



## ECOWAS Certification for Sustainable Energy Skills (ECSES)

### Sample Examination for Certification as Certified Off-Grid Solar PV Technician with Answers

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ECOWAS CENTRE FOR RENEWABLE ENERGY AND ENERGY EFFICIENCY

CENTRO PARA AS ENERGIAS RENOVÁVEIS E EFICIÊNCIA ENERGÉTICA DA CEDEAD

CENTRE POUR LES ENERGIES RENOUVELABLES ET L'EFFICACITÉ ENERGÉTIQUE DE LA CEDEAD

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International Renewable Energy Agency

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## 1. Working safely with Photovoltaic systems

### 1.1 Maintain safe and appropriate work habits

If a battery weighs more than 30kgs what is the minimum number of people that should be used to lift the inverter?

Answer: Two.

### 1.2 Demonstrate safe and proper use of required tools and equipment

No question - practical only

### 1.3 Adequately ensure safe and accepted practices for the protection of personnel and property

When a system is being installed or being maintained in a school, what should a company ensure **NEVER** happens when away from the site?

- a) Fence off the work area.
- b) Have warning signs
- c) Lock the battery room door.
- d) Let the students use the power tools.

### 1.4 Possess knowledge related to health and safety hazards and prevention

The system you are installing includes an MPPT and the solar array will comprise five (5) 60 cell solar modules in series. Each solar module has an open circuit voltage of 35V and short circuit current of 7A. What is the electrical danger with this system?

- a) There are 5 modules that must be lifted onto the roof.
- b) The MPPT must be wired correctly.
- c) The solar array is rated at 175V DC open circuit and hence LV
- d) The MPPT must be connected to a battery bank

### 1.5 Apply appropriate codes and standards concerning installation, operation, safety, and maintenance of PV systems and equipment

Can you install batteries outside in the sun?

Answer: No

### 1.6 Identify safety hazards for personnel and property associated with PV installations

What is the risk when connecting batteries together?

- a) The voltage is increasing.
- b) There is current going into the batteries.
- c) Someone might short the terminals.
- d) The batteries might fall over.

## 1.7 Ability to administer first aid in case of accidents

On site, your colleague has battery acid in his eyes?

- a) Run away so you don't get acid on you.
- b) Call for friends
- c) Rinse his eyes with plenty of water.
- d) Call the boss.

## 2. Understanding Solar Energy and PV System Basics

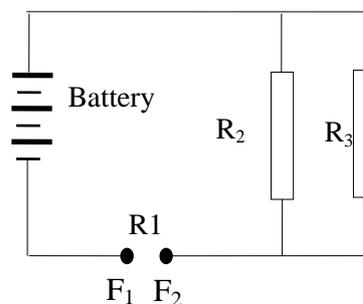
### 2.1 Demonstrate knowledge of correct units for electrical potential (voltage), electrical flow (current), electrical resistance, power, and energy

A DC load is connected to 24 V and the current is 2 A. What is the power of the load?

- a) 24 W
- b) 48 W
- c) 12 W
- d) 26 W

### 2.2 Demonstrate knowledge of basic electric circuit theory and be able to identify series, parallel and series/parallel circuits

1. In the following figure, assuming a total parallel resistance of 240 ohms and a battery voltage of 24 volts, what voltage will we measure across the points  $F_1$  &  $F_2$ ?



- a) Zero
- b) 240 volts
- c) 24 volts
- d) None of the above

### 2.3 Understand Ohm's and Power Laws to be able to calculate energy load

A LED lamp rated 9 W is on for 40 minutes and TV of 60 W is on for 2 hours. How much energy has been used?

- a) 69 Wh
- b) 360 Wh
- c) 126 Wh
- d) 960 Wh

**2.4 Demonstrate an understanding of differences between AC and DC power, power factor and true power vs. real power**

A certain appliance has a true power rating of 300W and an apparent power of 400VA. What is the power factor of this appliance?

Answer p.f. =  $300W / 400VA = 0.75$

**2.5 Demonstrate necessary knowledge for proper orientation and inclination of solar array**

How do you get the maximum instantaneous output power from a solar module??

Answer: By pointing it directly at the sun.

**2.6 Demonstrate an understanding of the term “peak sun hours” (irradiation) and the impact of irradiation on battery charging and overall energy generation**

The energy received at the site for a photovoltaic installation is  $22.14 \text{ MJ/m}^2$ . What is the number of peak sun hours at the site?

- a) 79.7
- b) 6.15**
- c) 25.74
- d) 4.94

**2.7 Interpret the technical specifications and output characteristics of photovoltaic modules (e.g.  $I_{sc}$ ,  $V_{oc}$ ,  $I_{mp}$ ,  $V_{mp}$ ,  $P_{max}$ ) and the controller, the inverter and battery**

A solar module has  $I_{sc} = 6.05 \text{ A}$ ,  $I_{mp} = 5.8 \text{ A}$ ,  $V_{oc} = 42 \text{ V}$  and  $V_{mp} = 34.5 \text{ V}$ .

What is the maximum power rating of the module?

Answer:  $P_{mp} = 5.8 \times 34.5 = 200.1 \text{ W}$  or 200 W

**2.8 Demonstrate an understanding of the factors which influence the output characteristics of photovoltaic modules (irradiance, temperature, load, etc.)**

As the temperature of a solar cell decreases how do the current and the voltage change?

- a) Current decreases and voltage increases**
- b) Current increases and voltage increases
- c) Current decreases and voltage decreases
- d) Current increases and voltage decreases

**2.9 Demonstrate an understanding of the effect on array output (current, voltage, power) of connecting modules in series, parallel and series/parallel configurations**

I am using a 150 watts solar module and nominal voltage is 12V.

I have calculated I need a 3,000 watts solar array with a system voltage of 48V.

What will be the configuration of the array? That is how many modules in series and how many parallel strings?

Answer

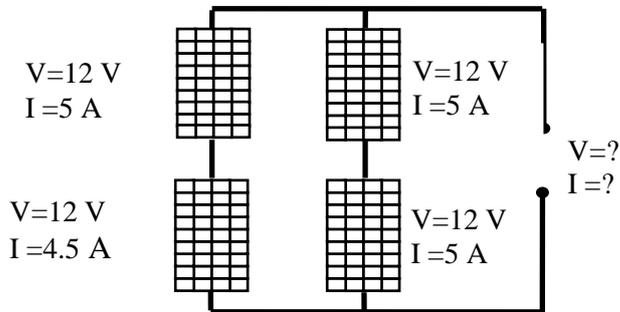
$3,000 / 150 = 20$  modules required.

4 in series to give 48 V

therefore 5 parallel strings

### 2.10 Understand the disadvantages of using dissimilar modules in the same array

What is the voltage and current measured at the output of the array below?



Answer 24V 9.5A

### 2.11 Demonstrate the impact of shading on overall production of solar energy

The following is the hourly irradiation readings for a site where a solar array will be installed.

Time	Irradiation recorded for Wh/m <sup>2</sup>
7.00 am - 8.00 am	150
8.00 am - 9.00 am	300
9.00 am - 10.00 am	400
10.00 am - 11.00 am	600
11.00 am - 12.00 am	800
12.00 noon - 1.00 pm	800
1.00 pm - 2.00 pm	600
2.00 pm - 3.00 pm	400
3.00 pm - 4.00 pm	300
4.00 pm - 5.00 pm	150
Total Irradiation (kWh/m <sup>2</sup> )	4.5 kWh/m <sup>2</sup>

If the site is shaded from 11 AM to 2.00 PM what is the total available daily irradiation for the site?

- a) 3.00 kWh/m<sup>2</sup>
- b) 2.30 kWh/m<sup>2</sup>
- c) 4.50 kWh/m<sup>2</sup>
- d) 3.30 kWh/m<sup>2</sup>

### 2.12 Understand the installation techniques for pole mounted as well as roof mounted PV arrays

When installing a solar module on a roof, things to be considered are?

- a) Obstructions on the roof.

- b) The condition of the roof.
- c) Far shading.
- d) All of the above.

**2.13 Interpret and explain different PV module and battery technologies, criteria for battery selection and major factors affecting battery performance characteristics**

Name at least three factors that influence useful daily PV module output to the controller?

Answer: Any three of the following:

- Dust
- Temperature
- Tilt angle.
- Shading
- Azimuth
- Cable length and diameter

**2.14 Understand the operating principles of charge controllers and explain the major controller features (e.g. low voltage disconnect)**

The only solar modules that are available have 36 cells. The battery bank for the system is 12V and the array will comprise a number of modules. What type of solar controller must you use for this type of system?

Answer: Either of Conventional or PWM Controller

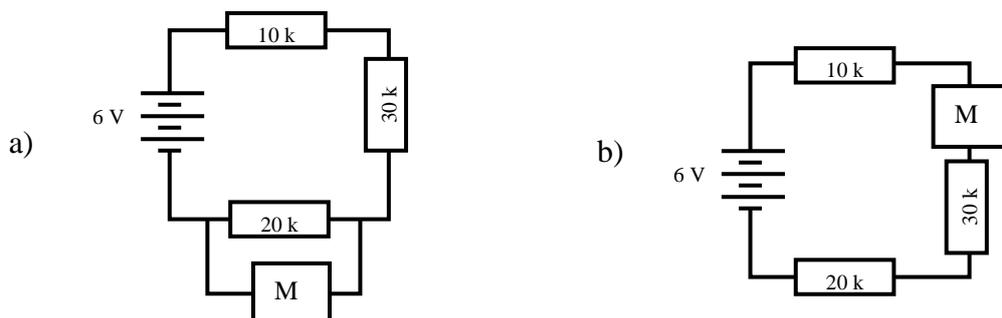
**2.15 Understand basic operating principles of an inverter and list factors which affect efficiency and reliability of inverters**

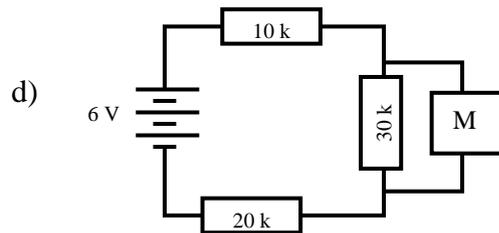
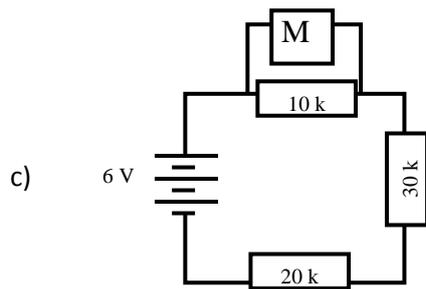
1. I have a 230 V AC appliance that is rated 600 Watts however it requires a surge current of 4 amps and the inverter we are selecting is rated at unity power factor. You have four inverters with surge ratings below to choose from, which inverter you would select to operate this appliance?

- a) 600 Watts (600VA)
- b) 2400 Watts (2400VA)
- c) 300 Watts (300VA)
- d) 1000 Watts (1000 VA)

**2.16 Know how to properly use electric measuring instruments**

If you were to measure the voltage across the 30 k resistor in the diagram below, indicate which diagram below would be the correct way to connect the multimeter into the circuit.





Answer: d)

### 3. Understanding PV Design

#### 3.1 Confirm system design matches client expectation, e.g. load assessments, site drawings

(Note; these questions are ensuring array is sized to meet the client's requirements –in 3.2— questions look at batteries and inverters)

**Table 1: Loads are DC only**

Loads DC only										
Daily Load Energy That system can supply										
Size of Array (watts)										
PSH	25	50	100	150	200	250	300	350	400	450
3.5	52	103	207	310	413	516	620	723	826	929
4	59	118	236	354	472	590	708	826	944	1062
4.5	66	133	266	398	531	664	797	929	1062	1195
5	74	148	295	443	590	738	885	1033	1180	1328

The client is operating four 20 watt lights for 5 hours per night and one 50 watt TV for 3 hours per night. The loads are all DC only and the site has peak sun hours of 4.5 in the lowest month of the year. Using table 1 what size array would meet the clients load needs?

Answer: 250 W

#### 3.2 Review and confirm compatibility of chosen major system components with sizing requirements

A client's daily energy usage is 480 Wh. The system is to be 24 V and the client wants the battery bank to have 5 days autonomy and the manufacturer only allows the battery to have a minimum state of charge of 50%. What is the minimum sized battery bank in Ah that would meet the clients load requirements?

Answer:  $480/24 \times 5 / 50\% = 200 \text{ Ah}$

### 3.3 Locate and evaluate desired PV array and equipment locations

Identify the best location for the inverter from the list.

- a) Inside a sealed box
- b) Outside and exposed to sunshine
- c) Near to, but not directly above, the battery
- d) On the battery

### 3.4 Identify and assess any site specific safety hazards associated with the installation of the system

Which one out of the following is a potential safety hazard?

- a) A flat roof with a sound structure
- b) A car parked underneath
- c) The roof is rusted.
- d) A small tree shading the roof

### 3.5 Verify the appropriate module/array layout, orientation and mounting method for ease of installation, electrical configuration and maintenance

What type of mounting system is appropriate for a flat concrete roof?

Answer: A tilted system

### 3.6 Verify suitable location for battery bank, including ventilation and access requirements

The client has recommended a number of locations where the battery could be installed. Which location is the best location for the battery to be installed?

- a) On the verandah in the sun.
- b) In a battery box that is located on the verandah with ventilation inlets and outlet vents on opposite sides and removable lid that could be locked for security reasons.
- c) In a box in the bathroom with inlet and outlet vents to the room.
- d) Directly under the inverter and controller.

### 3.7 Understand selected conductor type, ampacity, ratings and run distance

**Table 4: Ampacity or Current Carrying Capacity**

Cable Cross Sectional Area	Free air (touching) Current A
1 mm <sup>2</sup>	13
1.5mm <sup>2</sup>	17
2.5 mm <sup>2</sup>	22
4 mm <sup>2</sup>	30
6 mm <sup>2</sup>	38
10 mm <sup>2</sup>	54

16 mm <sup>2</sup>	71
25 mm <sup>2</sup>	94
35 mm <sup>2</sup>	117
50 mm <sup>2</sup>	147
70 mm <sup>2</sup>	185
95 mm <sup>2</sup>	223
120 mm <sup>2</sup>	265

**Table 5: Maximum Cable Lengths in Metres for 12V System 3% Voltage Drop**

Current (A)	1mm <sup>2</sup>	1.5mm <sup>2</sup>	2.5mm <sup>2</sup>	4mm <sup>2</sup>	6mm <sup>2</sup>	10mm <sup>2</sup>	16mm <sup>2</sup>
1	9.8	14.8	24.6	39.3	59.0	98.4	157.4
2	4.9	7.4	12.3	19.7	29.5	49.2	78.7
3	3.3	4.9	8.2	13.1	19.7	32.8	52.5
4	2.5	3.7	6.1	9.8	14.8	24.6	39.3
5	2.0	3.0	4.9	7.9	11.8	19.7	31.5
6	1.6	2.5	4.1	6.6	9.8	16.4	26.2
7	1.4	2.1	3.5	5.6	8.4	14.1	22.5
8	1.2	1.8	3.1	4.9	7.4	12.3	19.7
9	1.1	1.6	2.7	4.4	6.6	10.9	17.5
10	1.0	1.5	2.5	3.9	5.9	9.8	15.7
11	0.9	1.3	2.2	3.6	5.4	8.9	14.3
12	0.8	1.2	2.0	3.3	4.9	8.2	13.1
13		1.1	1.9	3.0	4.5	7.6	12.1
14		1.1	1.8	2.8	4.2	7.0	11.2
15		1.0	1.6	2.6	3.9	6.6	10.5
16		0.9	1.5	2.5	3.7	6.1	9.8
17			1.4	2.3	3.5	5.8	9.3
18			1.4	2.2	3.3	5.5	8.7
19			1.3	2.1	3.1	5.2	8.3
20			1.2	2.0	3.0	4.9	7.9

**Table 6: Maximum Cable Lengths in Metres for 12 V System 5% Voltage Drop**

Current (A)	1mm <sup>2</sup>	1.5mm <sup>2</sup>	2.5mm <sup>2</sup>	4mm <sup>2</sup>	6mm <sup>2</sup>	10mm <sup>2</sup>	16mm <sup>2</sup>
1	16.4	24.6	41.0	65.6	98.4	163.9	262.3
2	8.2	12.3	20.5	32.8	49.2	82.0	131.1
3	5.5	8.2	13.7	21.9	32.8	54.6	87.4
4	4.1	6.1	10.2	16.4	24.6	41.0	65.6
5	3.3	4.9	8.2	13.1	19.7	32.8	52.5

6	2.7	4.1	6.8	10.9	16.4	27.3	43.7
7	2.3	3.5	5.9	9.4	14.1	23.4	37.5
8	2.0	3.1	5.1	8.2	12.3	20.5	32.8
9	1.8	2.7	4.6	7.3	10.9	18.2	29.1
10	1.6	2.5	4.1	6.6	9.8	16.4	26.2
11	1.5	2.2	3.7	6.0	8.9	14.9	23.8
12	1.4	2.0	3.4	5.5	8.2	13.7	21.9
13		1.9	3.2	5.0	7.6	12.6	20.2
14		1.8	2.9	4.7	7.0	11.7	18.7
15		1.6	2.7	4.4	6.6	10.9	17.5
16		1.5	2.6	4.1	6.1	10.2	16.4
17			2.4	3.9	5.8	9.6	15.4
18			2.3	3.6	5.5	9.1	14.6
19			2.2	3.5	5.2	8.6	13.8
20			2.0	3.3	4.9	8.2	13.1

**Table 7: Maximum Cable Lengths in Metres for 24V System 3% Voltage Drop**

Current (A)	1mm <sup>2</sup>	1.5mm <sup>2</sup>	2.5mm <sup>2</sup>	4mm <sup>2</sup>	6mm <sup>2</sup>	10mm <sup>2</sup>	16mm <sup>2</sup>
1	19.7	29.5	49.2	78.7	118.0	196.7	314.8
2	9.8	14.8	24.6	39.3	59.0	98.4	157.4
3	6.6	9.8	16.4	26.2	39.3	65.6	104.9
4	4.9	7.4	12.3	19.7	29.5	49.2	78.7
5	3.9	5.9	9.8	15.7	23.6	39.3	63.0
6	3.3	4.9	8.2	13.1	19.7	32.8	52.5
7	2.8	4.2	7.0	11.2	16.9	28.1	45.0
8	2.5	3.7	6.1	9.8	14.8	24.6	39.3
9	2.2	3.3	5.5	8.7	13.1	21.9	35.0
10	2.0	3.0	4.9	7.9	11.8	19.7	31.5
11	1.8	2.7	4.5	7.2	10.7	17.9	28.6
12	1.6	2.5	4.1	6.6	9.8	16.4	26.2
13		2.3	3.8	6.1	9.1	15.1	24.2
14		2.1	3.5	5.6	8.4	14.1	22.5
15		2.0	3.3	5.2	7.9	13.1	21.0
16		1.8	3.1	4.9	7.4	12.3	19.7
17			2.9	4.6	6.9	11.6	18.5
18			2.7	4.4	6.6	10.9	17.5
19			2.6	4.1	6.2	10.4	16.6
20			2.5	3.9	5.9	9.8	15.7

**Table 8: Maximum Cable Lengths in Metres for 24V System 5% Voltage Drop**

Current (A)	1mm <sup>2</sup>	1.5mm <sup>2</sup>	2.5mm <sup>2</sup>	4mm <sup>2</sup>	6mm <sup>2</sup>	10mm <sup>2</sup>	16mm <sup>2</sup>
1	32.8	49.2	82.0	131.1	196.7	327.9	524.6
2	16.4	24.6	41.0	65.6	98.4	163.9	262.3
3	10.9	16.4	27.3	43.7	65.6	109.3	174.9
4	8.2	12.3	20.5	32.8	49.2	82.0	131.1
5	6.6	9.8	16.4	26.2	39.3	65.6	104.9
6	5.5	8.2	13.7	21.9	32.8	54.6	87.4
7	4.7	7.0	11.7	18.7	28.1	46.8	74.9
8	4.1	6.1	10.2	16.4	24.6	41.0	65.6
9	3.6	5.5	9.1	14.6	21.9	36.4	58.3
10	3.3	4.9	8.2	13.1	19.7	32.8	52.5
11	3.0	4.5	7.5	11.9	17.9	29.8	47.7
12	2.7	4.1	6.8	10.9	16.4	27.3	43.7
13		3.8	6.3	10.1	15.1	25.2	40.4
14		3.5	5.9	9.4	14.1	23.4	37.5
15		3.3	5.5	8.7	13.1	21.9	35.0
16		3.1	5.1	8.2	12.3	20.5	32.8
17			4.8	7.7	11.6	19.3	30.9
18			4.6	7.3	10.9	18.2	29.1
19			4.3	6.9	10.4	17.3	27.6
20			4.1	6.6	9.8	16.4	26.2

The system includes an appliance that is rated at 480VA at 24V. It is located 15 metres from the battery. Using tables 4, 5, 6, 7 and 8 what is the minimum sized cable that could be installed between the appliance and battery to ensure the cable can carry the required current and have less than 5% voltage drop.

Answer: Cable to meet current carry carrying capacity (20A) is 2.5 mm<sup>2</sup> but to meet voltage drop requirement is 10 mm<sup>2</sup>. So answer is 10 mm<sup>2</sup>.

### **3.8 Confirm location, size and type of selected grounding method and if overcurrent protection is appropriate for the application**

Which one of the following is an overcurrent protection device?

- a) Isolator
- b) Combiner box
- c) gPV fuse
- d) Terminal block

### 3.9 Verify the compliance of protective elements between the different components of a photovoltaic system

The minimum voltage rating of a protection device in a PV system must be equal to:

- a) Array  $V_{oc}$  at midday on a hottest expected day
- b) 2 x module  $V_{mpp}$
- c) Array  $V_{oc}$  at coldest temperature for the site
- d)  $I_{sc} \times V_{oc}$

## 4. Installing Mechanical and Electrical PV Components

### 4.1 Demonstrate necessary mounting techniques for attaching modules to array frame and array frame to its supporting structure

1. Which of the following methods is recommended for attaching an array frame to the supporting structure?
  - a) Using suitable screws through the mounting feet of the array through the metal roof into the rafters under the roof.
  - b) Using appropriate roof tile brackets that slide under the tile, are screwed or bolted onto the rafter and the array frame bolts to the appropriate location on the bracket.
  - c) Using plastic cable ties.
  - d) Both a and b.

### 4.2 Demonstrate necessary working knowledge of how to fit PV arrays to roofs by interpreting layout diagrams and apply different methods of fixing PV arrays at optimum pitch and orientation to roofs typical within the country of installation

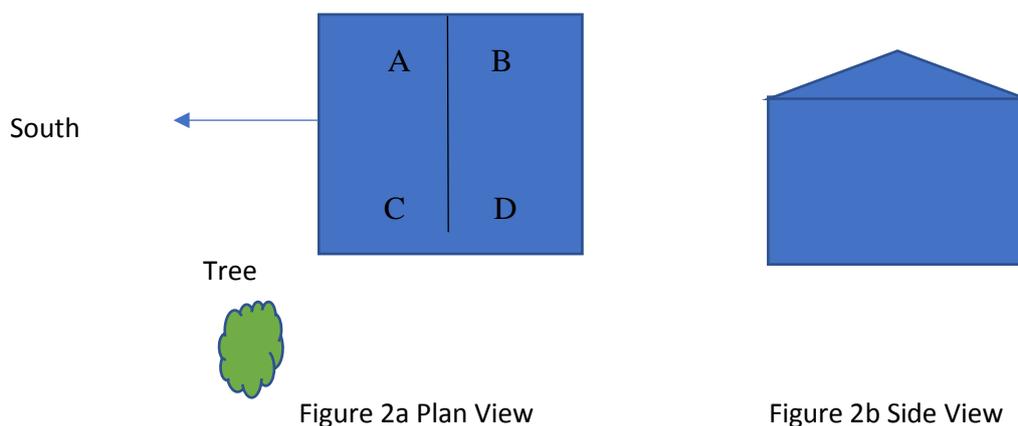


Figure 2 is the roof of a house, and the roof has a pitch to the center of 15 degrees. The system will consist of 2 modules mounted on top. There is a tree that will shade the south-east section of the roof. The latitude is 20 degrees north. On what section of the roof (A, B, C or D) should the modules be installed?

Answer: A

### 4.3 Demonstrate the safe handling of batteries and its appropriate placement to ensure good aeration

When lifting a tall wet lead acid battery to the site how should the battery be handled?

- a) With two installers at each end when it is on its side then tipped up.
- b) In an upright position.**
- c) Using hooks through the battery terminals.
- d) Carried on the shoulder

### 4.4 Choose the correct layout, safe positioning and sound mounting techniques of all system components, e.g. charge controllers, inverters and appliances

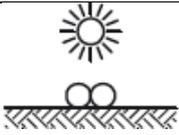
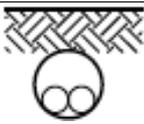
How should a lead acid battery bank be installed?

- a) In a battery box inside a building with the ventilation outlet at the highest point on the box to the inside of the building...
- b) In a dedicated room with the with the ventilation outlet vented to the outside at the highest point in the room.**
- c) In a dedicated room with the with the ventilation outlet vented to the outside at the lowest point in the room
- d) Any of the above

## 5. Installing Cables, Connectors and Protection Devices

### 5.1 Discuss current carrying capacity and the implications for proper cable selection

**Table 9: Ampacity or Current Carrying Capacity for Flexible double insulated cable**

Cable Cross Sectional Area	Spaced Current A	Touching Current A	Exposed to Sunlight Current A	In Conduit in air Current A	In Conduit Buried Current A
					
1mm <sup>2</sup>	17	13	8	14	19
1.5mm <sup>2</sup>	21	17	10	18	23
2.5 mm <sup>2</sup>	29	22	13	24	31
4 mm <sup>2</sup>	38	30	17	31	40
6 mm <sup>2</sup>	49	38	21	40	50
10 mm <sup>2</sup>	69	54	29	54	68
16 mm <sup>2</sup>	91	71	38	69	87
25 mm <sup>2</sup>	150	94	49	91	112
35 mm <sup>2</sup>	189	117	59	110	136
50 mm <sup>2</sup>	180	147	73	139	168
70 mm <sup>2</sup>	238	185	89	169	205
95 mm <sup>2</sup>	287	223	104	206	244
120 mm <sup>2</sup>	341	265	120	237	282

The cable from the solar array will be mounted directly on the wall and exposed to direct sunlight. The maximum current will be 18 A, using table 9 what is the minimum size cable that selected to ensure it meets the current carrying capacity?

- a) 4 mm<sup>2</sup>
- b) 6 mm<sup>2</sup>
- c) 10 mm<sup>2</sup>
- d) 16 mm<sup>2</sup>

## 5.2 Demonstrate the calculation and measurement of voltage drop in a conductor

This question will use the following formula for determining voltage drop in DC systems:

$$V_d = \frac{2 \times L_{\text{CABLE}} \times I \times \rho}{A_{\text{CABLE}}}$$

$$\text{Voltage drop (in percentage)} = \frac{V_d}{V_{\text{MAX}}} \times 100$$

Where:

- $L_{\text{CABLE}}$  = route length of cable in metres (multiplying it by two adjusts for total circuit wire length since a complete circuit requires a wire out and another wire back along the route).
- $I$  = current in amperes.
- $\rho$  = resistivity of the wire in  $\Omega/\text{m}/\text{mm}^2$
- $A_{\text{CABLE}}$  = cross sectional area (CSA) of cable in  $\text{mm}^2$ .
- $V_{\text{MAX}}$  = maximum system voltage applied to the relevant cables

Resistivity can vary depending on number of strands and type of cable. For this examination we assume copper is 0.0183.

The solar array is 20 metres from the battery bank interconnected by a cable with cross sectional area of 10 mm<sup>2</sup>. The controller is a standard controller and the battery bank is 24V. The array has a maximum short circuit current of 13A. What is the voltage drop between the array and the battery bank to three decimal places?

Answer: 0.952 V

## 5.3 Apply voltage drop and current carrying capacity calculations to select appropriate cables for a stand-alone PV energy system

This question will use table 9 and also the voltage drop formula applied in last question

$$V_d = \frac{2 \times L_{\text{CABLE}} \times I \times \rho}{A_{\text{CABLE}}}$$

$$\text{Voltage drop (in percentage)} = \frac{V_d}{V_{\text{MAX}}} \times 100$$

The solar array is 15 metres from the solar controller and the solar cable will be buried in conduit in the ground. The controller is a standard controller and the battery bank is 48 V. The array has a maximum short circuit current of 26 A. Using the formula and the cables available in table 9 above what is the minimum sized cable that could be installed between the array and controller to ensure the cable can carry the required current and have less than 3% voltage drop.

The minimum sized cable based on Table 9 for current carrying capacity is 2.5 mm<sup>2</sup>.

$$V_d = \frac{2 \times L_{\text{CABLE}} \times I \times \rho}{A_{\text{CABLE}}}$$

Maximum voltage drop is 3% this represents 0.03 x 48V = 1.44

Rearranging above formula:

$$A_{\text{CABLE}} = \frac{2 \times L_{\text{CABLE}} \times I \times \rho}{V_d}$$

The minimum size cable = (2 x 15 x 26 x 0.0183)/1.44 = 39.65 or 40 mm<sup>2</sup>

Based on cable available in the table, **50 mm<sup>2</sup>** will be required.

#### 5.4 Specify appropriate protection for all conductors in a circuit

A string cable requires overcurrent protection, what should be the maximum rating of the protective device if the short circuit current for the module in the string is 6.8 A and the reverse current is 14 A?

- a) 13.6 A
- b) 8.75 A
- c) 6.8 A
- d) 14 A

#### 5.5 Understand the need for and recognize the different modes of grounding (earthing) on a system as well as component level

Describe the difference between functional earthing (grounding) and protective earthing (grounding) in a PV array system?

Answer: Functional grounding (earthing) when either the positive or negative of the PV array is connected to ground (earth) while Protective grounding (earthing) is when the metal on array frame and solar modules are connected to the ground (earth) connection for the site.

#### 5.6 Perform safe techniques for laying, securing and terminating cables

Cables terminated on the flooded lead acid battery banks should be?

- a) Bolted to the battery terminals using suitable lugs with insulation covers over the terminals.
- b) Bare wire wrapped around the terminals and covered in grease.
- c) Run via the shortest route over the filler/inspection caps.
- d) Connected with crocodile /alligator clips for easy disconnection.

## 5.7 Label, install and terminate electrical wiring, verify proper connections, continuity, voltage and polarity relationships

A continuity and polarity test shall be performed on the DC system. What should NOT be done when performing this test?

- a) Confirming that all modules that are connected in parallel are connected with the correct polarity. That is positive to positive and negative to negative.
- b) Measuring the continuity between the inverter input positive and negative input terminals to ensure the polarity and voltage are correct.
- c) Confirming that the positive cable of the array connects to the terminal marked solar positive on the solar controller.
- d) Confirming that positive of the battery is connected to the terminal marked battery positive on the solar charge controller.

## 6. Completing System Installation, Testing and Commissioning

### 6.1 Visually inspect entire installation, identifying and resolving any deficiencies in workmanship

Study the following photo and state what is wrong with the system?



Answer: The insulation on the earth (ground cable) has not been stripped back to form a connection

## 6.2 Check system mechanical installation for structural integrity and weather sealing

Study the following photo and state what is wrong with the array



Answer: The array frame is not bolted down—it is being held up only by bricks.

## 6.3 Check electrical installation for proper wiring practice, polarity, earthing, and integrity of terminations

Practical only

## 6.4 Activate system and verify overall system functionality and performance; compare them with expectations

Practical only

## 6.5 Apply procedures for connecting and disconnecting the system and equipment from all sources

The system is 24 V DC with a standard solar charge controller. Which of the following is NOT what you do first when disconnecting the system for maintenance purposes?

- a) Turn off the AC isolator on the inverter
- b) Undo the cable connection to the battery positive or battery negative terminal first.**
- c) Turn off the loads in the house.
- d) Turn off or open the PV array isolating device.

## 6.6 Explain to end user safety issues associated with operation and maintenance of system

**This is important and there should not be six different questions. Should be one standard question, however questions 2 through to 7 have been prepared if this is required.**

From the following list circle all the safety issues that shall be explained to the end user?

- a) The dangers of battery electrolyte
- b) What to do if battery electrolyte gets on their body or in their eyes.
- c) What to do if there is a spillage of electrolyte
- d) How to open the inverter and get access to the internal boards.
- e) The safety equipment that should be worn of measuring the specific gravity of a wet lead acid battery
- f) How to remove the solar controller from where it is mounted.
- g) How to shut down the system safely
- h) How to start up the system safely
- i) How to turn on a light switch.
- j) The dangers of shortening out any battery terminals
- k) The dangers of the fumes of the lead acid battery and hence the risk of battery explosion.
- l) How to turn a wet lead acid battery on its side to drain the electrolyte.
- m) Emphasizing no smoking or sparks near the battery
- n) Emphasizing not to store things above the battery
- o) How to safely clean the solar module.
- p) How to turn off the loads in the house.

## 6.7 Complete system documentation and transfer system documentation package to end user/operator

What information would NOT be provided on the equipment in a system documentation?

- a) Brand and manufacturer.
- b) Serial number.
- c) The number of products sold that year
- d) Model.

## 7. Conducting Maintenance and Trouble Shooting Activities

### 7.1 Identify maintenance needs on system and component level, design appropriate maintenance plan and demonstrate proficiency in selecting and using of required tools

1. If the monitoring of the system shows that over time the batteries are reducing in state of charge, what could be the cause and rectification plan?
  - a) There are corroded connections in the wiring inducing voltage drop. Visual and meter checks.
  - b) The end-user has increased their loads and load management and the design load needs to be emphasized.
  - c) The modules are becoming dirty and more regular cleaning is required.
  - d) Any/all of the above

**7.2 Perform visual inspection of the entire installation, check mounting systems, ventilation, cable runs and connections/ junction boxes**

Assessed in the practical only

**7.3 Verify system operation by measuring system performance and electric parameters, by comparing with specifications and expected performance parameters, by performing diagnostic procedures and by recommending corrective actions**

The user has stated that the system shuts down and stops supplying power to the loads. The system includes a solar charge controller that monitors and records the total Ah that the solar array produces each day and the load Ah via the controller. The end user has stated the loads are not operating for the same number of hours that they were when the system was first installed and that the site has been sunny every day for the two weeks. What would you do to check the system.

Answers:

Review the monitored data for the array Ah to check if average output is as expected.

Review the monitored average load Ah to check if it is as per design.

Check to see if other equipment/loads have been connected that are not monitored.

Ask the user if there have been unusual circumstances that may have temporarily increased the load.

At least one of these should be stated.

**7.4 Identify performance and safety issues and perform corrective measures**

During a system maintenance visit to a system you have noticed that the system owner has connected a 12V car battery directly to the half (12V) of the 24 V battery system with crocodile/alligator clips. What are you going to advise the client?

Possible answers:

Using clips can create a spark that could result in explosion of hydrogen.

The charging current to the system's original 24V battery bank will not be equal in the 24V string resulting in dissimilar state of charge.

Connecting a probably flat battery in parallel could result in extremely, unprotected high current flow.

**7.5 Verify effectiveness of corrective actions by retesting system operations and electrical parameters**

A battery bank consists of twelve 2 V cells. Two were faulty and were replaced. What test should not be performed when system is reconnected?

- a) Polarity of the battery bank.
- b) Voltage of each cell
- c) Overall battery bank voltage.
- d) All of the above

## 7.6 Compile and maintain records of system operations, performance and maintenance

What would be recorded in a maintenance logbook for a system comprising individual 2V wet lead acid batteries and a solar array?

- a) Individual battery voltages.
- b) Date the modules were cleaned.
- c) Specific gravity readings for each battery cell.
- d) All of the above.

## 7.7 Demonstrate knowledge of the environmental impacts

The system comprises a large wet lead acid battery bank containing twenty four (24) 2 V cells. The batteries are mounted in an outside shed but the batteries have had their cases broken by vandals. What would be one potential environmental risk from the damaged batteries?

- a) The lead is now exposed to the atmosphere.
- b) The damaged cases are sharp.
- c) The electrolyte has spilled into the soil and into the water table.
- d) The battery cannot supply power to the system.