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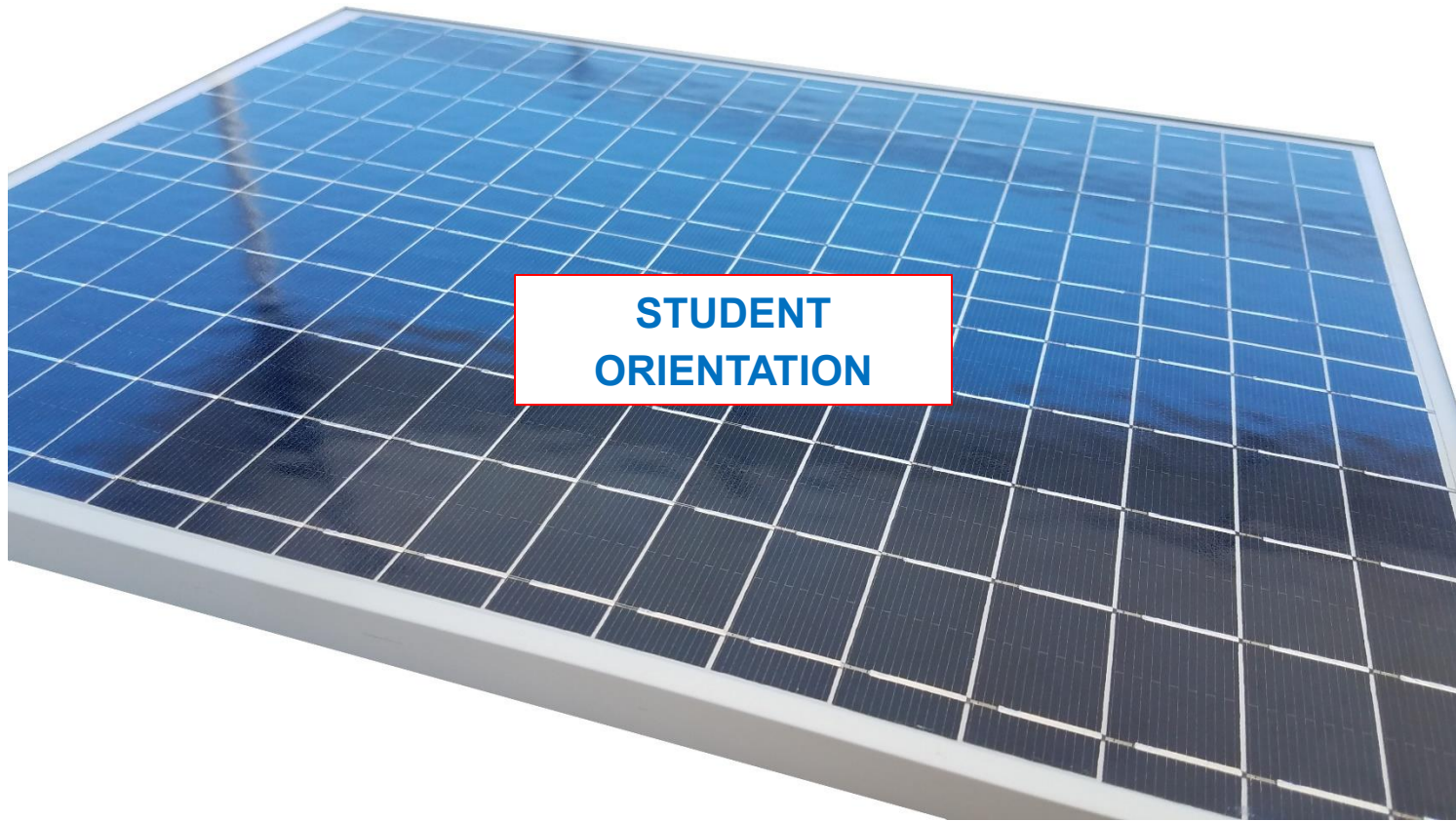
Center for  
Renewable  
Energy  
Advanced  
Technological  
Education



Name: \_\_\_\_\_

Date: \_\_\_\_ / \_\_\_\_ / \_\_\_\_ Class Hour: \_\_\_\_

## SOLAR PV: MODULE PERFORMANCE



**STUDENT  
ORIENTATION**



Name: \_\_\_\_\_

Date: \_\_\_\_ / \_\_\_\_ / \_\_\_\_ Class Hour: \_\_\_\_

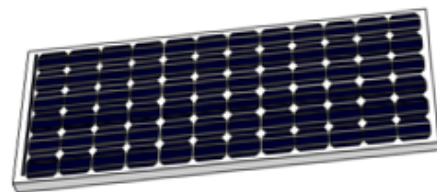
## SOLAR PV: MODULE PERFORMANCE

### Introduction

Like most people, you probably understand that a solar PV module works best in lots of sunlight. But do you know how an array of solar PV modules should be positioned to get maximum sunlight in the first place? What about shading? Sometimes a small amount of shading on a PV array is unavoidable. But is all shading the same? What other environmental factors significantly affect module performance and in what ways?

In this lesson, you'll answer these questions by taking common industry measurements on a solar PV module. In doing so, you'll use tools of the trade in everyday use in the solar industry to measure:

- How much sunlight is hitting a module's surface
- Module temperature
- Module electric potential (Volts)
- Module current (Amps)

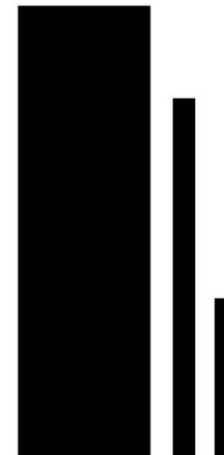
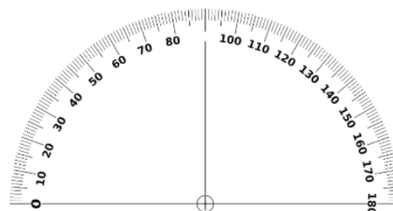


By the conclusion of the lesson you'll know the most important factors affecting solar PV module performance, and the critical relationships between them.



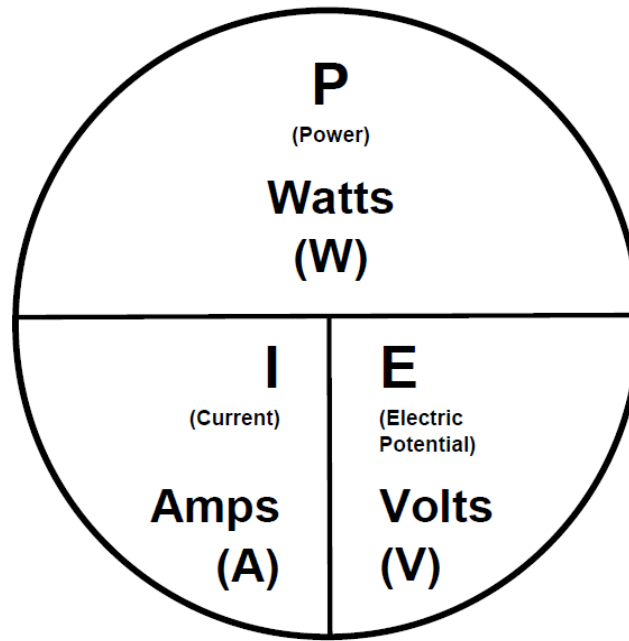
## Materials

- Solar PV Module
- Multimeter with alligator leads
- Pyranometer
- Protractor
- High intensity LED Lamp (optional)
- Wire connector
- Amp clamp
- Infrared thermometer
- Pre-cut module shading materials

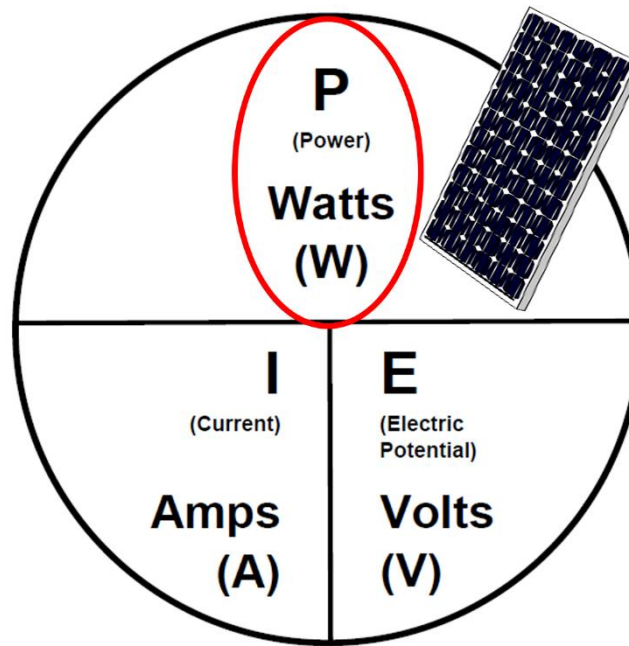




# Electrical Measurements & Using A Multimeter (1)

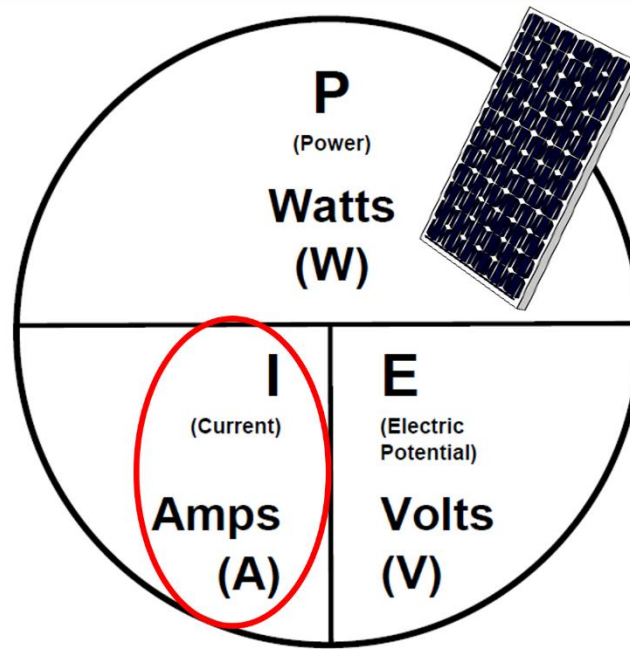


# Electrical Measurements & Using A Multimeter (2)



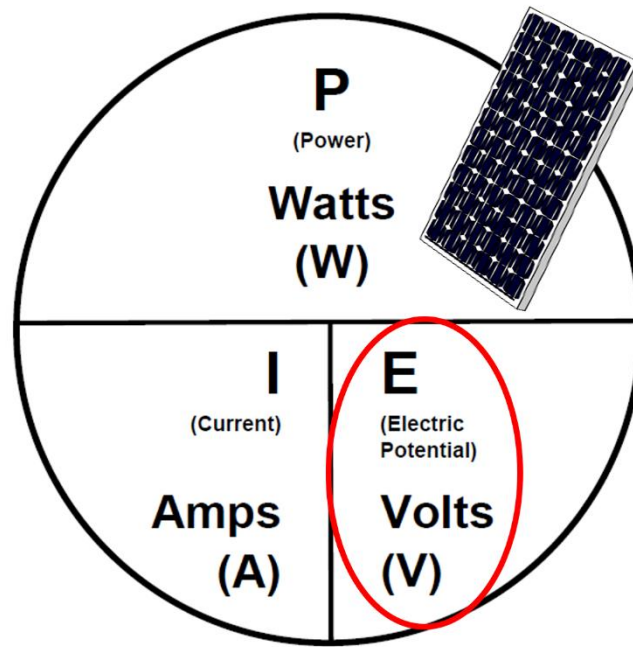
<b>Power (P)</b> is measured in units of <b>Watts (W)</b>	Power is the rate at which work is done (and energy is used) in an electrical circuit.
<b>Current (I)</b> is measured in units of <b>Amps (A)</b>	Current is the rate at which electrons flow through an electrical circuit.
<b>Electric Potential</b> is measured in units of <b>Volts (V)</b>	Electric Potential is the amount of potential energy available to push electrons through an electrical circuit.

# Electrical Measurements & Using A Multimeter (3)



<b>Power (P)</b> is measured in units of <b>Watts (W)</b>	Power is the rate at which work is done (and energy is used) in an electrical circuit.
<b><u>Current ( I )</u></b> is measured in units of <b>Amps (A)</b>	Current is the rate at which electrons flow through an electrical circuit.
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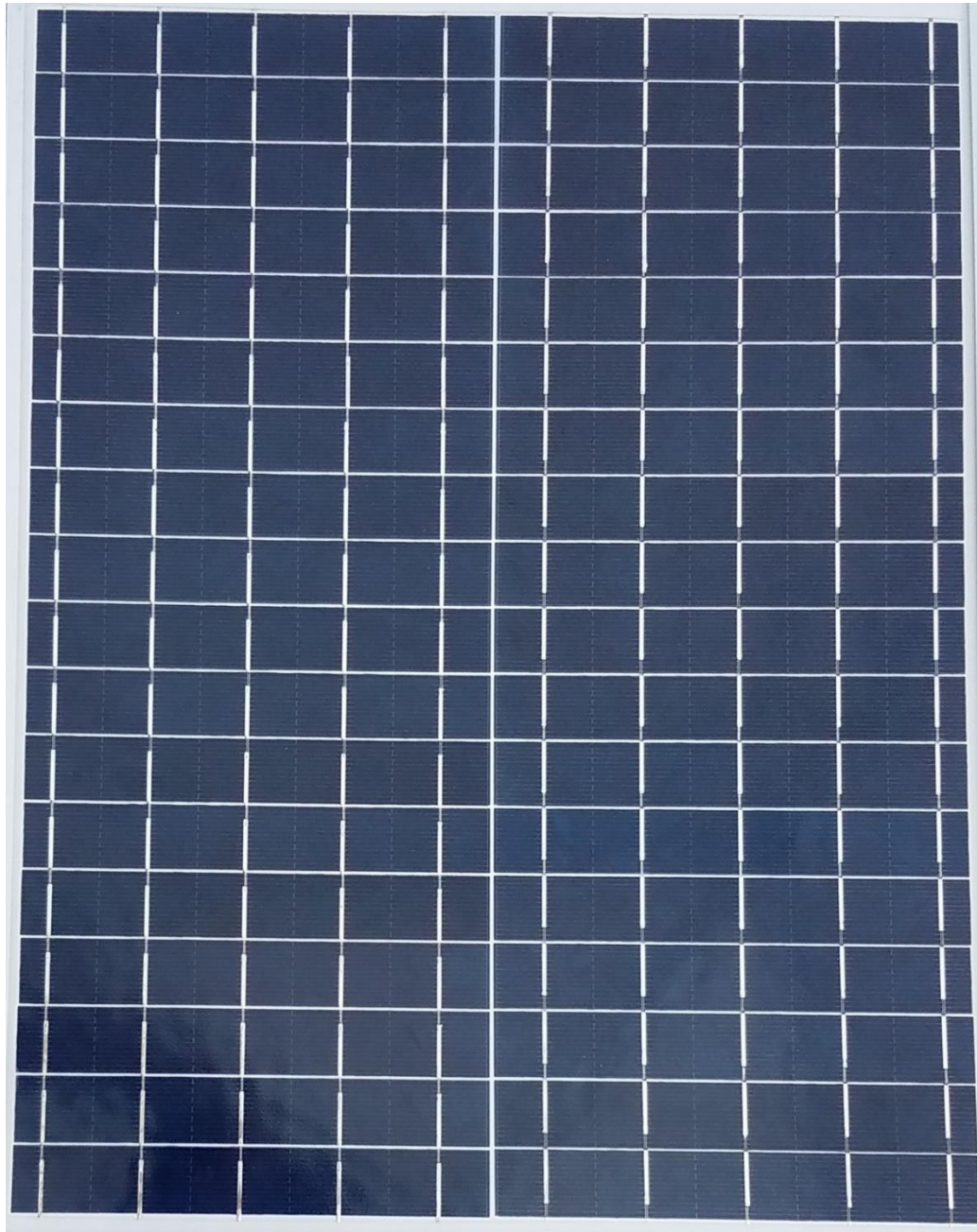
# Electrical Measurements & Using A Multimeter (4)



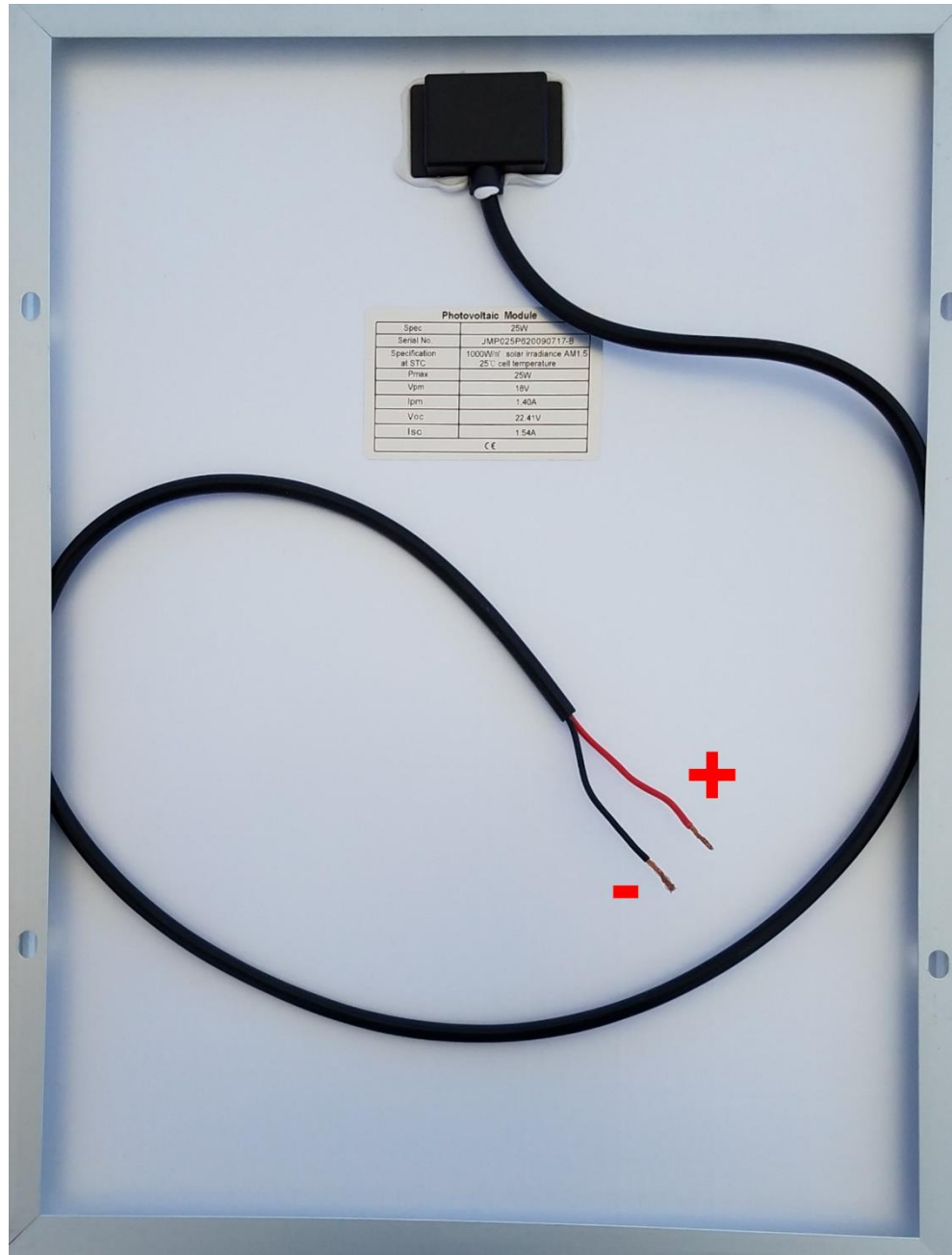
<b>Power (P)</b> is measured in units of <b>Watts (W)</b>	Power is the rate at which work is done (and energy is used) in an electrical circuit.
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<b><u>Electric Potential</u></b> is measured in units of <b>Volts (V)</b>	Electric Potential is the amount of potential energy available to push electrons through an electrical circuit.



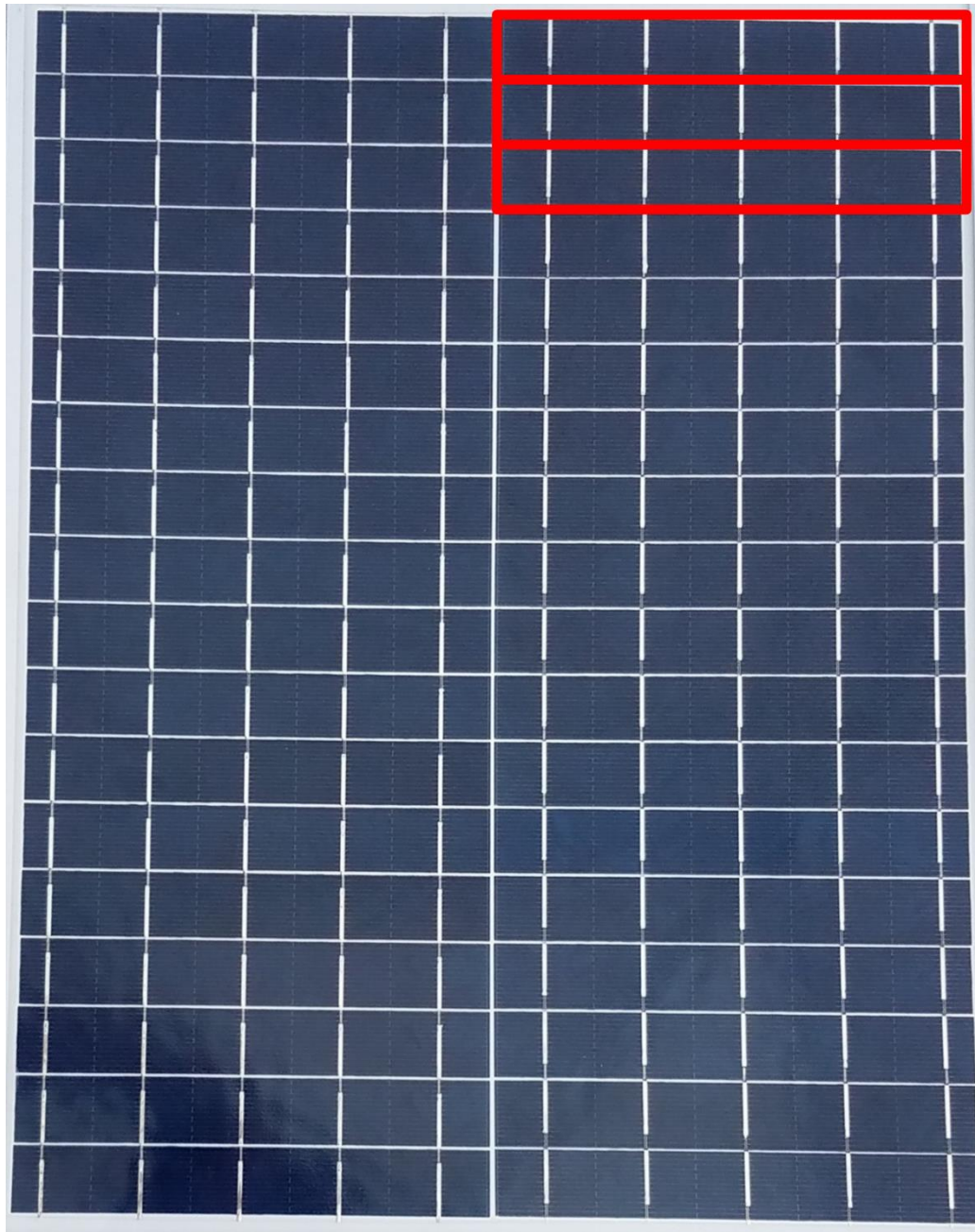
**Your Solar  
PV Module  
(1)**



# Your Solar PV Module (2)



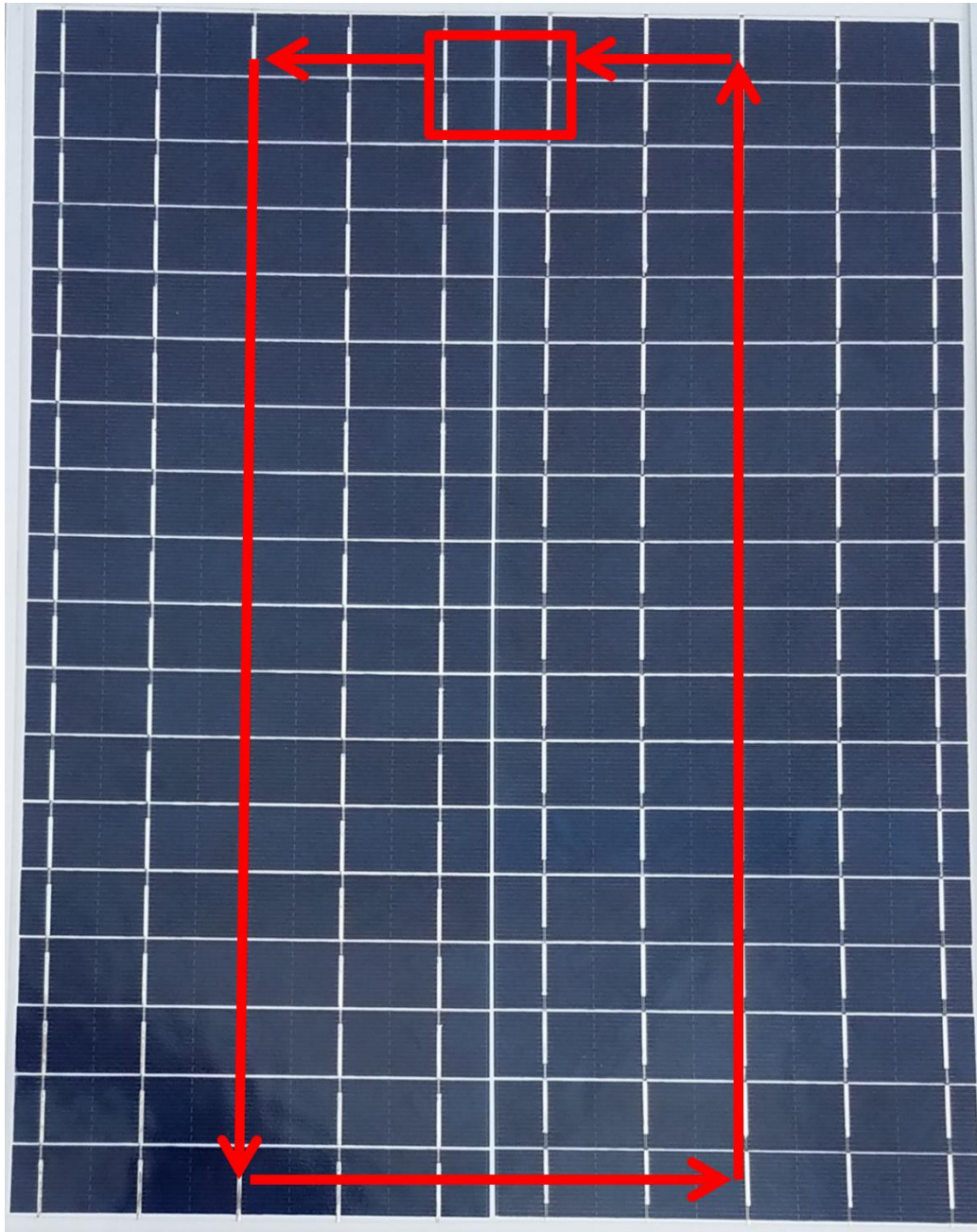
# Your Solar PV Module (3)



Each  
of  
these  
is one  
PV  
cell

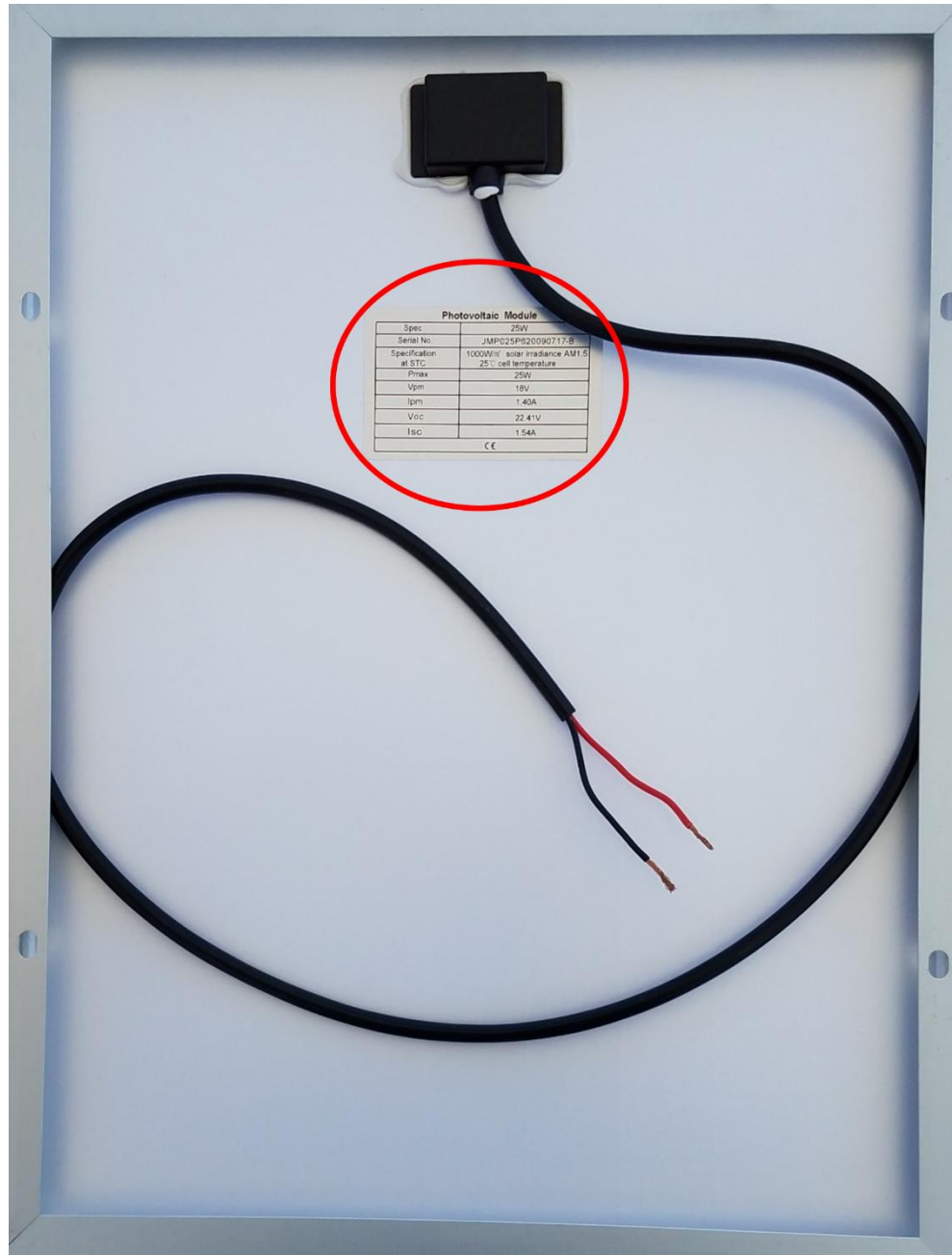


# Your Solar PV Module (4)





# Your Solar PV Module (5)



Your Solar  
PV Module  
(6)

Photovoltaic Module

Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Your Solar  
PV Module  
(7)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Standard Test Conditions STC	Standard conditions for testing solar modules: <ul style="list-style-type: none"><li>• Module temperature of 25°C (77°F).</li><li>• Light intensity (irradiance) of 1000 Watts/m<sup>2</sup>.</li><li>• Atmospheric air mass of 1.5.</li></ul>
---------------------------------	--

Your Solar  
PV Module  
(8)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Standard Test Conditions STC	Standard conditions for testing solar modules: <ul style="list-style-type: none"><li>• Module temperature of 25°C (77°F).</li><li>• Light intensity (irradiance) of 1000 Watts/m<sup>2</sup>.</li><li>• Atmospheric air mass of 1.5.</li></ul>
---------------------------------	--



Your Solar  
PV Module  
(9)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Standard Test Conditions STC	Standard conditions for testing solar modules: <ul style="list-style-type: none"><li>• Module temperature of 25°C (77°F).</li><li>• Light intensity (irradiance) of 1000 Watts/m<sup>2</sup>.</li><li>• Atmospheric air mass of 1.5.</li></ul>
---------------------------------	--

**Your Solar  
PV Module  
(10)**

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

<b>Standard Test Conditions STC</b>	Standard conditions for testing solar modules: <ul style="list-style-type: none"><li>• Module temperature of 25°C (77°F).</li><li>• Light intensity (irradiance) of 1000 Watts/m<sup>2</sup>.</li><li>• Atmospheric air mass of 1.5.</li></ul>
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Your Solar  
PV Module  
(11)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Standard Test Conditions STC	Standard conditions for testing solar modules: <ul style="list-style-type: none"><li>• Module temperature of 25°C (77°F).</li><li>• Light intensity (irradiance) of 1000 Watts/m<sup>2</sup>.</li><li>• Atmospheric air mass of 1.5.</li></ul>
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Your Solar  
PV Module  
(12)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Open Circuit Voltage <u>Voc</u>	Electric potential (Volts) of your module in an open circuit condition. This is the maximum Volts the module can produce at STC.
*	



Your Solar  
PV Module  
(13)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Short Circuit Current	Current (Amps) your module will produce in a short circuit condition. This is the maximum Amps the module can produce at STC.
<u>Isc</u>	
*	

Your Solar  
PV Module  
(14)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Maximum Power Voltage Vmp [ Vmpp ] [ Vpm ]	Maximum electric potential (Volts) of your module when connected to complimentary equipment at STC.
*	

Your Solar  
PV Module  
(15)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
Ipm	1.40A
Voc	22.41V
Isc	1.54A
CE	

Maximum Power Current Imp [ Impp ] [ Ipm ]	Maximum current (Amps) your module will produce when connected to complimentary equipment at STC.
*	

Your Solar  
PV Module  
(16)

Photovoltaic Module	
Spec	25W
Serial No.	JMP025P620090717-B
Specification at STC	1000W/m <sup>2</sup> solar irradiance AM1.5 25°C cell temperature
Pmax	25W
Vpm	18V
lpm	1.40A
Voc	22.41V
Isc	1.54A
C €	

<b>Maximum Power Point</b> <b>Pmax [ Pmp ] [ Pmpp ]</b>	Maximum power (Watts) your module will produce when connected to complimentary equipment at STC. Since Watts = Volts X Amps, Pmax = Vmp X Imp.
*	

Your Solar  
PV Module  
(17)

Table 1.

Module position or orientation  
▼

a.



Irradiance  
 $W/m^2$

b.



Temperature  
 $^{\circ}C$

c.



Electric  
Potential  
(Volts)  
open circuit  
condition  
 $V_{oc}$

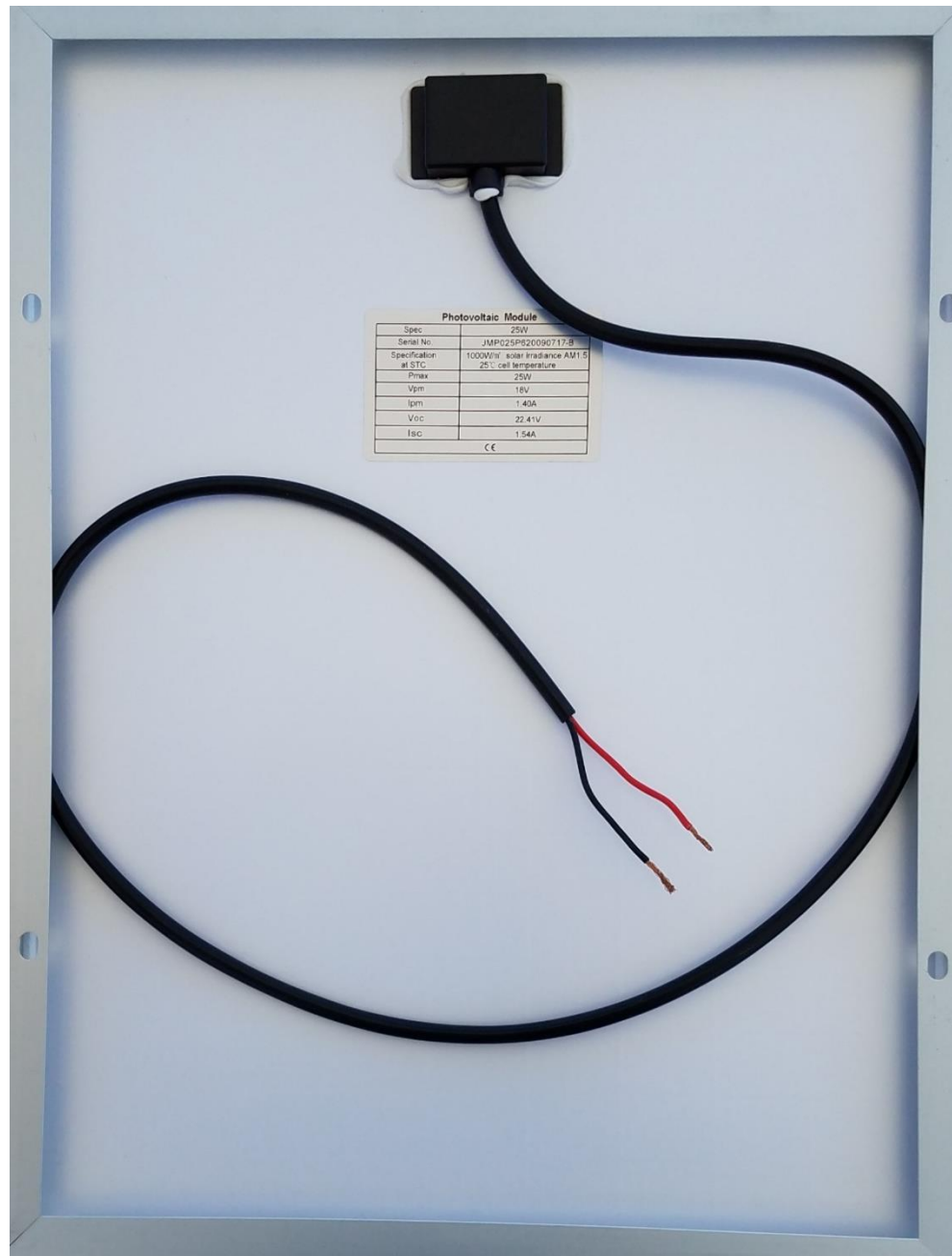
d.



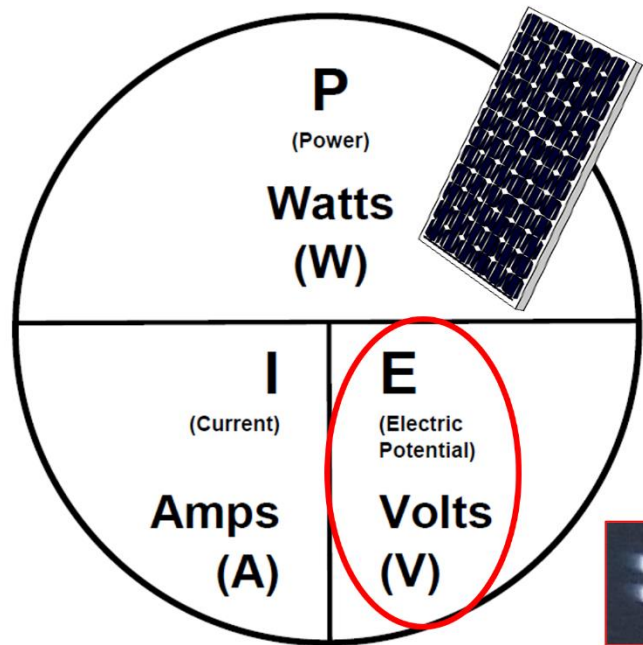
Current  
(Amps)  
short circuit  
condition  
 $I_{sc}$



# Your Solar PV Module (18)

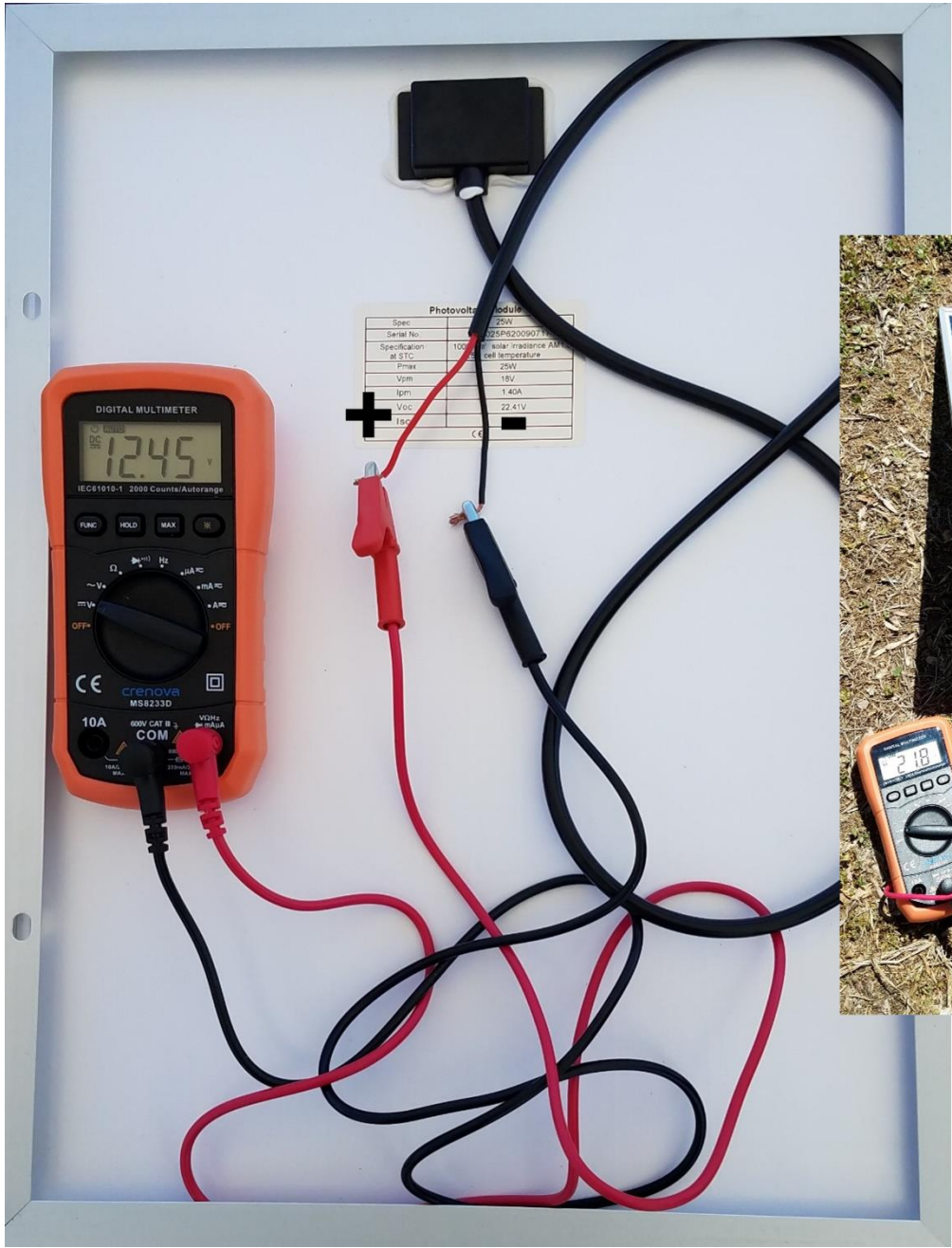


Your Solar  
PV Module  
(19)



<b>Power (P)</b> is measured in units of <b>Watts (W)</b>	Power is the rate at which work is done (and energy is used) in an electrical circuit.
<b>Current ( I )</b> is measured in units of <b>Amps (A)</b>	Current is the rate at which electrons flow through an electrical circuit.
<u><b>Electric Potential</b></u> is measured in units of <b>Volts (V)</b>	Electric Potential is the amount of potential energy available to push electrons through an electrical circuit.

Your Solar  
PV Module  
(20)





# Your Solar PV Module (21)





Your Solar  
PV Module  
(22)

Table 1.

Module position or orientation  
▼

a.



Irradiance  
 $W/m^2$

b.



Temperature  
 $^{\circ}C$

c.



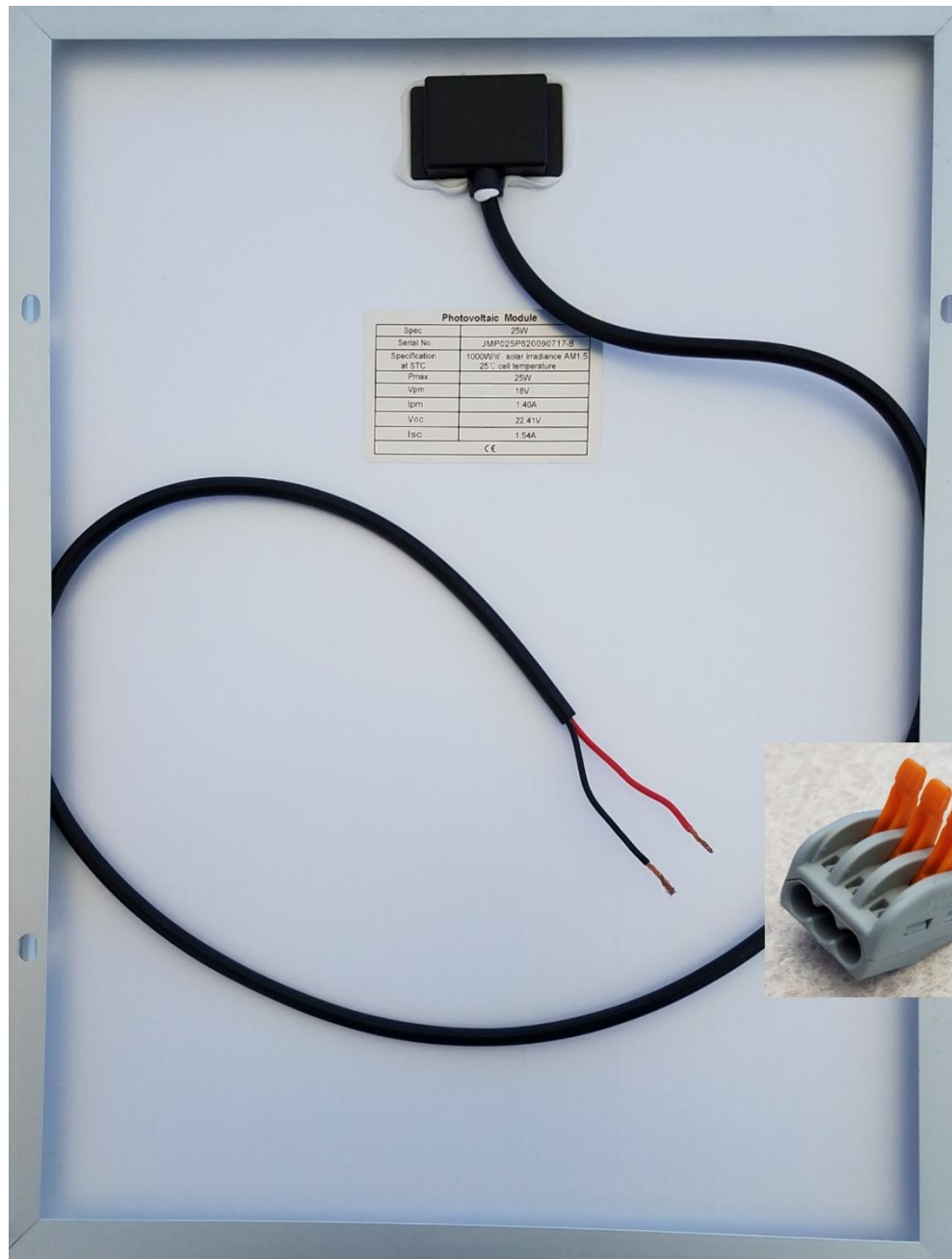
Electric  
Potential  
(Volts)  
open circuit  
condition  
 $V_{oc}$

d.

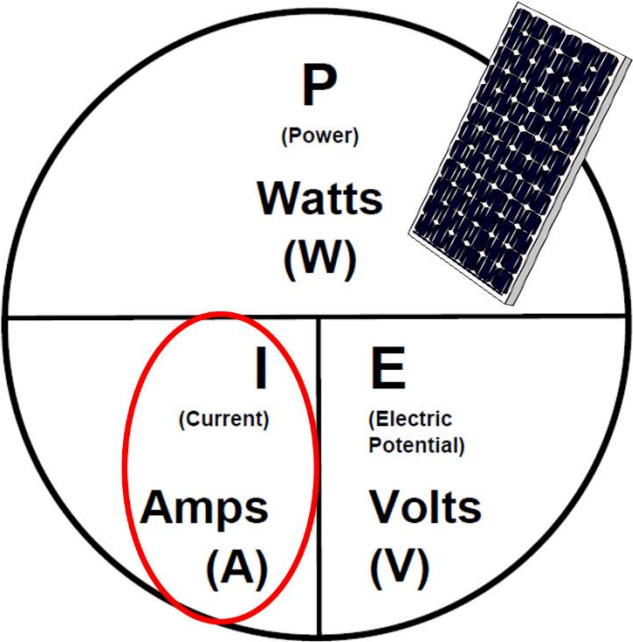


Current  
(Amps)  
short circuit  
condition  
 $I_{sc}$

# Your Solar PV Module (23)



Your Solar  
PV Module  
(24)



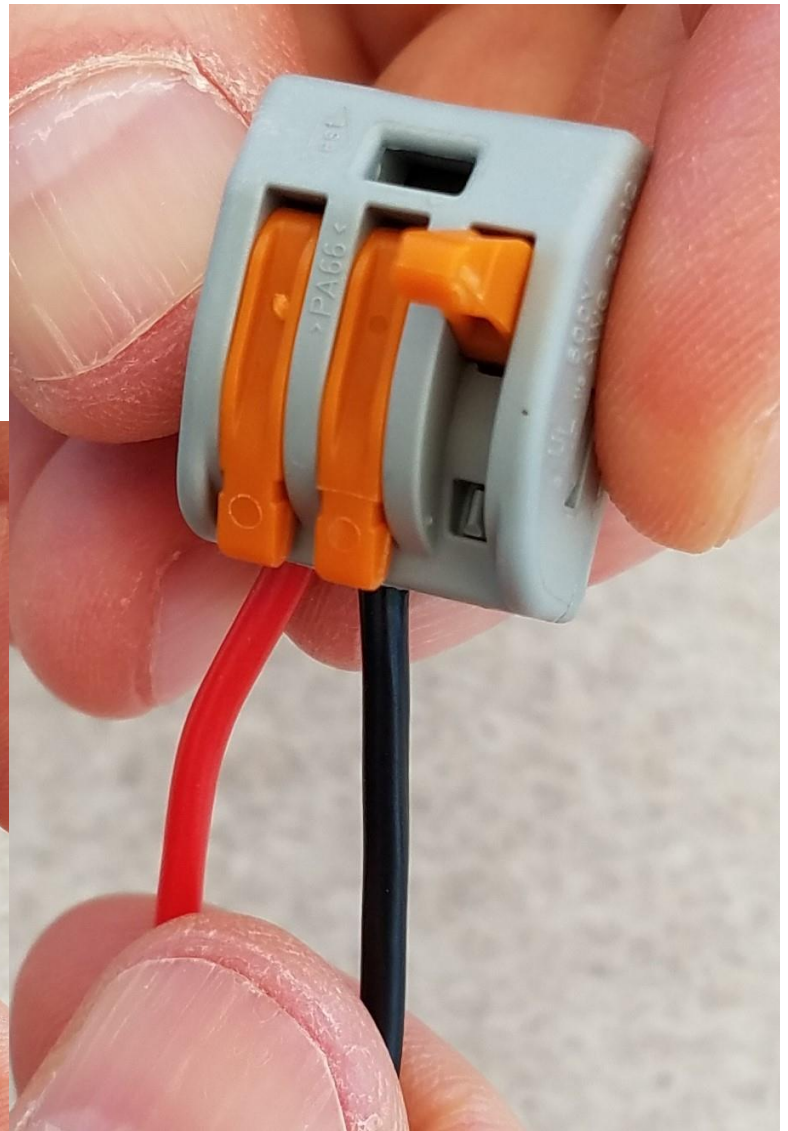
<b>Power (P)</b> is measured in units of <b>Watts (W)</b>	Power is the rate at which work is done (and energy is used) in an electrical circuit.
<b><u>Current ( I )</u></b> is measured in units of <b>Amps (A)</b>	Current is the rate at which electrons flow through an electrical circuit.
<b>Electric Potential</b> is measured in units of <b>Volts (V)</b>	Electric Potential is the amount of potential energy available to push electrons through an electrical circuit.

# Your Solar PV Module (25)



**Wire connector**

**Connecting**



**Connected**



## Your Solar PV Module (26)

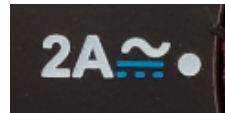


**Don't touch  
these your two  
module leads  
together...**

**...especially  
don't touch  
them together  
with the  
module facing  
toward the  
sun.**

**Demo  
([click here](#))**

# Your Solar PV Module (27)



**Before each current measurement, the amp clamp should be “zeroed out”.**

**Turn amp clamp on, turning dial to the 2A setting.**



**Press blue SELECT button to measure DC instead of AC current.**



**Press grey ZERO button while holding amp clamp tongs against a wire.**



## Your Solar PV Module (28)



**Now wrap the amp  
clamp tongs around  
the wire you zeroed  
out against.  
Record your Isc  
measurement.**

# Using a Pyranometer (1)

**Table 1.**

**Module position or orientation**



**a.**



Irradiance  
 $\text{W/m}^2$

**b.**



Temperature  
 $^{\circ}\text{C}$

**c.**



Electric  
Potential  
(Volts)  
open circuit  
condition  
**Voc**

**d.**



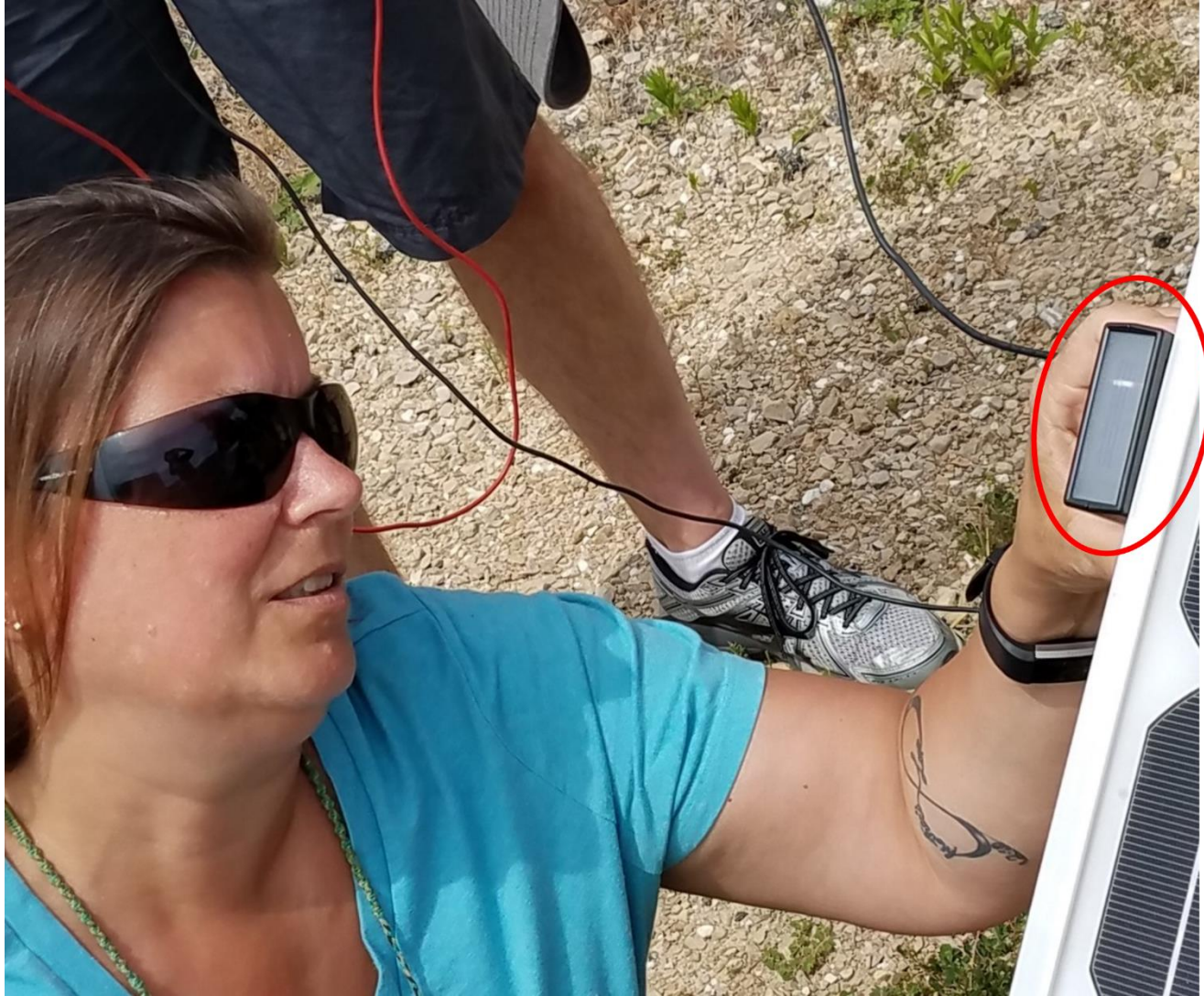
Current  
(Amps)  
short circuit  
condition  
**Isc**



## Using a Pyranometer (2)



## Using a Pyranometer (3)



# Using an Infrared Thermometer (1)

Table 1.

Module position or orientation  
▼

a.



Irradiance  
 $\text{W/m}^2$

b.



Temperature  
 $^{\circ}\text{C}$

c.



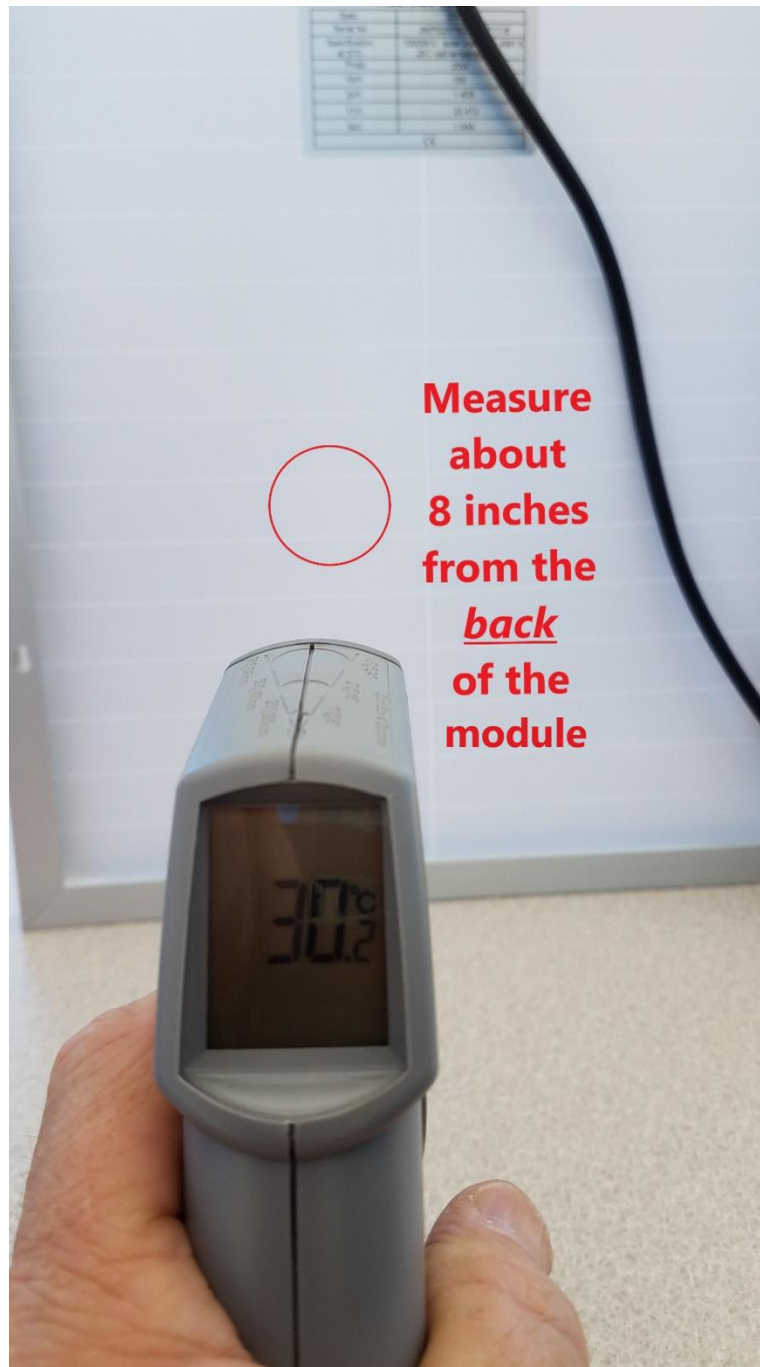
Electric  
Potential  
(Volts)  
open circuit  
condition  
 $V_{oc}$

d.



Current  
(Amps)  
short circuit  
condition  
 $I_{sc}$

## Using an Infrared Thermometer (2)





# Module Positioning (1)









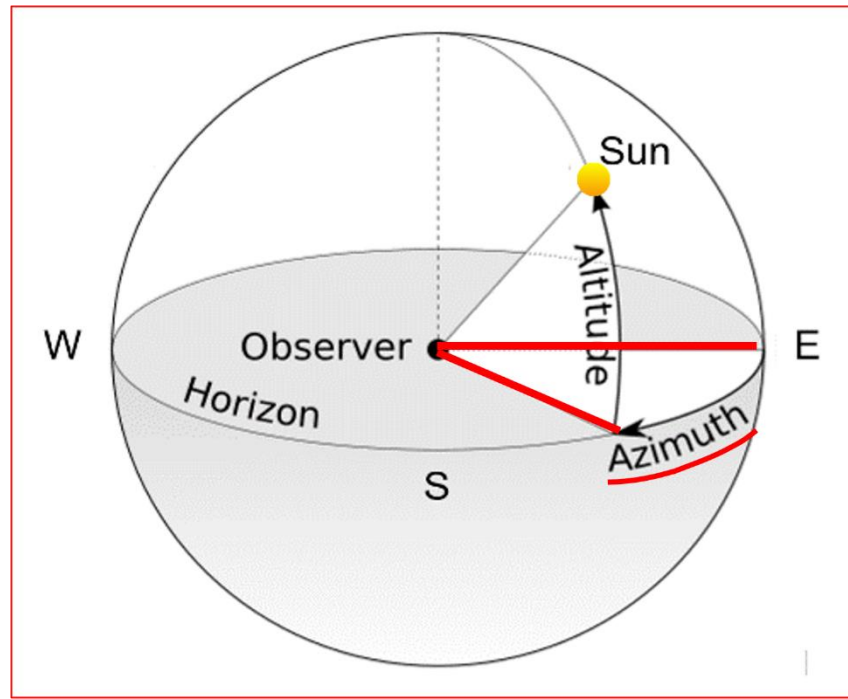
Table 1.	a.	b.	c.	d.
Module position or orientation ▼	 Irradiance W/m <sup>2</sup>	 Temperature °C	 Electric Potential (Volts) open circuit condition V <sub>oc</sub>	 Current (Amps) short circuit condition I <sub>sc</sub>
1. Ideal direction and ideal tilt angle, <b>module cool</b>  Ideal azimuth and ideal tilt angle	*	*	*	*
2. Ideal direction and Vertical (module upright at 90°)  Ideal azimuth and 90° tilt angle	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
3. Horizontal (face up, flat on the ground )  Azimuth doesn't matter and 0° tilt angle	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
4. Facing north and vertical (no sunlight hitting module front)  0° azimuth and 90° tilt angle	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
5. Ideal direction and ideal tilt angle, <b>module warm</b>  Ideal azimuth and ideal tilt angle	*	*	*	*

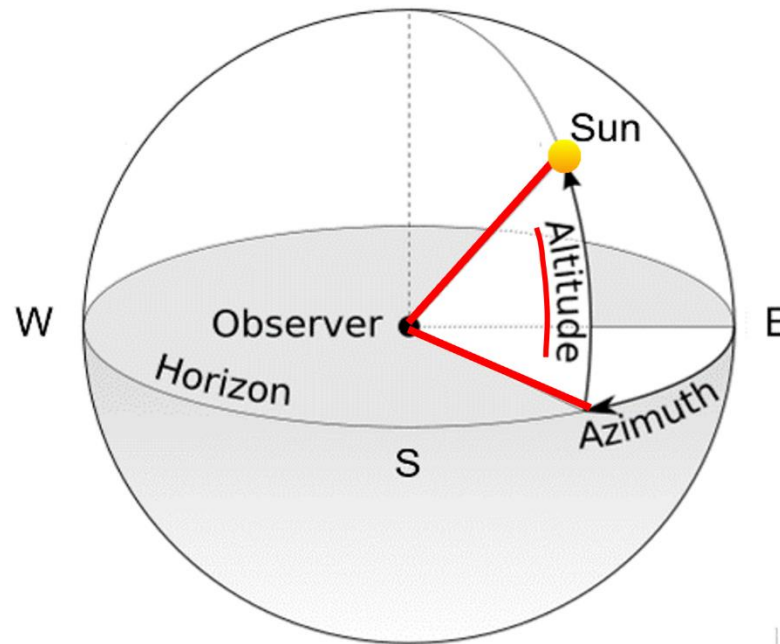
Table 1.	a.	b.	c.	d.
<b>Module position or orientation</b> ▼			 Electric Potential (Volts) open circuit condition <b>Voc</b>	 Current (Amps) short circuit condition <b>Isc</b>
<b>1. Ideal direction and ideal tilt angle, module cool</b> <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*
<b>2. Ideal direction and Vertical</b> (module upright at 90°) <i>Ideal azimuth and 90° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>3. Horizontal</b> (face up, flat on the ground ) <i>Azimuth doesn't matter and 0° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>4. Facing north and vertical</b> (no sunlight hitting module front) <i>0° azimuth and 90° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>5. Ideal direction and ideal tilt angle, module warm</b> <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*

# Module Positioning (3)



<b><u>Solar Azimuth</u></b>	Solar azimuth is the compass degree ( $0^{\circ}$ - $360^{\circ}$ ) that describes the position of the sun along the horizon at any given time.
*	
<b>Solar Altitude (Solar Elevation)</b>	Solar Altitude is the vertical angle formed between the horizon and the center of the sun's disc at any given time.
*	
<b>Ideal Tilt Angle (Lab)</b>	The Ideal Tilt Angle we'll use for this lab is $90^{\circ}$ - current Solar Altitude.
*	

# Module Positioning (4)



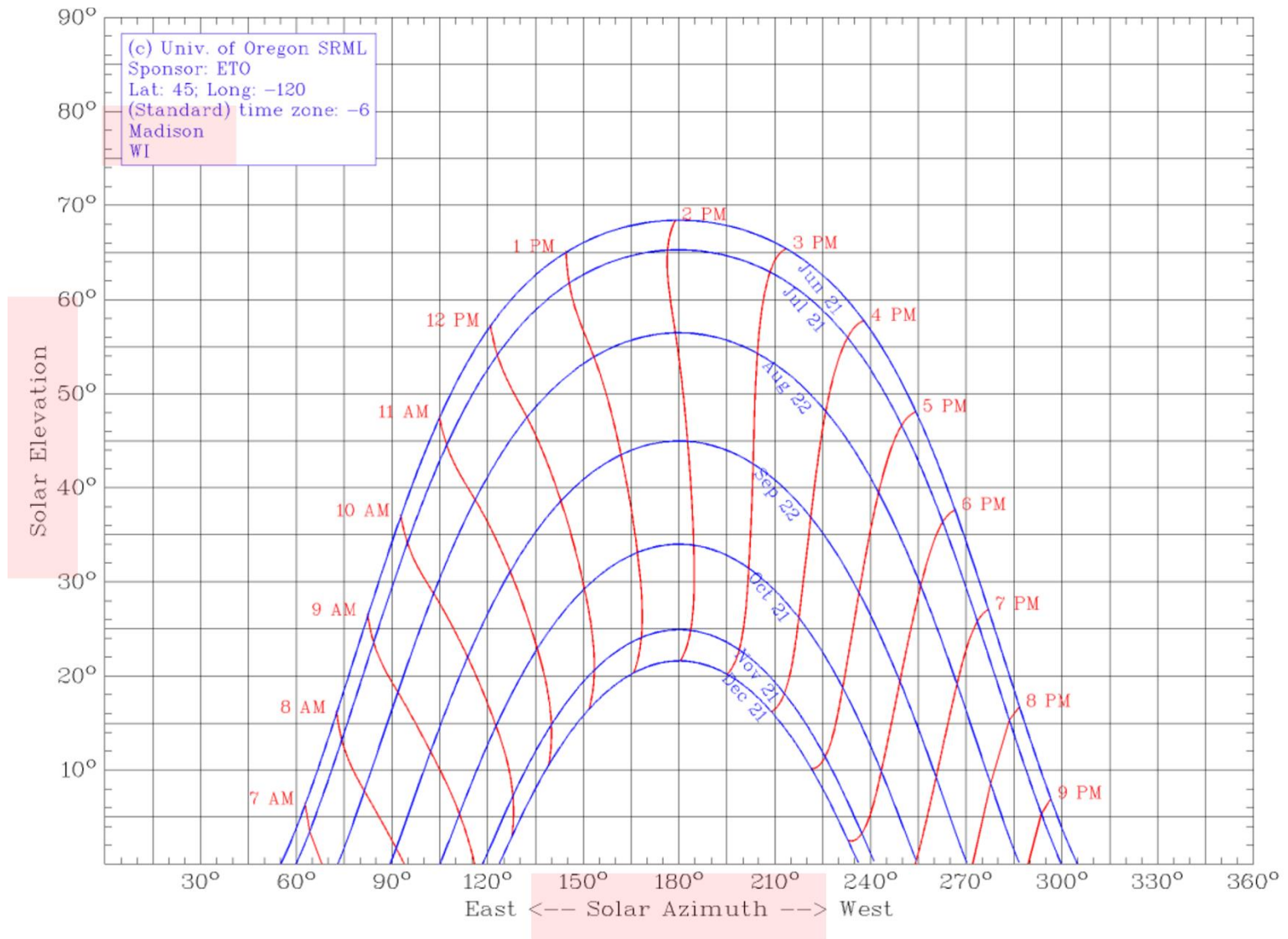
<b>Solar Azimuth</b>	Solar azimuth is the compass degree ( $0^{\circ}$ - $360^{\circ}$ ) that describes the position of the sun along the horizon at any given time.
*	
<b><u>Solar Altitude</u> (Solar Elevation)</b>	Solar Altitude is the vertical angle formed between the horizon and the center of the sun's disc at any given time.
*	
<b>Ideal Tilt Angle (Lab)</b>	The Ideal Tilt Angle we'll use for this lab is $90^{\circ}$ - current Solar Altitude.
*	



# Module Positioning (5)

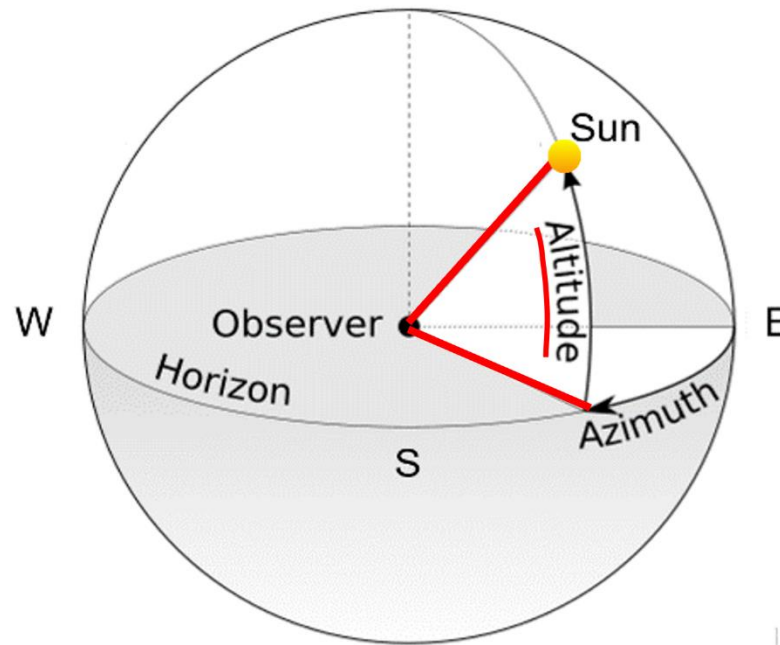


# Module Positioning (6)







University of Oregon Sun Path Chart Program ([click here](#))

# Module Positioning (7)



<b>Solar Azimuth</b>	Solar azimuth is the compass degree ( $0^{\circ}$ - $360^{\circ}$ ) that describes the position of the sun along the horizon at any given time.
*	
<b>Solar Altitude (Solar Elevation)</b>	Solar Altitude is the vertical angle formed between the horizon and the center of the sun's disc at any given time.
*	
<b><u>Ideal Tilt Angle (Lab)</u></b>	The Ideal Tilt Angle we'll use for this lab is $90^{\circ}$ - current Solar Altitude.
*	

Table 1.	a.	b.	c.	d.
<b>Module position or orientation</b> ▼				
	Irradiance $W/m^2$	Temperature $^{\circ}C$	Electric Potential (Volts) open circuit condition <b>Voc</b>	Current (Amps) short circuit condition <b>Isc</b>
<b>1. Ideal direction</b> and <b>ideal tilt angle</b> , <b>module cool</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*
<b>2. Ideal direction</b> and <b>Vertical</b> (module upright at $90^{\circ}$ )  <i>Ideal azimuth and <math>90^{\circ}</math> tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>3. Horizontal</b> (face up, flat on the ground )  <i>Azimuth doesn't matter and <math>0^{\circ}</math> tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>4. Facing north</b> and <b>vertical</b> (no sunlight hitting module front)  <i><math>0^{\circ}</math> azimuth and <math>90^{\circ}</math> tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>5. Ideal direction</b> and <b>ideal tilt angle</b> , <b>module warm</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*



# Module Positioning (9)

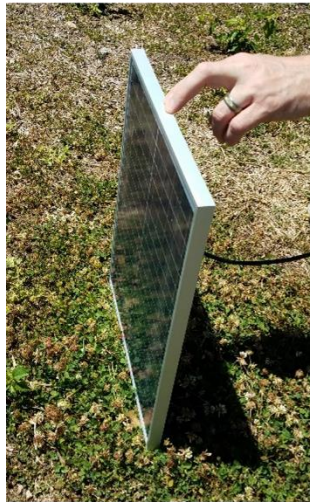










Table 1.	a.	b.	c.	d.
				
<b>Module position or orientation</b> ▼	Irradiance $W/m^2$	Temperature $^{\circ}C$	Electric Potential (Volts) open circuit condition <b>Voc</b>	Current (Amps) short circuit condition <b>Isc</b>
<b>1. Ideal direction and ideal tilt angle, module cool</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*
<b>2. Ideal direction and Vertical (module upright at 90°)</b>  <i>Ideal azimuth and 90° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>3. Horizontal (face up, flat on the ground )</b>  <i>Azimuth doesn't matter and 0° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>4. Facing north and vertical (no sunlight hitting module front)</b>  <i>0° azimuth and 90° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>5. Ideal direction and ideal tilt angle, module warm</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*

Table 1.	a.	b.	c.	d.
				
<b>Module position or orientation</b> ▼	Irradiance <b>W/m<sup>2</sup></b>	Temperature <b>°C</b>	Electric Potential (Volts) open circuit condition <b>V<sub>oc</sub></b>	Current (Amps) short circuit condition <b>I<sub>sc</sub></b>
<b>1. Ideal direction</b> and <b>ideal tilt angle, module cool</b>	*	*	*	*
<i>Ideal azimuth and ideal tilt angle</i>				
<b>2. Ideal direction</b> and <b>Vertical</b> (module upright at 90°)	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<i>Ideal azimuth and 90° tilt angle</i>				
<b>3. Horizontal</b> (face up, flat on the ground )	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<i>Azimuth doesn't matter and 0° tilt angle</i>				
<b>4. Facing north</b> and <b>vertical</b> (no sunlight hitting module front)	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<i>0° azimuth and 90° tilt angle</i>				
<b>5. Ideal direction</b> and <b>ideal tilt angle, module warm</b>	*	*	*	*
<i>Ideal azimuth and ideal tilt angle</i>				

# Module Positioning (11)











Table 1.	a.	b.	c.	d.
				
<b>Module position or orientation</b> ▼	Irradiance $\text{W/m}^2$	Temperature $^{\circ}\text{C}$	Electric Potential (Volts) open circuit condition <b>Voc</b>	Current (Amps) short circuit condition <b>Isc</b>
<b>1. Ideal direction and ideal tilt angle, module cool</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*
<b>2. Ideal direction and Vertical</b> (module upright at $90^{\circ}$ )  <i>Ideal azimuth and <math>90^{\circ}</math> tilt angle</i>	*	It is not necessary to take a temperature measurement on your module here.	It is not necessary to take a Volts measurement on your module here.	*
<b>3. Horizontal</b> (face up, flat on the ground )  <i>Azimuth doesn't matter and <math>0^{\circ}</math> tilt angle</i>	*	It is not necessary to take a temperature measurement on your module here.	It is not necessary to take a Volts measurement on your module here.	*
<b>4. Facing north and vertical</b> (no sunlight hitting module front)  <i><math>0^{\circ}</math> azimuth and <math>90^{\circ}</math> tilt angle</i>	*	It is not necessary to take a temperature measurement on your module here.	It is not necessary to take a Volts measurement on your module here.	*
<b>5. Ideal direction and ideal tilt angle, module warm</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*









Table 1.	a.	b.	c.	d.
				
<b>Module position or orientation</b> ▼	Irradiance <b>W/m<sup>2</sup></b>	Temperature <b>°C</b>	Electric Potential (Volts) open circuit condition <b>Voc</b>	Current (Amps) short circuit condition <b>Isc</b>
<b>1. Ideal direction and ideal tilt angle, module cool</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*
<b>2. Ideal direction and Vertical</b> (module upright at 90°)  <i>Ideal azimuth and 90° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>3. Horizontal</b> (face up, flat on the ground )  <i>Azimuth doesn't matter and 0° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>4. Facing north and vertical</b> (no sunlight hitting module front)  <i>0° azimuth and 90° tilt angle</i>	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<b>5. Ideal direction and ideal tilt angle, module warm</b>  <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*







## Reminders and Pointers (1)

Table 1.	a.	b.	c.	d.
				
<b>Module position or orientation</b> ▼	Irradiance $\text{W/m}^2$	Temperature $^{\circ}\text{C}$	Electric Potential (Volts) open circuit condition $V_{oc}$	Current (Amps) short circuit condition $I_{sc}$
<b>1. Ideal direction and ideal tilt :</b>				
<i>Ideal azimuth and ideal tilt angle</i>	▲	▲	▲	▲
<b>2. Ideal direction and ideal tilt :</b>				
<i>Ideal azimuth and 90° tilt angle</i>				
<b>3. Horizontal position and ideal tilt :</b>				
<i>Azimuth and 0° tilt angle</i>				
<b>4. Facing direction and ideal tilt :</b>				
<i>0° azimuth and 90° tilt angle</i>				
<b>5. Ideal direction and ideal tilt :</b>				
<i>Ideal azimuth and ideal tilt angle</i>				

Before performing the lab,  
you'll practice taking each  
of these measurements in  
the shade...




...out of the sun  
with the module cool.

# Reminders and Pointers (2)

<p>Table 1.</p>	<p>a.</p> 	<p>b.</p> 	<p>c.</p>  <p>Electric Potential (Volts) open circuit condition <b>Voc</b></p>	<p>d.</p>  <p>Current (Amps) short circuit condition <b>Isc</b></p>
<p>Module position or orientation ▼</p>	<p>Irradiance <b>W/m<sup>2</sup></b></p>	<p>Temperature <b>°C</b></p>		
<p>1. Ideal direction and ideal tilt angle, <b>module cool</b></p> <p><i>Ideal azimuth and ideal tilt angle</i></p>	<p>◀ To begin the lab, move your module into position in the sun and take your first set of measurements as quickly as possible while the module is still cool.</p>			
<p>2. Ideal direction and Vertical (module upright at 90°)</p> <p><i>Ideal azimuth and 90° tilt angle</i></p>				
<p>3. Horizontal (face up, flat on the ground )</p> <p><i>Azimuth doesn't matter and 0° tilt angle</i></p>				
<p>4. Facing north and vertical (no sunlight hitting module front)</p> <p><i>0° azimuth and 90° tilt angle</i></p>				
<p>5. Ideal direction and ideal tilt angle, <b>module warm</b></p> <p><i>Ideal azimuth and ideal tilt angle</i></p>	<p>*</p>	<p>your module here.</p> <p>*</p>	<p>your module here.</p> <p>*</p>	<p>*</p>





## Reminders and Pointers (3)

**Perform  
lab activity  
position by  
position  
(L to R, top  
to bottom)**

Table 1.	a.	b.	c.	d.
				
<b>Module position or orientation</b> ▼	Irradiance <b>W/m<sup>2</sup></b>	Temperature <b>°C</b>	Electric Potential (Volts) open circuit condition <b>Voc</b>	Current (Amps) short circuit condition <b>Isc</b>
<b>1. Ideal direction</b> and <b>ideal tilt angle, module cool</b>	*	*	*	*
<i>Ideal azimuth and ideal tilt angle</i>				
<b>2. Ideal direction</b> and <b>Vertical</b> (module upright at 90°)	*	It is not necessary to take a <b>temperature</b> your module here.	It is not necessary to take a <b>Volts</b> your module here.	*
<i>Ideal azimuth and 90° tilt angle</i>				
<b>3. Horizontal</b> (face up, flat on the ground )	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<i>Azimuth doesn't matter and 0° tilt angle</i>				
<b>4. Facing north</b> and <b>vertical</b> (no sunlight hitting module front)	*	It is not necessary to take a <b>temperature</b> measurement on your module here.	It is not necessary to take a <b>Volts</b> measurement on your module here.	*
<i>0° azimuth and 90° tilt angle</i>				
<b>5. Ideal direction</b> and <b>ideal tilt angle, module warm</b>	*	*	*	*
<i>Ideal azimuth and ideal tilt angle</i>				

## Reminders and Pointers (4)

Keep these  
two  
positions  
as identical  
as possible

Table 1.	a.	b.	c.	d.
				
<b>Module position or orientation</b> ▼	Irradiance $\text{W/m}^2$	Temperature $^{\circ}\text{C}$	Electric Potential (Volts) open circuit condition <b>Voc</b>	Current (Amps) short circuit condition <b>Isc</b>
<b>1. Ideal direction and ideal tilt angle, module cool</b> <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*
<b>2. Ideal direction and Vertical</b> (module upright at $90^{\circ}$ ) <i>Ideal azimuth and <math>90^{\circ}</math> tilt angle</i>	*	It is not necessary to take a temperature measurement on your module here.	It is not necessary to take a Volts measurement on your module here.	*
<b>3. Horizontal</b> (face up, flat on the ground) <i>Azimuth doesn't matter and <math>0^{\circ}</math> tilt angle</i>	*	It is not necessary to take a temperature measurement on your module here.	It is not necessary to take a Volts measurement on your module here.	*
<b>4. Facing north and vertical</b> (no sunlight hitting module front) <i><math>0^{\circ}</math> azimuth and <math>90^{\circ}</math> tilt angle</i>	*	It is not necessary to take a temperature measurement on your module here.	It is not necessary to take a Volts measurement on your module here.	*
<b>5. Ideal direction and ideal tilt angle, module warm</b> <i>Ideal azimuth and ideal tilt angle</i>	*	*	*	*

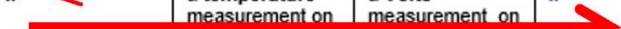


# Reminders and Pointers (5)







Table 1.		a.	b.	c.	d.
				Current (Amps) short circuit condition	Current (Amps) short circuit condition I <sub>sc</sub>
Module position					
1. Ideal direction and ideal tilt angle,					
Ideal azimuth and ideal tilt angle					
2. Ideal direction (module upright)					
Ideal azimuth and 90° tilt angle					
3. Horizontal (face up, flat on the ground)					
Azimuth doesn't matter and 0° tilt angle					
4. Facing north and vertical (no sunlight hitting module front)					
0° azimuth and 90° tilt angle					
5. Ideal direction and ideal tilt angle, module warm					
Ideal azimuth and ideal tilt angle					

Connect and disconnect wires for I<sub>sc</sub> measurements (5 times) with your module faced completely away from the sun!



# Lesson Part Two: Experimenting With Module Shading (1)

<div>Table 2.</div> <div>Module position or orientation</div> <div>▼</div>	<div>a.</div> <div></div> <div>Irradiance W/m<sup>2</sup></div>	<div>b.</div> <div></div> <div>Temperature °C</div>	<div>c.</div> <div></div> <div>Electric Potential (Volts) open circuit condition <b>Voc</b></div>	<div>d.</div> <div></div> <div>Current (Amps) short circuit condition <b>Isc</b></div>
<div>6. Ideal direction (azimuth), ideal tilt angle, and one <u>cell</u> shaded</div>	*	*	*	*
<div>7. Ideal direction (azimuth), ideal tilt angle, and one <u>row</u> shaded</div>	*	*	*	*
<div>8. Ideal direction (azimuth), ideal tilt angle, and one <u>column</u> shaded</div>	*	*	*	*

# Lesson Part Two: Experimenting With Module Shading (2)



One cell shaded



One row shaded



One column shaded

## Reminders and Pointers (6)



**Dealing  
with  
clouds...**

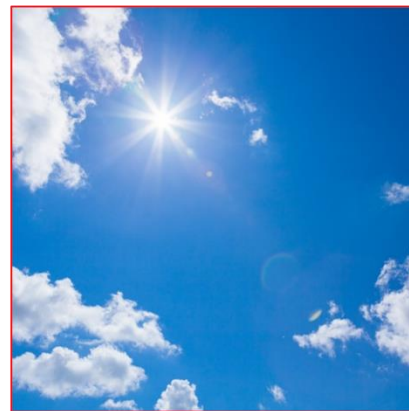
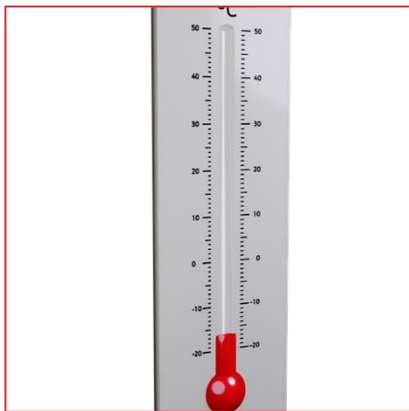
**...it's  
never  
easy**



**Reminders  
and  
Pointers (9)**

**Easy to  
accidentally  
make this  
mistake**





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