and put it back in the VΩmA hole and move the knob to off so there can be no damage.

WHAT DO THE LETTERS MEAN?

You may have noticed that some of the items on the multimeter selection dial have a letter (such as m, k or µ) after the number. These letters are a quick way of saying that you need to multiply the reading on the display by a certain number to get the correct measurement.

Letter	Multiply by
µ	0.000 001
m	0.001
k	1000

Example

The multimeter reads “3.44” while the multimeter dial is at mA. This means that the real measurement is:

3.44 x 0.001 = 0.00344 A

DAY 2: PARTS OF A SOLAR LIGHTING SYSTEM

INTRODUCTION

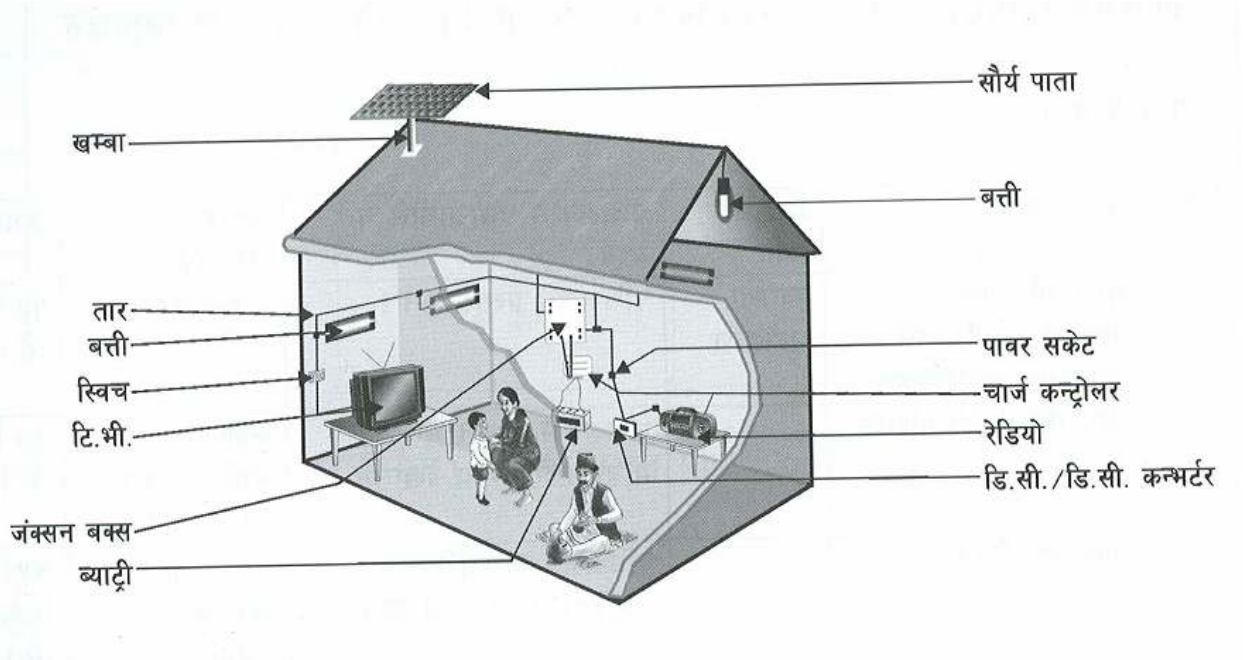


FIGURE 1: SYSTEM DIAGRAM

SOLAR PANEL

The solar panel converts sunlight into electricity – you just have to place it in the sun and connect the wires to make electricity. A solar panel is made up of many individual solar cells connected together.

TAKING CARE OF THE SOLAR PANEL

The amount of electricity that the solar panel produces is affected by several factors. For each factor below, write down what you would need to do to get the most electricity from your solar panel.

Solar panels are affected by…	To get the most from my solar panel I should…
The brightness of the sunlight – the brighter the sunlight, the more electricity is produced. Clouds and shade reduce the amount of sunlight. Trees, bushes and plants grow and thus can cause shadows or full shading of the solar panel, reducing their power generation.	
The direction that the panel is facing – more electricity is produced if the panel is pointed directly at the sun. The sun moves from east to west each day, and also moves north and south with the seasons. The midday sun in winter is "lower" and thus appears to be more in the south, while the midday sun in the summer is "higher" and thus appears more in the north.	
The temperature of the panel – the hotter the panel, the less electricity is produced.	

MEASUREMENTS

The maximum current that a solar panel can produce from a given amount of sunlight is when there is a short circuit. The maximum voltage that a solar panel can produce is when there is an open circuit. These can be measured using a multimeter across the solar panel's positive and negative wires.

	Is also called…
The maximum current that the solar panel can produce	
The maximum voltage that the solar panel can produce	

If the open circuit voltage is lower than usual under bright sunlight, then the solar panel may be wrongly connected, shaded, dirty or damaged. If the short circuit current is much lower than usual under bright sunlight then the solar panel may also be broken.

SOLAR BATTERY

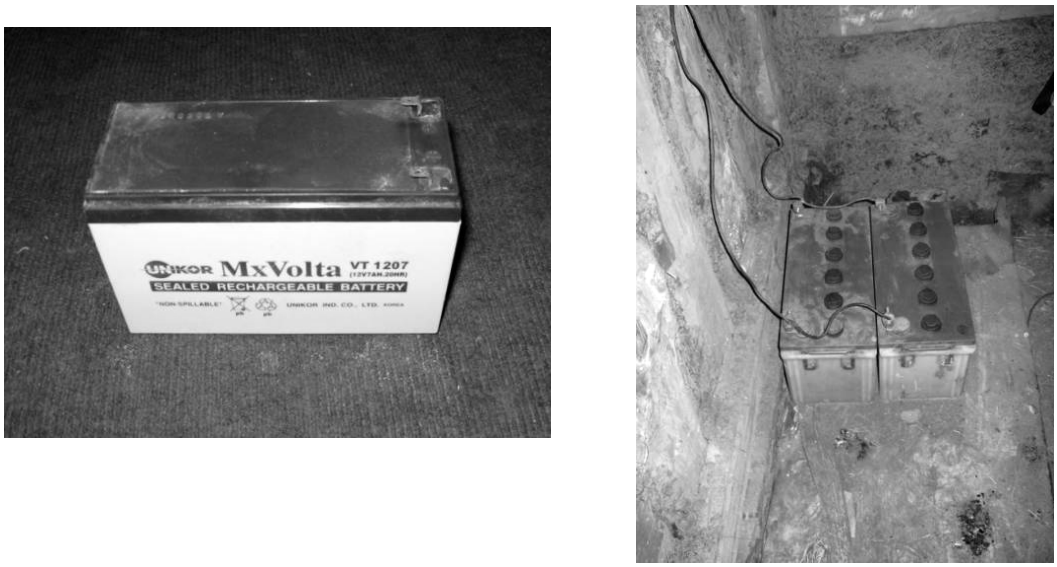


FIGURE 2: SEALED BATTERY (LEFT) & OPEN VENTED BATTERIES (RIGHT)

The battery stores the electricity generated by the solar panel for later use, so batteries allow the lights to work at night. We can think of batteries as a water tank that stores the water until it is needed. Solar batteries are designed to be used in solar lighting systems and are different from other types of batteries (such as those used in radios). When replacing the batteries in the solar lighting system, it is important to use the same kind which was originally installed. There are two different types of batteries used in RIDS-Nepal solar lighting systems.

	Sealed batteries	Open vented batteries
Use	Solar home systems	Cluster and central (tracker) systems
Advantages	• No need to top up with clean rain water • No risk of acid spills • Little explosive gas emitted	• Longer lifetime • Less expensive
Disadvantages	• Shorter lifetime • More expensive	• Need to top up with clean rain water regularly • Risk of acid spills • More explosive gas emitted

TAKING CARE OF THE BATTERIES

The batteries are one of the most expensive parts of the solar lighting system, so they must be used and maintained carefully. A battery's ability to store electricity is called its capacity. Batteries will lose their capacity slowly over time, until they have to be replaced. However, there are several ways to slow down this process so that they last longer.

A battery's lifetime is affected by…	Effects	To prolong the battery lifetime I should…
Depth of discharge	Batteries lose their capacity if they are discharged too much too often.	• Use electricity wisely – turn off the lights when not in use. • Do not leave the batteries at a low state of charge for long periods of time. Make sure that they are fully charged in the afternoon on most days. • Always use the appropriate charge controller with the batteries and make sure it is working properly.
Overcharging	Batteries lose water and capacity if too much electricity is passed to it from the solar panels.	Always use the appropriate charge controller with the batteries and make sure it is working properly.
Heat and cold	Batteries lose their capacity the hotter it is. They also lose capacity if it is very cold.	Keep the batteries in an insulated wooden box and in room you feel comfortable with regard to the temperature,, but make sure that there are some air gaps in the box.
Dust	Batteries may lose charge by itself if there is a lot of dust on the top cover between the terminals.	Keep the batteries clean.

SAFETY AROUND BATTERIES

It is important to take care of yourself and other people around batteries as they can be dangerous.

Dangers	Safety measures
Batteries contain acid. This liquid can burn clothing and skin, and can cause blindness.	• Be careful not to spill battery acid (especially when adding rain water to open vented batteries). • If you get acid in your eye and it causes a burning sensation immediately use a large amount of water to flush the acid out of the eye. Do NOT rub the eye while it is burning. • Wash your hands after touching batteries. • Do not use the cloth you use for cleaning batteries for other purposes. • Battery acid can be neutralized using a mixture of baking soda and water.
Burns or electric sparks from battery terminals.	• Never use a multimeter to measure the current directly across the two battery terminals. • Use tools with plastic handles. • Remove metal jewelry from your wrists, neck and hands before working with batteries.
Explosion. Batteries produce hydrogen gas which catches on fire easily.	• Keep batteries away from fire and sparks, such as stoves and cigarettes. • Make sure the charge controller and loads are switched off before connecting to the batteries. Otherwise, they may produce a spark.
Hazardous chemicals in the batteries. These chemicals may cause poisoning of people and animals.	• Take old batteries to RIDS Nepal for proper disposal. • Do not bury, burn or leave old batteries outside.
Keep the insulated battery box in a save place where children can't reach them	Keep the battery box fixed installed in a separate corner in the living/kitchen room and at a height small children can't reach.

MEASUREMENTS

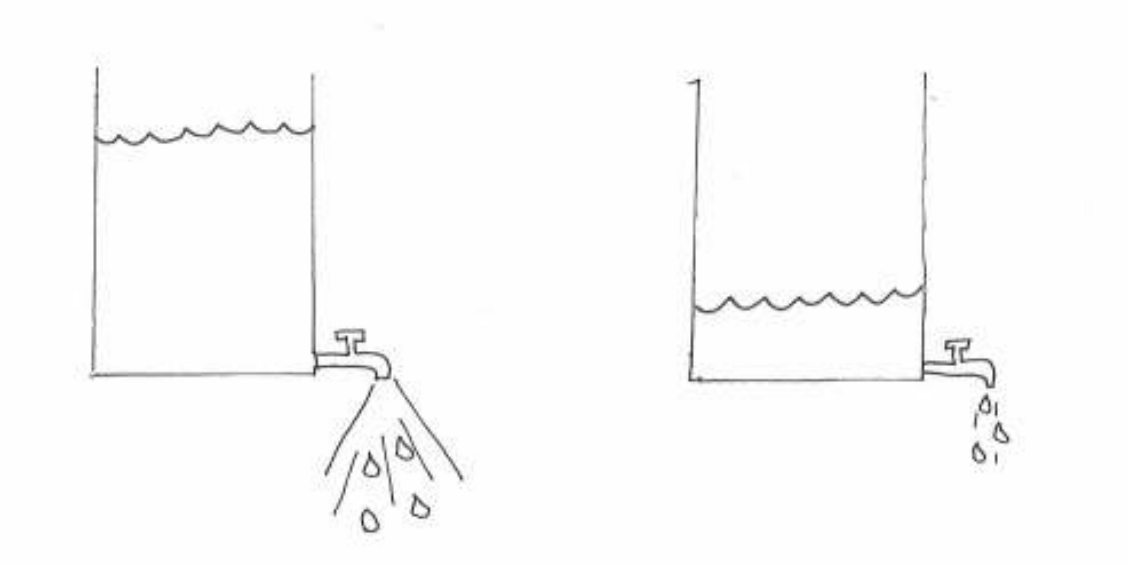


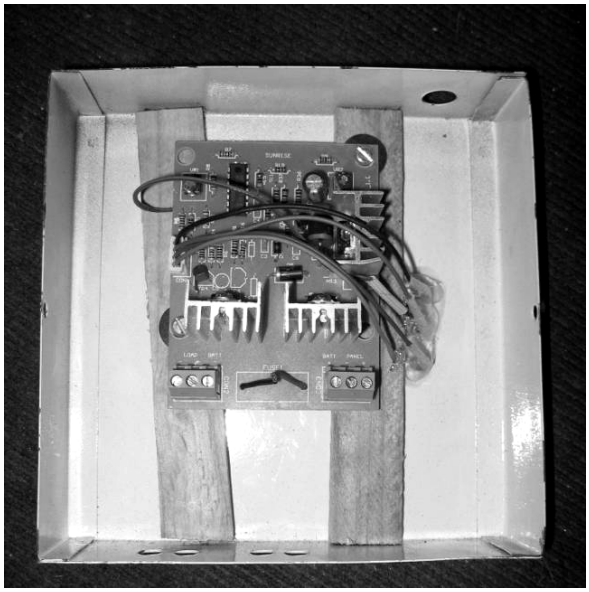
FIGURE 3: THE WATER TANK ON THE LEFT HAS MORE WATER THAN THE TANK ON THE RIGHT, SO THE TAP ON THE LEFT HAS MORE PRESSURE THAN THE ONE ON THE RIGHT

In a water tank, the pressure at the tap increases as the amount of water increases. Likewise, the electrical pressure (or voltage) of a battery increases with the amount of electricity stored in the battery. So we can see how much electricity is in the batteries by measuring the voltage between the two battery terminals when there are no loads connected. The higher the voltage of a particular battery, the more electricity is stored in the battery. This is called the open circuit voltage.

For the sealed batteries used in the solar home systems, the following table gives you an estimate of how full the battery is (or its state of charge) according to the open circuit voltage.

Open circuit voltage (V)	State of charge
13.8	100 %
12.8	80 %
11.8	40%
10.8	20%

CHARGE CONTROLLER



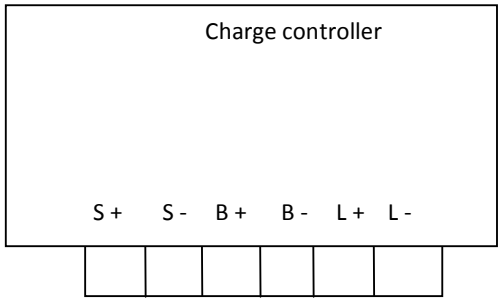


FIGURE 4: CONTROLLER INSIDE THE BOX: PHOTO (TOP) AND WIRING CONNECTIONS (BOTTOM)

INTRODUCTION

A charge/discharge controller (or controller for short) protects against:

- the batteries from becoming too full (overcharge)
- the batteries from becoming too empty (over-discharge)
- the wires causing a fire in case of a short circuit

So the controller makes the batteries last longer and the system safer. It also has lights which show how much electricity is in the batteries. It is connected between the solar panel and the batteries, and between the load and the batteries.

PROTECTION FROM OVERCHARGE OR OVER-DISCHARGE

In a water system, it is sometimes important that a storage tank does not become too full or too empty. A valve can be installed at the inlet of the tank to turn off the water coming into the tank when the tank gets full. To keep water from leaving the tank when it gets too low, another valve can be installed at the outlet of the

tank. These two valves control the amount of water in the tank. In a solar system, a controller is used to keep the battery from getting too full and to ensure that the battery does not completely run out of electricity.

Without a charge controller the panels can force too much electricity into the battery and cause it to be overcharged. When a battery is overcharged it may be damaged because it can get too hot and it loses water rapidly. A charge controller works like a valve on a rainwater collection system that prevents the water tank from overflowing. The controller also keeps the appliances from taking too much electricity out of the battery and causing it to become too discharged. When a battery is too discharged, it may becomes weakened, lose some of its ability to be recharged, and its life may be shortened. The charge controller must be connected between the panels and the battery. It works by constantly checking the voltage of the battery and if the battery voltage is so high that it shows that the battery is full, the controller automatically keeps more electricity from being forced into the already full battery. Or if the battery voltage is so low that it shows that the battery is almost empty, the controller automatically disconnects the appliances so no more electricity can be taken from the nearly empty battery.

PROTECTION FROM FIRE

A fuse is installed in the controller to protect against fires. If there is a short circuit in the system, the high current in the wires may cause them to become very hot. This can not only damage the wires, but it can also cause fires. The fuse is a small piece of wire in a glass tube which 'breaks' the circuit when the current is too high from a fault in the system and so prevents them from becoming too hot. You can replace the broken fuse after you have found and repaired the fault in the system.

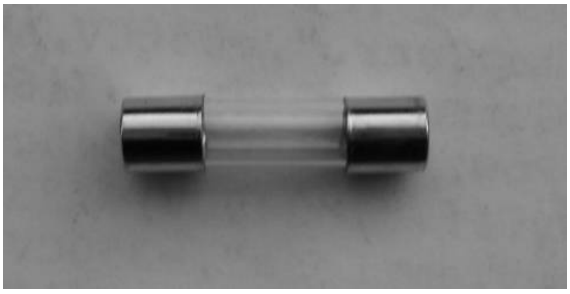


FIGURE 5: FUSE

CHARGE INDICATOR

Yellow light: charging
Green light: battery normal
Red light: battery low

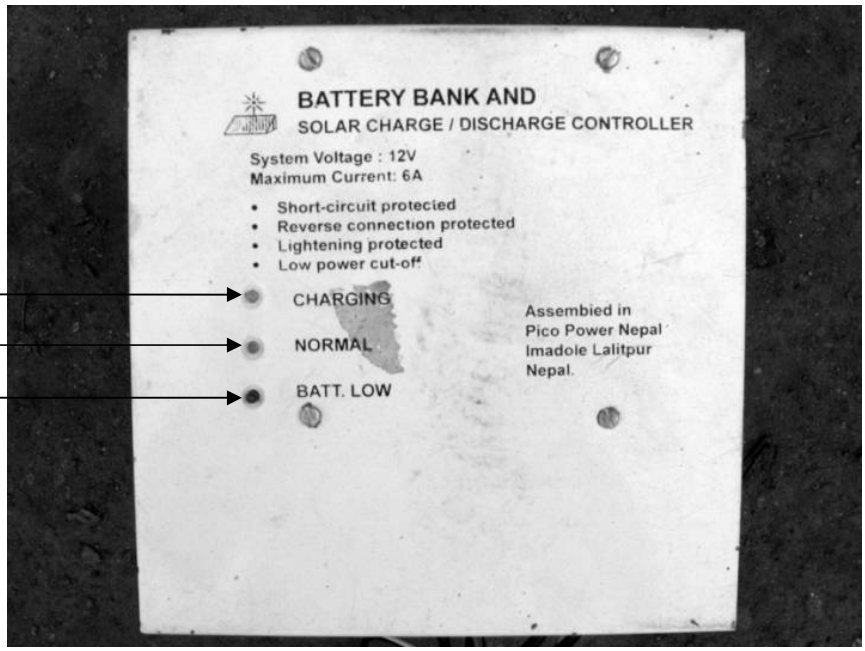


FIGURE 6: BATTERY BANK AND CONTROLLER BOX

The battery bank and controller box has three lights which show the state of the batteries.

- When the yellow light is on, it means that electricity is flowing from the solar panel to the batteries.
- When the green light is on, it means that the batteries are full and thus there is enough electricity in the batteries to be used.
- When the red light is on, it means that there is not enough electricity in the batteries to be used without damaging them and the controller will automatically switch off the lights.

LAMPS

FIGURE 7: WHITE LED LAMP WITH 12 DIODES

White LED (WLED) lamps are used in the solar lighting system. They provide a lot of light without using a lot of electricity. The system is designed to work with these types of lamps. Using different lamps may reduce the amount of light that the system can give or damage the batteries. So it is important to replace broken WLED lamps with the same type of WLED lamp.

SWITCHES

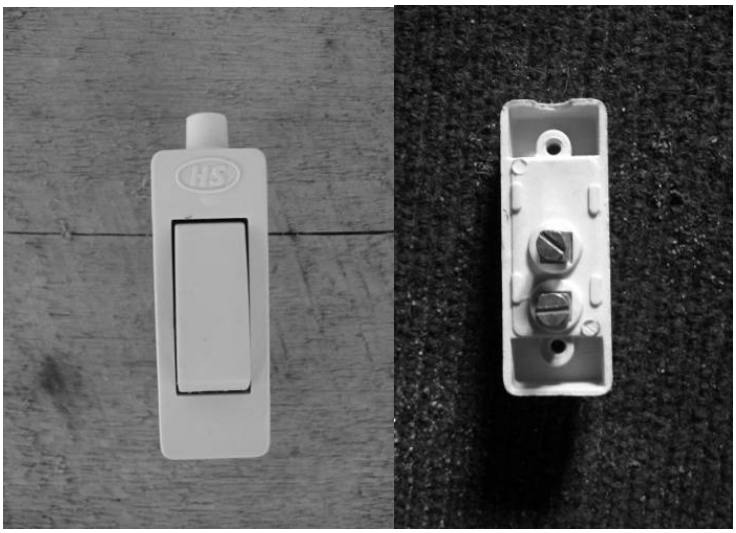


FIGURE 8: SWITCH CASING (LEFT) AND INSIDE THE SWITCH (RIGHT)

Switches are a neat way of connecting and disconnecting wires to turn the lamps on and off. When you switch the lamp on, a small strip of metal connects the wires in and out of the switch. When you switch the lamp off, the strip of metal lifts off the wires and creates an open circuit so that the electricity cannot flow through.

DAY 3: CIRCUITS AND WIRING

CIRCUITS: PARALLEL AND SERIES [1]

Now we will learn more about different types of circuits and what happens to them when there is a break in the wire.

Figure 9 is called a *series circuit* because the light bulbs are along the same wire. The electricity flows from the battery through the first light bulb, into the second light bulb, through the switch and back into the battery. When the switch is turned off, both light bulbs turn off.

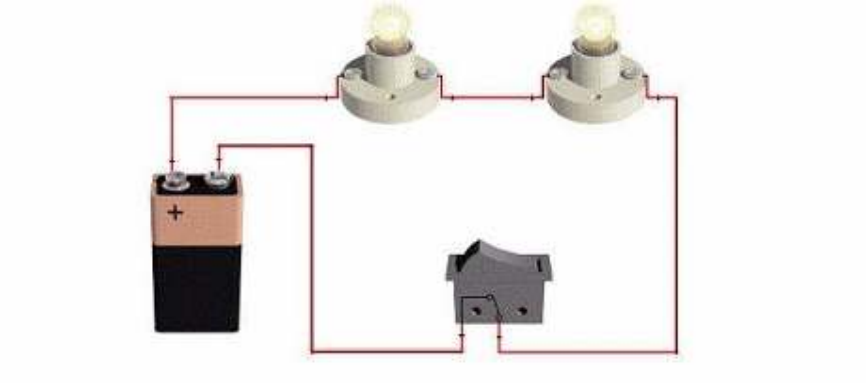


FIGURE 9: SERIES CIRCUIT

Figure 10 is called a *parallel circuit* because the light bulbs are on different branches. The electricity flows from the battery, and splits into three branches and into the three light bulbs, before flowing through the switch. So the electricity flows like water in a pipe which splits into three. If the switch is turned off, all three light bulbs would turn off because the switch is connected to all three branches.

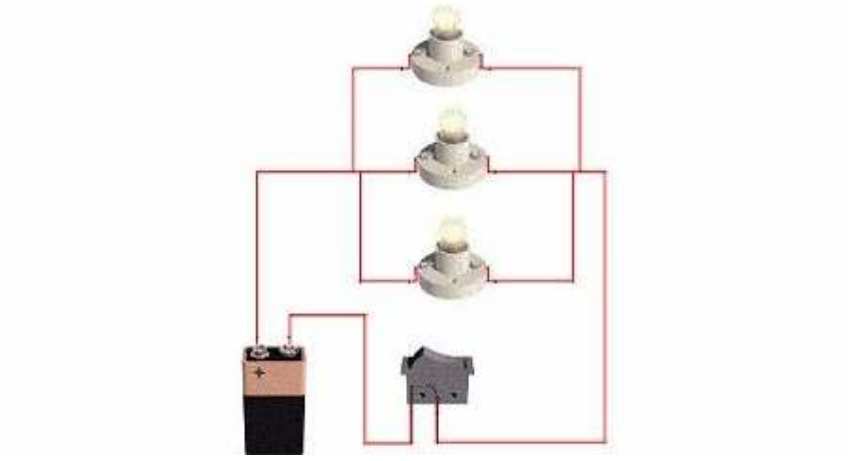


FIGURE 10: PARALLEL CIRCUIT

[1] Graphics and explanations in this section originally by Bill Willis (2000), http://www.geocities.com/thesciencefiles/electric/

Figure 11 is a parallel circuit with switches on each branch. Now you can turn one light off at a time. The switch for one on the lights has been turned off, but electricity continues to flow through the other branch, so the other light remains on.

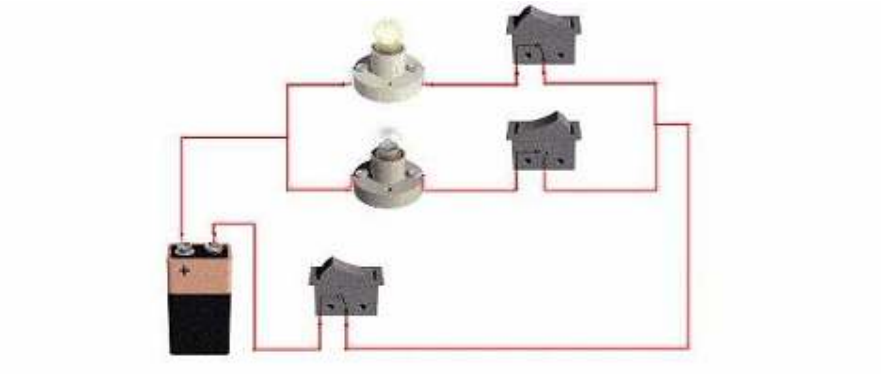


FIGURE 11: PARALLEL CIRCUIT WITH SWITCHES ON EACH BRANCH

Figure 12 is a parallel circuit with a break. Electricity cannot flow in the top branch, so one light bulb is off. But the electricity can still flow through the other two branches, so two lights remain on.

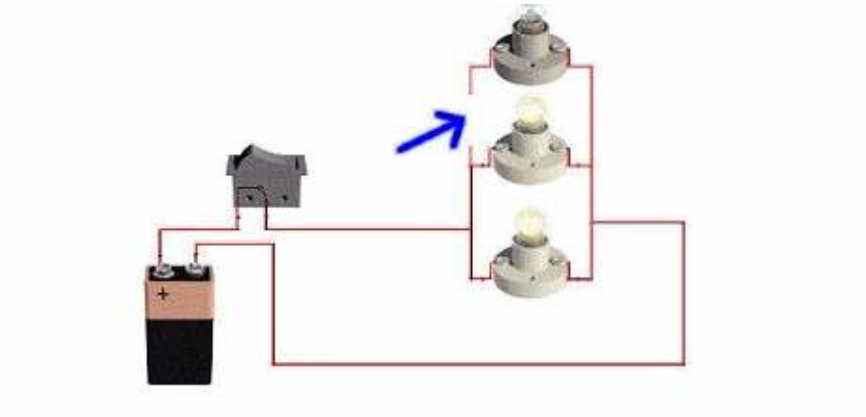


FIGURE 12: PARALLEL CIRCUIT WITH A BREAK IN THE WIRE

Series and parallel circuits are import for understanding the wiring in a PV lighting system and for finding faults.

CHOOSING WIRES

If a water system is installed using pipes that are too small, water pressure will be lost in the pipes. By the time the water reaches the user, the pressure may be so low that not enough comes out to be useful. The reason for the loss of pressure is that the small pipe has too high a resistance and most of the pressure is used up just keeping the water flowing in the pipe. In an electrical system, if the wires are too small, voltage is lost and appliances may not be able to get enough electricity to work properly. The reason for the loss of voltage is that the wires have too high a resistance and a lot of the voltage is used up just keeping the electricity moving in the wire.

TYPES OF WIRES

Each wire is made up of individual strands of copper.

FIGURE 13: COPPER STRANDS IN PLASTIC WIRE INSULATION

The plastic around the wire (the insulation) prevents accidental connections along the wire and protects the wire. Wires used outdoors have special insulation that protects it from the sun and rain (called UV resistive wire). The insulations on these cables are made of Ultra Violet light resistant materials thus are not harmed by the sun light. Make sure that you use this type of wire to connect the solar panel.

The types of wire we will use in the solar lighting system are:

- 23/60: red and black striped wire
- 40/60: red and black striped heavy duty wire
- 23/30: white and black striped UV resistive wire

The first numbers are for the number of stands of copper in the wire. The second numbers are the thickness of each strand of copper (using the British Standard Wire Gauge system of measurement). The wire with lower second number (indicating the gauge) is thicker than those of higher number. For example, the 23/30 white and black striped UV resistive wire has thicker strands of copper than the 40/60 red and black striped wire.

RIGHT WIRES FOR THE SYSTEM

In a water system, more pressure is needed to force water through a long or narrow pipe than a short or wide pipe. In an electrical system, more voltage is needed to force electricity through a wire which is long or thin than one that is short or thick. That is, the resistance in a wire increases as the wire becomes thinner or longer. So we need to choose the right type of wire for each part of the system so that not too much voltage is lost in the wires.

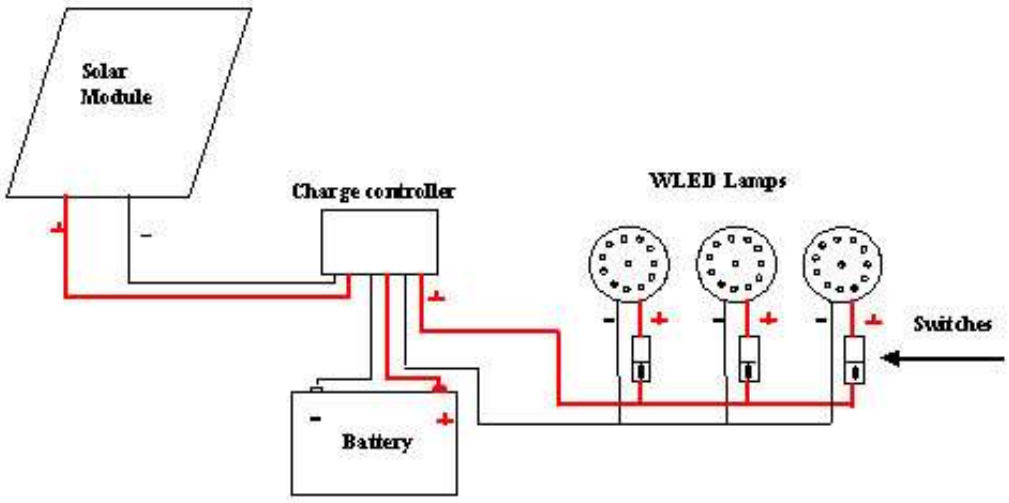


Figure 14: PV lighting system diagram showing the types of wires required to link each component except for the lamps

Because the lamps can be located near or far from the battery and controller box, different thicknesses of wire may be needed. The table below shows the type of wire needed depending on how far the lamp is from the battery and controller box.

Distance	Wire Type
Up to 5 meters	23/60: red and black striped wire
Over 5 meters	40/60: red and black striped heavy duty wire
Solar PV to battery box	23/30: white and black striped UV resistive wire

If the lamp does not turn on after installation, what might be the problem with the wiring?

(the voltage at the lamps may be too low because the wires between the charge controller and lamps may be too long or too thin)

MAKING GOOD CONNECTIONS

Good connections are important in keeping the resistance in the wire low and to make sure that the connection stays for a long time. Before connecting wires, strip the wire by making a cut in the insulation 1-2 cm from the end of the wire and twisting it off. Always use connectors, do not simply twist wires together as this increases the resistance in the wires and disconnects easily.

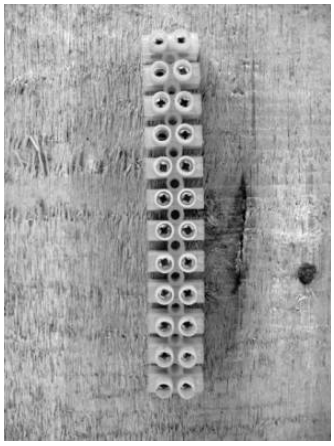


FIGURE 14: WIRE CONNECTORS

CONNECTION PROCEDURE

After fixing the PV panel, lamps and wires to the lamps in place, do the following to connect everything together:

1. Check battery open circuit voltage
2. Connect batteries in parallel (battery 1 plus with battery 2 plus and battery 1 minus with battery 2 minus)

3. Connect battery to controller (battery 1 minus with controller minus, battery 2 plus with controller plus)
4. Check that the battery voltage at the terminal, battery voltage at the controller and load voltage at the controller are all the same at this stage
5. Check that the battery state of charge indicator on the controller is working
6. Check PV panel open circuit voltage and short circuit current
7. Connect PV panel to charge controller (PV panel minus to controller minus, PV panel plus to controller plus)
8. Check that the battery charging indicator on the charge controller is working
9. Connect the wires from the lamps and switches to the load junction box (make sure the lamps are switched off).
10. Connect the load junction box to the controller (load minus to controller minus, load plus to controller plus)
11. Check all parts of the system with a multimeter again

Safety tip: When connecting the positive wires, lightly touch the wire to the terminal first. If there is a large spark, this means that there is a fault in the wiring or the equipment. Fix the fault or try turning all the switches off before completing the connection safely.

DISCONNECTION PROCEDURE

Before disconnecting make sure that you remember that which wires are connected to which points of charge controller and battery terminals etc. If you are confused, make a note in your notebook the colors of wire and their connection.

1. Disconnect PV panel from controller and tape both ends
2. Disconnect battery from controller and tape both ends as you proceed
3. Make sure all the switches are off. Disconnect load junction box from charge controller and tape both ends

DAY 4: MAINTENANCE

A solar PV system requires regular care or maintenance so that it works well and so that it lasts a long time. It is important to check the system regularly and to repair small problems. This will prevent bigger problems for occurring which would be difficult and expensive to fix. Maintenance needs to be done even if nothing seems to be broken.

WHAT IS DONE DURING A MAINTENANCE VISIT?

1) The user is questioned about the operation of the system to see if there are any problems.

The user of the PV system is most familiar with how well it works. Just as when you are becoming sick, you notice changes in the way your body works, when a PV system is starting to have problems, the user will notice changes in the way it works. When changes in system operation are noticed by the user, it is time to do a careful check of the system. Even if you found nothing wrong in the system, always write down what changes the user has noticed. So if a problem does develop there will be a record of how it started.

2) Every part of the solar PV system is checked for proper operation, cleanliness and good connections.

Problems with any part of the system will cause the entire system to work poorly. In particular, problems with wiring, panels or the controller can damage the battery and greatly shorten its life. Dirt and corrosion always cause problems with electrical equipment. Connections which are loose or corroded will cause problems. A thorough check of all parts of the system needs to be done at least every 3 months. The batteries should be checked every month for voltage. If the battery has removable caps (lead-acid type) then, you will also need to make sure the cell liquid is not too low .

3) Components that are not in good condition are repaired or replaced.

If a component is not working properly, if it is not immediately repaired or replaced with a good unit, the system will not work properly and other components, particularly the expensive battery, may be damaged. If you can not repair the PV system yourself, contact the RIDS-Nepal office in Dharapori or Simikot or even Kathmandu as soon as you can for support.

4) The system is checked to be sure that no changes have been made which have not been authorised.

It is strictly FORBIDDEN to add more appliances to an existing solar PV system. Because the system has been carefully designed around the original lights, adding any new appliances will cause the system to have problems and the battery life to be shortened. If more appliances are wanted by the user, they must purchase another solar PV system. The present system is designed just for lighting.

5) A record is made of any action taken during the maintenance visit.

Problems with solar PV systems often develop slowly. If careful records are kept, it will be much easier to know what repairs to make when the system finally does break down. Also, a record of maintenance activities will point out particular components that are not working the way they are supposed to and RIDS-Nepal can make improvements. This feedback is very important for designer and manufacturer for the further improvement and rectifying the problems in forthcoming productions.

MAINTENANCE CHECKLIST

Below are the maintenance tasks you should complete every month and every three months. Read through the tasks and write down next to each task what you would expect to find if everything is working normally.

EVERY MONTH

Part	Task	Normal State
Batteries	Write down the battery voltage at the charge controller	
	Write down the voltage of each battery at the battery terminals. Check if no mice have entered the battery box. Check if the battery box is neither too warm nor too cold. Best temperature is if you feel it with your hand and it is just comfortable warm (20°C -25°C). Check also the physical status of the battery if it is swelled or leaked and for any abnormality. If leaked or corroded or power collected at the terminals, clean it with soft soda water.	
Charge controller	Check that the yellow 'charging' indicator is on when it is sunny. Check battery voltage when charging light is flickering.	
Solar PV module	Clean the module with water and a soft rag if it is dirty (only in the early morning BEFORE sunrise or in the evening AFTER sunset)	
General area	Help the household to keep the area around the PV system clean and tidy	

AT LEAST EVERY 3 MONTHS

Part	Task	Normal State
Solar PV module	Check the solar PV panel frame to be sure it is strong and well attached. If it is broken or loose, repair it. If there is provisions for adjusting the tile angle, adjust this angle at noon 12PM exactly facing at the centre of the sun.	
	Check that the glass of the solar PV panel is not broken. If it is, find out why it has been broken and send immediate word to RIDS-Nepal.	
	Check the connection wires to be sure that the wires are not damaged or loose and that the water seals are good. Check inside the connection box if insects have nested in it. If yes, clean it to remove the nests.	
	Check to see if there is any shadow falling on the solar PV panel (especially between 8 am and 4 pm). If there is, arrange to remove vegetation.	
Wires	Check the insulation on all wires for breaks or cracks. If it is damaged, replace the wire.	
	Check that all wires are secured well.	
	Check that all connections are tight, with no corrosion.	
	If someone had added new wiring for appliances which are not part of the original lighting system, remove them immediately and warn the users not do so next time.	
	If someone has replaced wiring, check that it is the correct type and that the connections are done properly with connectors.	
Battery bank and charge	Check that the battery bank and charge	

controller box	controller box is not damaged and is placed in a safe, dry place and out of the reach of children.	
	Carefully open the box and write down the voltage across the solar panel connections.	
	Write down the voltage across the battery connections.	
	Write down the voltage across the load connections.	
	Write down the voltage across battery terminals for each battery.	
	Check that all the connections at the charge controller and at the battery terminals are tight and without corrosion.	
	Clean the battery bank and charge controller box and the tops of the batteries with a cloth if necessary.	
Lamps	Turn on each lamp and check that it is working.	
	Check that the lamps are mounted securely.	
	Clean the outside surface of the lamps with a slightly wet cotton cloth. Use damped cloth in a light solution of soap water to clean heavily coated front glass.	

LOGBOOK

As previously mentioned, whenever you perform maintenance checks or make any changes to the system, keep a record of what you did. Record in a small book which is kept with the solar PV system or, if you maintain the solar PV system regularly, keep the record with you. Remember to bring the record book with you to each maintenance visit. The following is an example of a record of a through system check.

Date:
System No.:
User Name and Village:
Time:
Weather:

User comments:

Charge controller
Solar PV module voltage:
Battery voltage:
Load voltage:

Battery bank
Battery 1 voltage:
Battery 2 voltage:

Actions taken and repairs made:

Name of the operator/maintenance person:

DAY 5: TROUBLE-SHOOTING & REVISION

TROUBLE-SHOOTING GUIDE

A well maintained solar PV system should operate well for many years, but problems will inevitably arise. This section will tell you how to find the source of the problem (called trouble-shooting) and suggest how to repair the fault. First, determine what type of failure is occurring, then follow the tests listed in that table to find the fault and try the suggested repair procedures.

FAILURE TYPE 1: TOTAL SYSTEM FAILURE

IF THE BATTERY IS DISCHARGED

That is, if the battery voltage is at 11.5V or below, even after a sunny day, then the fault is somewhere between the battery and the panel.

Possible Problem	Test	Repair Suggestions
Solar PV Panel or panel wiring faulty	Disconnect the leads to the solar PV panel terminals of the charge controller. Check the current across the two wires from the solar PV panel around noon when the sun is shining brightly. If the current is much less than 0.93A, there is a problem with the solar PV panel or the panel wiring. Before checking the current at PV terminals, be sure that your multimeter is in appropriate current range.	Disconnect the solar PV panel and carefully check it for proper operation (voltage and Amperes). Replace panels that are not working properly. Clean all terminals and wires. Reconnect the panels being sure the correct wires are connected to the correct terminals. WARNING!! Never measure battery current this way. It will burn the cables and can cause fire.
Controller faulty	Check the voltage at the battery connections and the panel connections on the controller when the sun is shining. If the voltage at the battery connection is less than 12.5V and at the same time the voltage at the panel connection is more than 13.5V, the controller probably has failed.	Contact RIDS-Nepal and report the problem, so that the controller can be replaced.
Wiring between the controller and battery is faulty	Turn on all the WLED lamps. Measure the voltage at the battery terminals of the controller and the voltage directly on the terminals of the battery (not on the battery connections, but on the actual terminals of the battery itself). If the voltage is more than 1 V lower at the controller than at the battery terminals, there is a wiring problem.	Disconnect all wires, remove connectors from battery terminals. Clean all connections and wires. Replace wires in connectors and terminals and tighten all connections. Check the wires to see if they have broken strands in between the charge controller and lamps.
Battery failure	Disconnect the batteries. Leave them separate and open for at	Replace the battery and check the solar PV panel, controller, wiring

	least 3 hours to settle each of them at its own voltage. If one battery's voltage reading is very different from the other, one battery with lower voltage may be damaged. If the battery readings are about the same but very low, connect the solar PV panel directly to the batteries for several days and let the voltage go over 15V at their terminals and see if the batteries will properly charge. If not connect the solar PV panel only to one battery for several days and then check the battery's voltage. If it remains 12.6V for few hours after disconnecting from PV terminals it is OK and the second battery can be tested likewise. If both are charged, reconnect the batteries in the system, otherwise only to the one which is still good and check the system for proper operation.	and disconnect, clean and reconnect all connections. Mark the damaged battery and seek for replacement.

IF THE BATTERY IS CHARGED

When the battery is charged but the appliances do not work, a wiring fault exists between the battery and the appliances.

Possible Problem	Test	Repair Suggestions
Fuse	Check the fuse located on the side of the battery and charge controller box. If the fuse is broken, replace with the new one of the same value. If it blows out immediately then there is a short circuit in the wiring or WLED lamps. Check all wiring and lamps.	Fix shorted wiring or faulty appliances and replace fuses and reset circuit breakers.
Wiring between controller and appliances	Check the voltage at the load connections on the discharge controller. If the load voltage is about equal to the battery voltage, the fault is in the wiring between the controller and the appliances.	Clean all connections, replace all wires that are damaged or that are not the correct size for their length.
Faulty switches	If there is one switch that controls all lamps, it may be the problem. Using a short wire, connect across the switch terminals. If the appliances work, then the problem is the switch.	Replace the switch.
Controller failure	Measure the voltage at the load terminals of the controller and at the battery terminals of the controller. If the load terminal voltage is zero or much lower than the battery terminal voltage (where the voltage at battery terminals is greater than 12V), the discharge controller may not be working properly.	Replace the controller

FAILURE TYPE 2: SOME WLED LAMPS WORK, SOME DO NOT

Possible Problem	Test	Repair Suggestions
There is a switch in the rooms that is faulty	Use a short wire and connect the switch terminals together. If the appliance works, the problem is the switch.	Replace the switch
The WLED lamp has been connected wrong	Check the connection at the appliance. Be sure the + wire of the appliance is connected to the + wire of the controller.	Connect the wires correctly
The WLED lamp is faulty	Check the battery voltage, If the battery voltage is low, there may be a controller problem if the voltage is over 12V, use a new wire of the correct size and connect the appliance directly to the battery, if it does not work, the WLED lamp is probably faulty. If the connection is OK, use a new wire and connect the appliance directly to the battery. If the appliance does not work, the problem is in the appliance.	Replace the lamp
The controller is not working properly	Check the battery voltage. If it is below 11V, the controller is not working correctly. If it is over 12V and the indicator on controller glowing 'low' and lamps do not turn on controller may not be working.	Replace or take the controller for repair
The wire size is too small or too long	Measure the length of the wire run. Check to see if the wire is too small for its length. If it is too small, that may be the problem. Check voltage at controller load point and at the lamp terminals while the lamp is turned on. If the voltage difference is over 1V, the wire is too thin or too long.	Replace the wire with the correct wire size and length.
Connections are loose or dirty	Look closely at all the wire connections between the WLED lamps and the controller to see if they are loose and/or dirty.	Remove wires from all connections between the WLED lamps and the controller. Clean the wires and terminals. Replace the wires and tighten the connections.

FAILURE TYPE 3: THE SYSTEM WORKS BUT RUNS OUT OF POWER

That is, the "battery low" (red) light on the controller turns on frequently, even if there was a lot of sunshine that day. This is the most common problem with solar PV systems and can be caused by many things acting alone or in combination. This type of failure is an indication that there is not enough charge in the battery to operate the WLED lamps for as many hours as the user desires.

Possible Problem	Test	Repair Suggestions
Too little charge from the solar PV panels	This can be due to shading, damaged solar PV panel, wiring too small or too long from PV panel to the battery, dirty or loose connections, solar PV panel not pointing the right direction or dirt on the solar PV panel.	Replace the wires from PV panel to battery with the thicker ones or correct ones. Remove the cause of the shade or move the solar PV panel so they are no longer shaded and are pointed correctly, report to RIDS-Nepal and possibly replace the solar PV panel if damaged, fix the wiring or clean the solar PV panel.
Adding more appliances or changing the type of lamp	This takes more energy from the battery than the system was designed for and causes the battery to discharge too quickly. Using these added appliances or other types of lamps may cause the system to run out of power too soon and seem to need repair when actually it is just being overused.	Remove extra appliances, change lamps to WLED type. Users need to be advised that if more appliances are to be used, then a separate solar PV system needs to be installed for those purposes.
Operating the appliances longer than originally intended	This takes more energy than the system was designed for.	Advise users that the WLED lamps should only be operated for less than 7 hours per day and make the habit to turn off the ones those are not in use.
Incorrect adjustment of the charge controller	This may prevent the battery from attaining full charge. You can check by asking the user to keep appliance use to a minimum for several sunny days so the battery will fully charge. Come to the site in the late afternoon of the third or fourth sunny day while the sun is still shining. Check the voltage at the battery terminals of the controller and the voltage at the solar PV panel terminals of the controller. If the two voltages are about the same and they are both above 13V, then the charge controller is probably working correctly. If the solar PV panel voltage is several volts higher than	Replace the controller and send the misadjusted unit for repair to RIDS-Nepal.

	the battery voltage and the battery voltage is less than 12.8V, then the charge controller may be disconnecting the system too soon and not allowing the battery to come to full charge. OR the controller could be disconnecting the battery before the allowable charge has been taken from the battery. If the battery shows more than half charge voltage when the appliances go off, the discharge controller is probably out of adjustment.	
The battery is getting weak and no longer can store sufficient charge to operate the appliances the full time.	The battery should be suspected if one battery shows readings much different from the other or the battery is more than four years old. If the battery is less than four years old, its failure may have been caused by another problem in the system. Any time a battery that is less than four years old must be replaced, check the rest of the system very carefully, be sure that the solar PV panel is not being shaded part of the day and be sure that the user is not trying to take more power from the system than it was designed to deliver. All of these things may have seriously shortened the life of the old battery and if allowed to continue will ruin the new battery as well.	Replace the battery but monitor the replacement carefully. If after the first month the system once again does not seem to be providing power as long as expected, one or more of the other five reasons for failure exists and must be corrected or else the new battery will also be rapidly weakened and fail. Follow the procedure mentioned at "Battery failure" section above.

REVISION QUIZ

1. If a 3A lamp is connected to a 12V battery, what is the resistance?

2. What is the function of a charge controller?

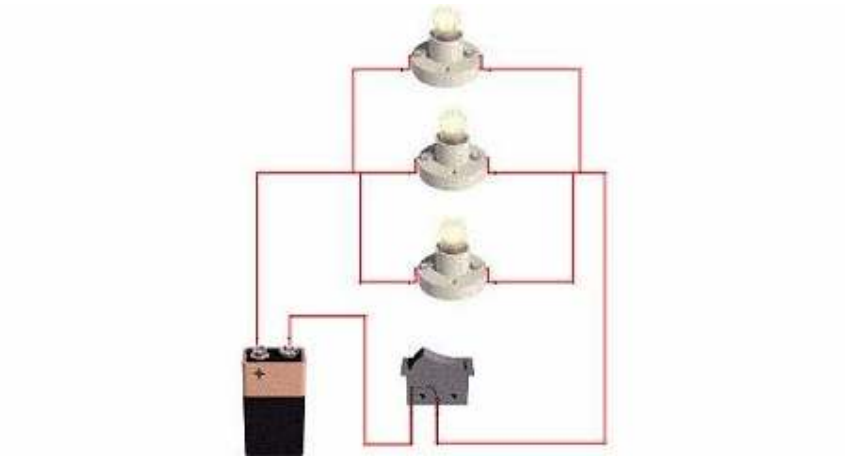
3. What is the function of a fuse?

4. Which direction should the PV panel be fixed?

5. A PV panel produces:
    a. AC electricity
    b. DC electricity

6. Current is measured in:
    a. Watts
    b. Ohms (Ω)
    c. Amps
    d. Volts

7. What would happen to each of the lights if the switch was turned off?



8. What wire size would be needed between a LED lamp and the controller if they were 6m apart?

9. Give 2 reasons why is regular maintenance important?

10. A PV system does not work and the battery is charged, name one possible problem. How would you test the system to find out and how would you repair it?