Solar Panel Project Log Book

Sadman Ahmed Shanto

Background Needed:

1. Understanding of semiconductors such as their band gap and p-n junctions.
2. Photovoltaic effect and the photoelectric effect.
3. Barrier potential and its importance.

Experiments Chosen:

1. V vs I, V vs P measurement
2. Effect of shadow on efficiency

Experiments Advice:

For each experiment be sure to record what time of day, weather, cloud coverage etc. Any environmental incidences that can help explain your results.

Questions:

1. Plot V vs I, as shown above. Discuss your circuit to collect data. Calculate maximum and average power output. Make sure to include uncertainties, $P \pm \Delta P$.
2. Is a solar panel a current source, voltage source, or both? Include a plot or diagram to explain your reasoning.
3. What is the efficiency of your solar panel? You can easily find out what the irradiance at the moment you are making your measurements outside. See West Texas Mesonet data for all kinds of weather related minute by minute information. For example, see [http://rain.ttu.edu/tech/1-output/mesonet.php (http://rain.ttu.edu/tech/1-output/mesonet.php)](http://rain.ttu.edu/tech/1-output/mesonet.php).
4. How much power is generated per solar panel?
5. Explain the p-n junction.
6. Explain the differences between the photovoltaic effect and the photoelectric effect. Why is this an important idea to understand?
7. Why are solar panels typically made of silicon? Could we use some other material?
8. Based on your measurements, estimate how many solar panels you would need to power a typical house. Make an estimate of the cost. Argue if it makes sense to go solar or not in Lubbock.

Experiment 1: V vs I, V vs P Measurement

The objective of this experiment as defined by the manual is to measure the maximum power you can receive from the panel.

We need to design a circuit to compute output power.

resource: [https://www.alternative-energy-tutorials.com/energy-articles/measuring-the-power-of-a-solar-panel.html (https://www.alternative-energy-tutorials.com/energy-articles/measuring-the-power-of-a-solar-panel.html)](https://www.alternative-energy-tutorials.com/energy-articles/measuring-the-power-of-a-solar-panel.html)

Theory

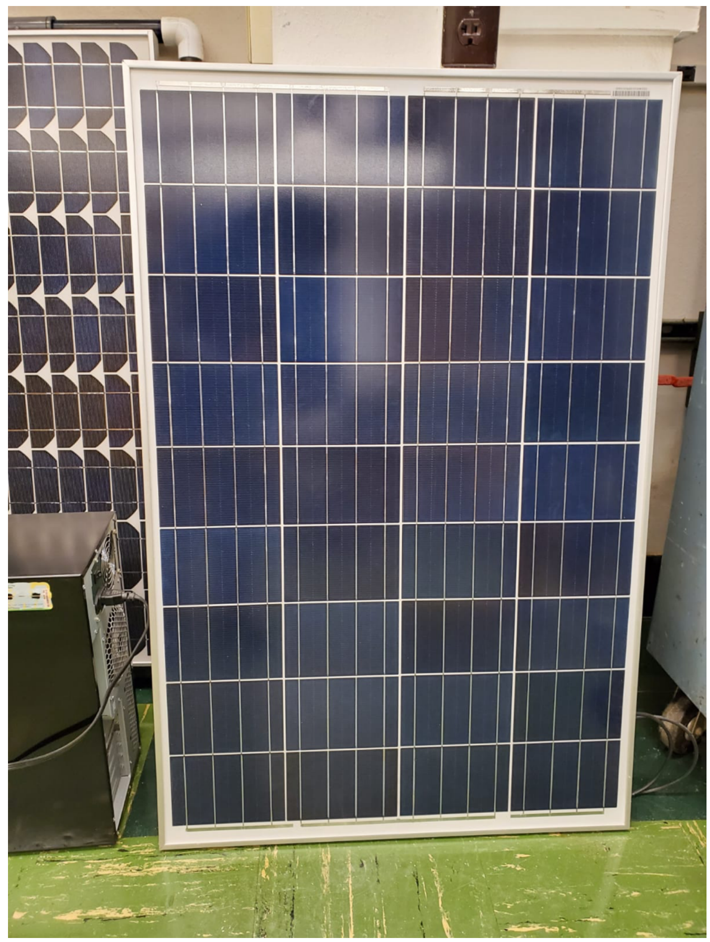
We the theoretical maximum power $P_{theo} = 100W$ and the maximum open circuit voltage $V_{oc} = 21.6V$. Therefore, the theoretical resistance for maximum power should be

$$R_{theo} = \frac{V_{oc}^2}{P_{theo}} = 4.6656\Omega$$

Solar Panel Info:

Manufacturer Info

Solar Panel Used



Methodology:

We are planning on varying the resistance source from short-circuit to open-circuit with 0 to 10 Ohm resistors connected to the circuit.

For each resistor connected, we measure the current and voltage. We calculate power using the following formula:

$$P = IV$$

We aim to repeat each reading 3 times to ensure accuracy of results and plan to tabulate all our data. Using this tabular data we would create the required **V vs I** and **V vs P** plots.

Day 1 (01/25/21):

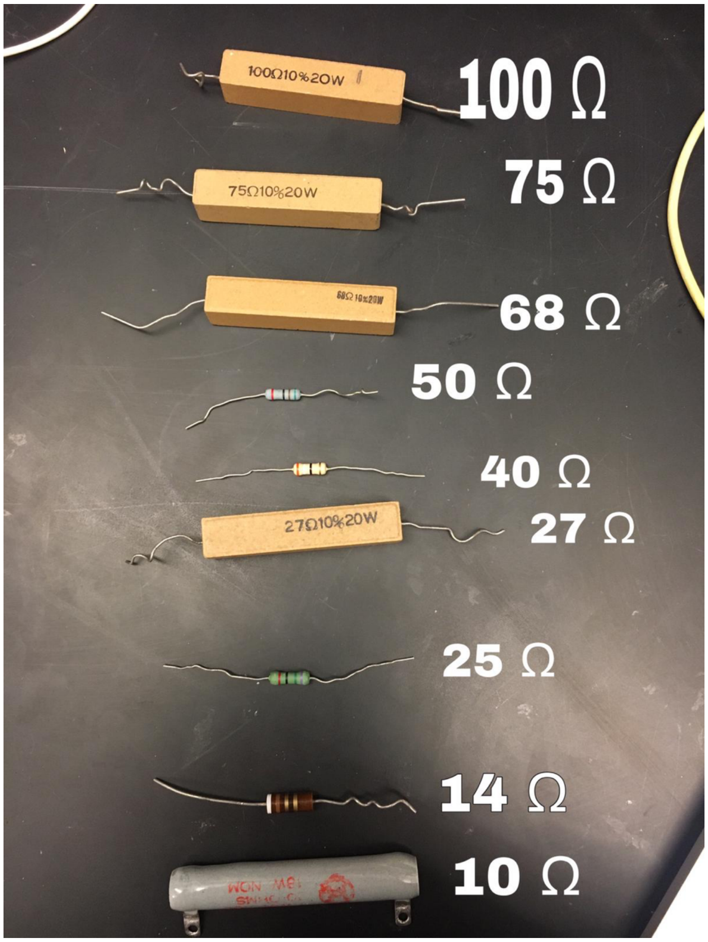
We are struggling to decide on the range of resistors needed. We are using the multimeter to figure out what each resistor is. Plans of using resistors in parallel are discussed to get small resistors since they were not available. This information is needed so that we don't fry the circuit.

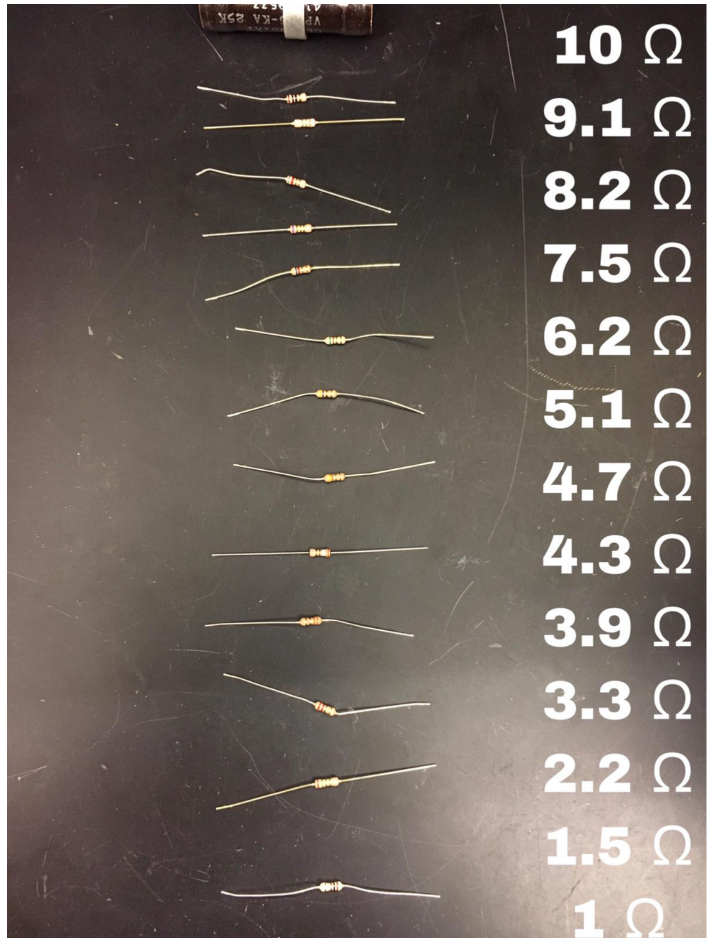
The resistors available to us are - 10 (3), 14, 25, 27, 40, 50, 68, 75, 100. We are gonna be using resistors in parallel to replicate smaller resistors.

Imtiaz asked us to wait to get the smaller resistors as some other lab group is using them.

After an hour of trying to find the resistors/making parallel resistors. Kim gave us his set of small resistors.

Resistors Avalailable in Room	Kim's Resistor Set





We are now using the following resistors:

In [10]:
```
r_sets = [1,1.5,2.2,3.3,3.9,4.3,4.7,5.1,6.2,7.5,8.2,9.1,10]
```

We are trying to understand how to safely connect the load to the solar panel. Experimenting with the panel in the room was giving us inconclusive results so we came outside trying to verify that our understanding is correct.

The time is 1:33 PM and the weather log is:

We have verified our open circuit voltage (21.4 V found experimentally).

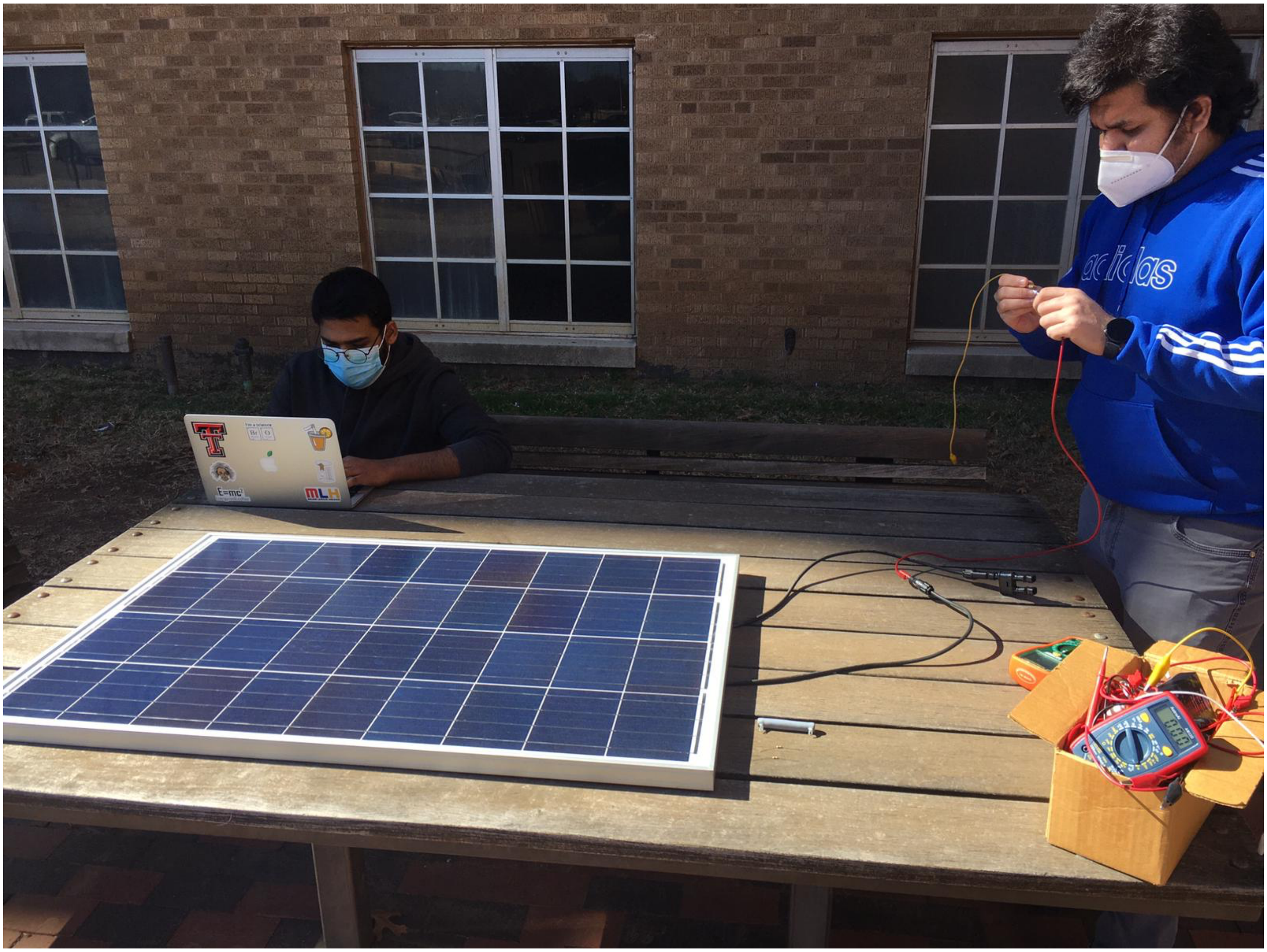


Image of Sunlight on our test run

However, we have ran into our first problem.

Problem 1:

The resistor when we connected to the circuit started to burn. This made us realize that the wattage for the resistors we recieved from Kim was 0.5 which was way too small for our experiment.

Resolution 1:

Since, we know that the maximum power attainable from this system is $100W$. We need resistors that are $100W$ or more.

Luckily, we ran into Kim and he gave us resistors of higher wattage (the ones we were looking for all along).

We chose the 10Ω variable resistor for our experiment.

We plan on taking data with these new resistors our next day in the lab.

Notes for Instructors:

- Having sticky notes in the lab would be very helpful

Day 2 (01/27/21):

We plan using the rheostat and the multimeter to mark resistances in increasing magnitudes of 1Ω.

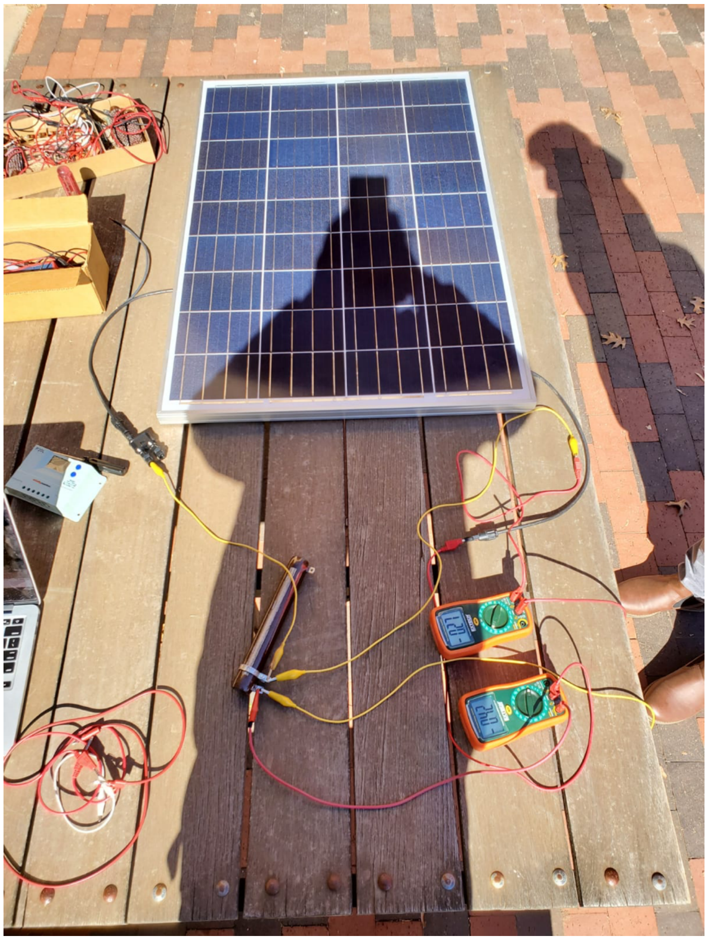
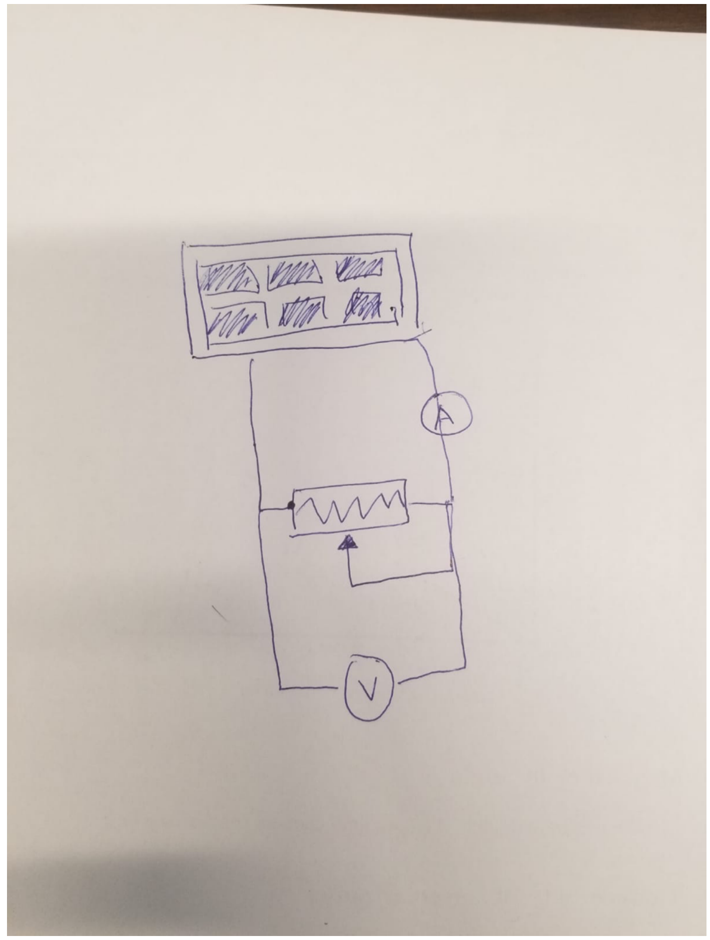
Rheostat

run 1: 12:42 PM

verified at max potential

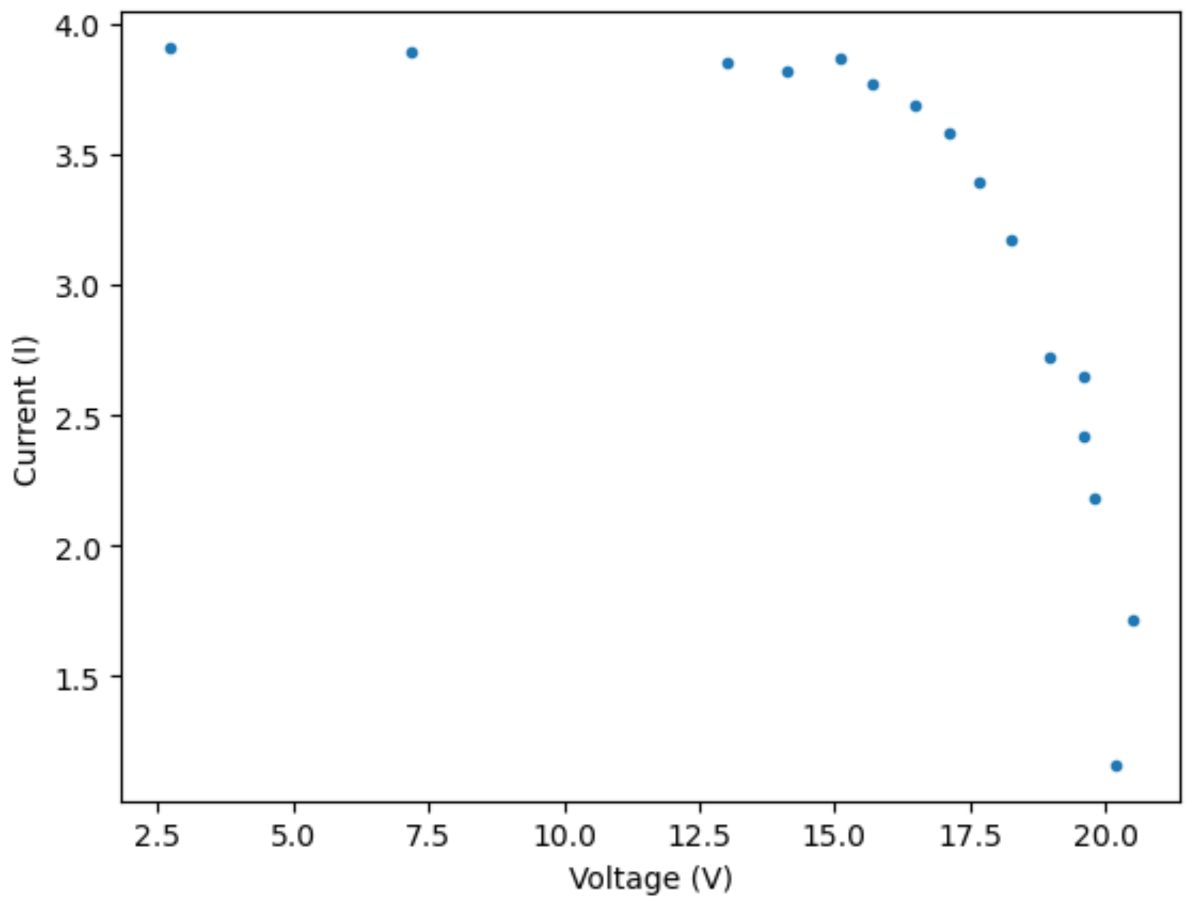
Sun Angle	Set Up
	

Circuit Used	Circuit Schema

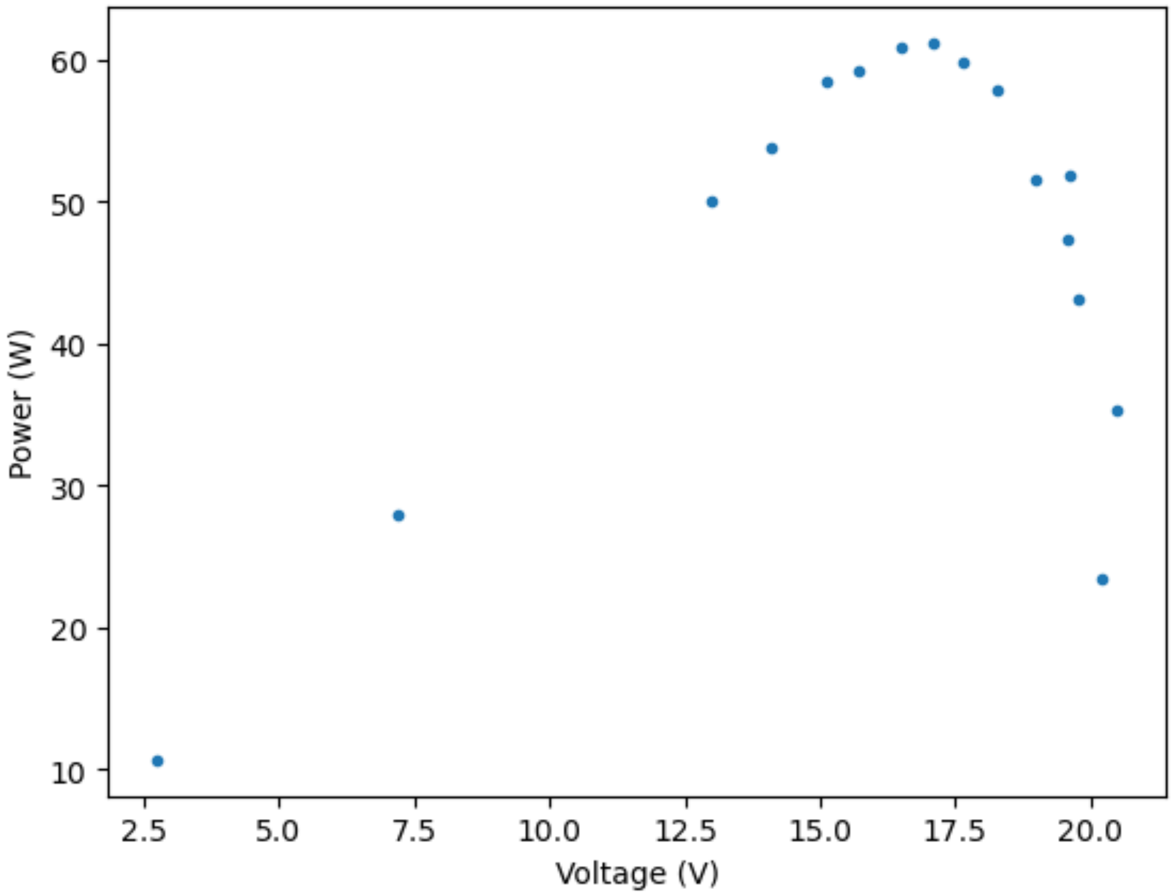



In [13]:
```
R = [1.5,2.1,3.4,3.7,4,4.4,4.7,5,5.5,6,7,8,9,10.5,12,17.2,25.2]
V = [2.72,7.18,15.1,13,14.1,15.7,16.5,17.1,17.66,18.26,18.98,19.6,19.58,19.78,20.5,20.2,10]
I = [3.91,3.89,3.87,3.85,3.82,3.77,3.69,3.58,3.39,3.17,2.72,2.65,2.42,2.18,1.72,1.16,0.4]
P = np.array(I)*np.array(V)
```

In [10]:
```
plt.plot(V[:-1],I[:-1],".")
plt.xlabel("Voltage (V)")
plt.ylabel("Current (I)")
plt.show()
```



In [14]:
```
plt.plot(V[:-1],P[:-1],".")
plt.xlabel("Voltage (V)")
plt.ylabel("Power (W)")
plt.show()
```



In [18]:
```
p_max = max(P)
p_mean = sum(P)/len(P)
p_max, p_mean
```

Out[18]: (61.218, 44.51291764705883)

In [21]:
```
dp_max = p_max*(np.sqrt((0.01/17.1)**2+(0.01/3.58)**2))
dp_max
```

Out[21]: 0.1747072980730914

In [23]:
```
dp_average = p_mean*(np.sqrt((0.01*len(I)/sum(I))**2+(0.01*len(V)/sum(
V))**2))
dp_average
```

Out[23]: 0.15343216625581438

Question: What is the efficiency of your solar panel? You can easily find out what the irradiance at the moment you are making your measurements outside. See West Texas Mesonet data for all kinds of weather related minute by minute information. For example, see [http://rain.ttu.edu/tech/1-output/mesonet.php (http://rain.ttu.edu/tech/1-output/mesonet.php)](http://rain.ttu.edu/tech/1-output/mesonet.php).

Solution:

Maximum Power,

$$\delta P_{max} \simeq \pm 0.2$$
$$\delta P_{average} \simeq \pm 0.2$$
$$P_{max} = 61.2 \pm 0.2$$
$$P_{average} = 44.5 \pm 0.2$$

Using [http://rain.ttu.edu/tech/1-output/mesonet.php (http://rain.ttu.edu/tech/1-output/mesonet.php)](http://rain.ttu.edu/tech/1-output/mesonet.php) to calculated expected power.

In [25]:
```
p_exp = 717*0.68005
p_exp
```

Out[25]: 487.59585000000004

In [27]:
```
eff_max = (p_max*100)/p_exp
eff_max
```

Out[27]: 12.555069941633013

In [28]:
```
eff = (p_mean*100)/p_exp
eff
```

Out[28]: 9.129059988320005

In [30]:
```
eff_system = p_mean * 100 / 100
eff_system
```

Out[30]: 44.51291764705883

Question:

Based on your measurements, estimate how many solar panels you would need to power a typical house. Make an estimate of the cost. Argue if it makes sense to go solar or not in Lubbock.

Solution:

$$C_{SP} = \frac{P_{house}}{P_{gen}}(C_{pW})$$

Makes sense if

$$C_{SP} < C_{electricity}$$

In [35]:
```
p_typ = 1,176 * 1000
p_gen = p_mean

n_sp = p_typ / p_gen
n_sp
```

Out[35]:
```
array([2.24653888e-02, 3.95390842e+03])
```

Experiment 2: Effect of Shadow on Solar Panels

The objective of this experiment as defined by the manual is to find out the effect of shadow on the efficiency of solar panels.

Day 2 (02/01/21):

We have planned out the experimental design for the shadow experiment on solar panels and collected the required materials for the experiment.

We discussed various ways to systematically generate the shadows and ended up using cardboards to quantitatively create the shadows. Thus, we cut cardboard pieces and measured the area of the pieces. Also, we measured the area of the solar panel.

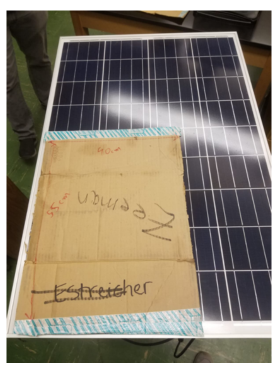
$$Area_{SP} = 5990cm^2 \pm 11$$
$$Area_{P1} = 525cm^2 \pm 5$$
$$Area_{P2} = 990cm^2 \pm 10$$
$$Area_{P3} = 2000cm^2 \pm 6$$
$$Area_{P4} = 3800cm^2 \pm 9$$
$$Area_{P5} = 5990cm^2 \pm 11$$

We plan on doing 5 different test cases of effective shadow covering region as described by the following pictures:

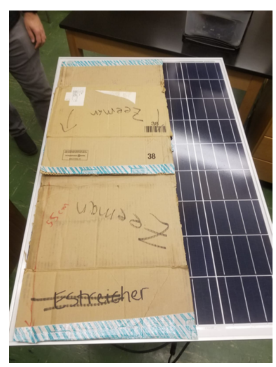
P1

P2

P3



P4



P5

We went outside to record the data for the experiment starting first with the baseline experiment without any shadow. We are using the load at $\sim 4.7\Omega$ since thats where we expect the theoretical Maximum Potential to be.

In [2]:
```
# dimensions (cm)
area_sp = 63 * 95
area_p1 = 10.45 * 50.45
area_p2 = 95 * 10.45
area_p3 = 40*50
area_p4 = 40*95
area_p5 = area_sp

def uncertainty(result,val1,val2,u1, u2):
    return result*(np.sqrt((u1/val1)**2+(u2/val2)**2))

u_sp = uncertainty(area_sp,63,95,0.1,0.1)
u_p1 = uncertainty(area_p1,10.45,50.45,0.1,0.1)
u_p2 = uncertainty(area_p2,95,10.45,0.1,0.1)
u_p3 = uncertainty(area_p3,50,40,0.1,0.1)
u_p4 = uncertainty(area_p4,50,95,0.1,0.1)
u_p5 = uncertainty(area_p5,63,95,0.1,0.1)

print("Area (cm^2): ",area_sp,area_p1,area_p2,area_p3,area_p4,area_p5)
print("Errors: ", u_sp,u_p1,u_p2,u_p3,u_p4,u_p5)
```

```
Area (cm^2):  5985 527.2025 992.7499999999999 2000 3800 5985
Errors:  11.39912277326637 5.152091808188204 9.55730218210139 6.4031
24237432849 8.588364221433554 11.39912277326637
```

We started our baseline test at 1:20 PM. Later, we started our test for the shadow covering at 1:22 PM and finished all tests at 1:25 PM.

The sun and the clouds during our experiment

Our Solar Panel/Experimental Set Up

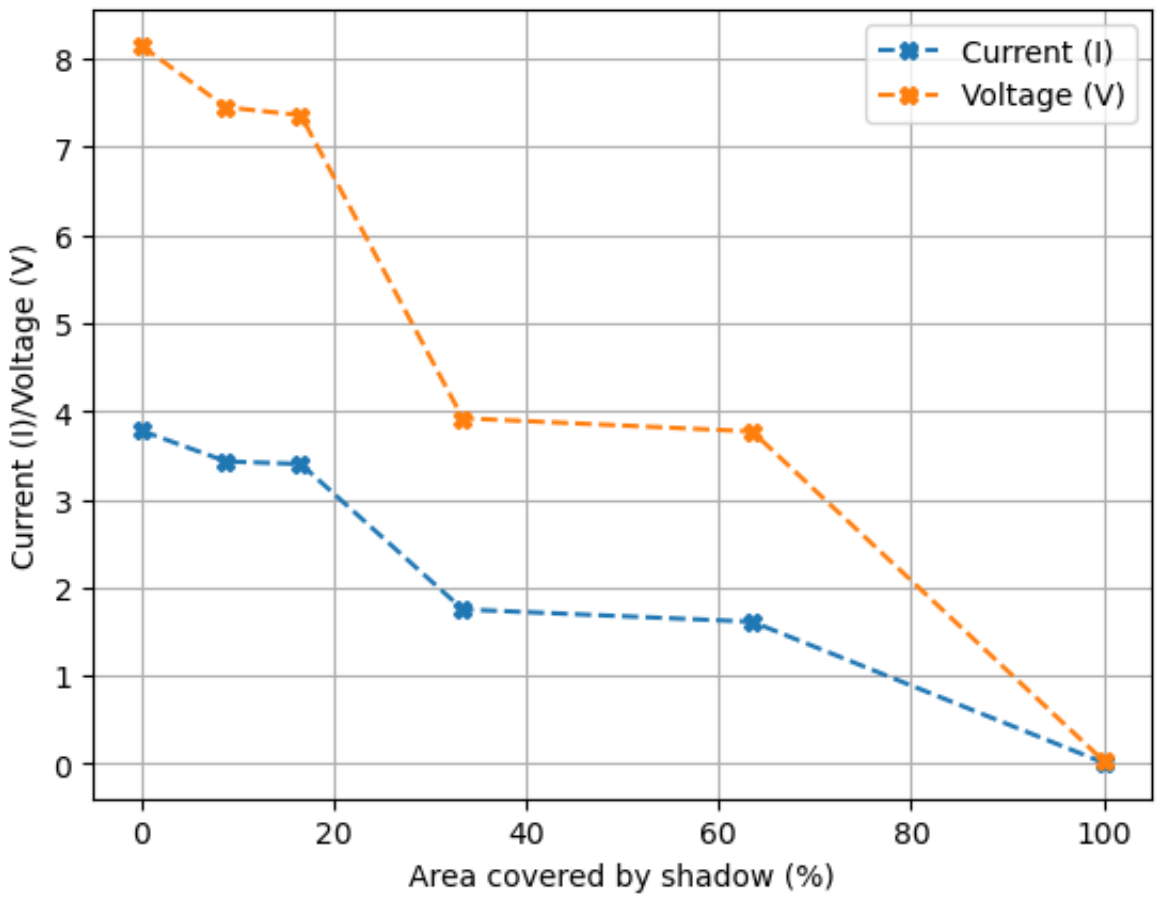
The weather, visibility, irradiance and wind index were as belows.

1:53 pm		59 °F	Broken clouds.	8 mph	↗	26%	30.28 "Hg	10 mi
12:53 pm		58 °F	Partly sunny.	10 mph	↑	31%	30.32 "Hg	10 mi

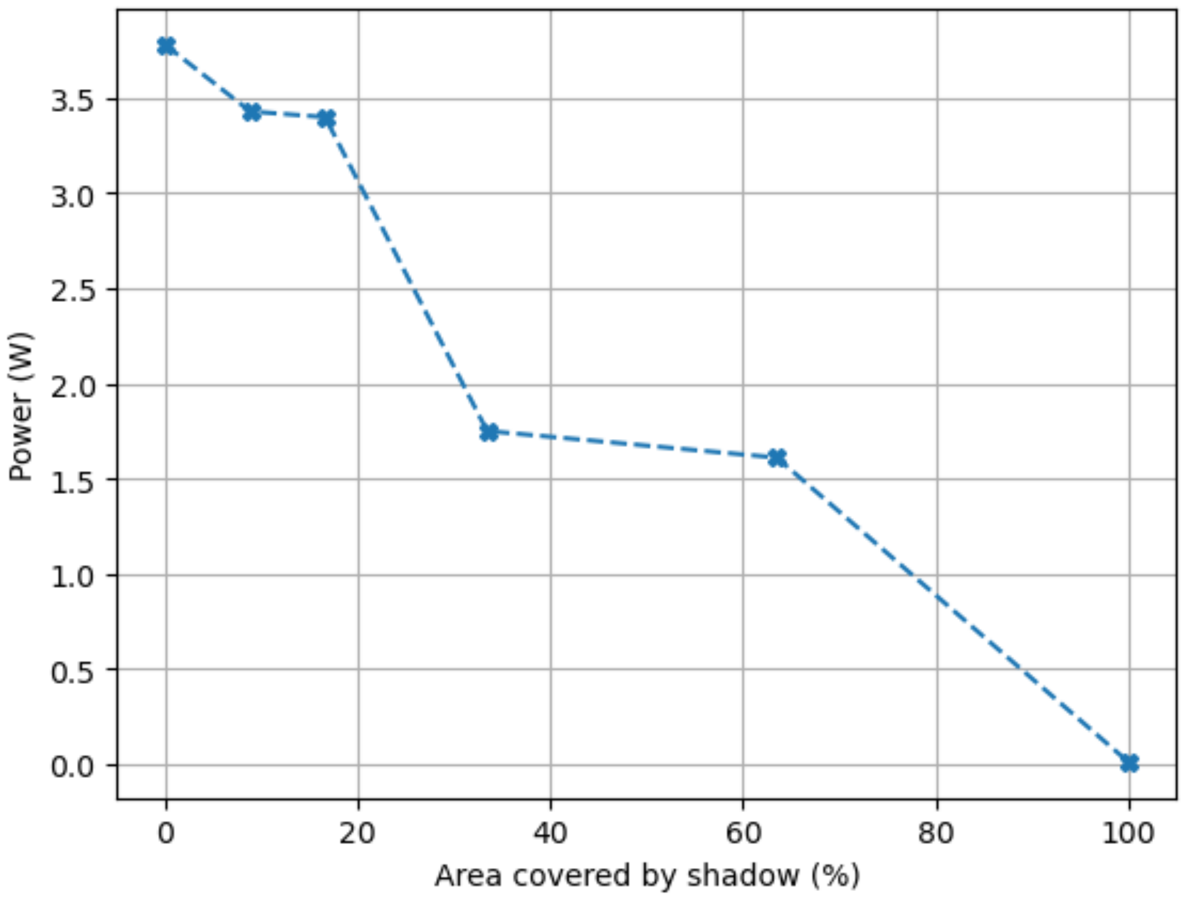
Time CST	Temperature (°F) 6ft	6.5ft	30ft	ΔT 6.5ft-30ft	Dew Point Temperature	Wind (mph) Direction	Speed	Gust	Wind Speed @ 6.5ft	Altimeter Setting	Relative Humidity	Rain	Solar Radiation	20 Ft Wind	RFTI
01:25 PM	59.1	59.0	56.9	2.1	24.6	170	10	14	7	30.34	27	0.00	691	0	0
01:20 PM	58.8	58.5	56.7	1.8	25.1	190	8	13	5	30.34	27	0.00	666	0	0

In [3]:
```
areas = 100*np.array([0, area_p1/area_sp,area_p2/area_sp,area_p3/area_sp,area_p4/area_sp,area_p5/area_sp]) #percentage of area covered
current_areas = np.array([3.78, 3.43,3.40,1.75,1.61,0.01]) #amperes
voltage_areas = np.array([8.15,7.45,7.36,3.92,3.77,0.03]) #volts
power_areas = voltage_areas*current_areas
```

In [23]:
```
plt.plot(areas,current_areas,'X--',label="Current (I)")
plt.plot(areas,voltage_areas,'X--',label="Voltage (V)")
plt.xlabel("Area covered by shadow (%)")
plt.ylabel("Current (I)/Voltage (V)")
plt.grid()
plt.legend()
plt.show()
```



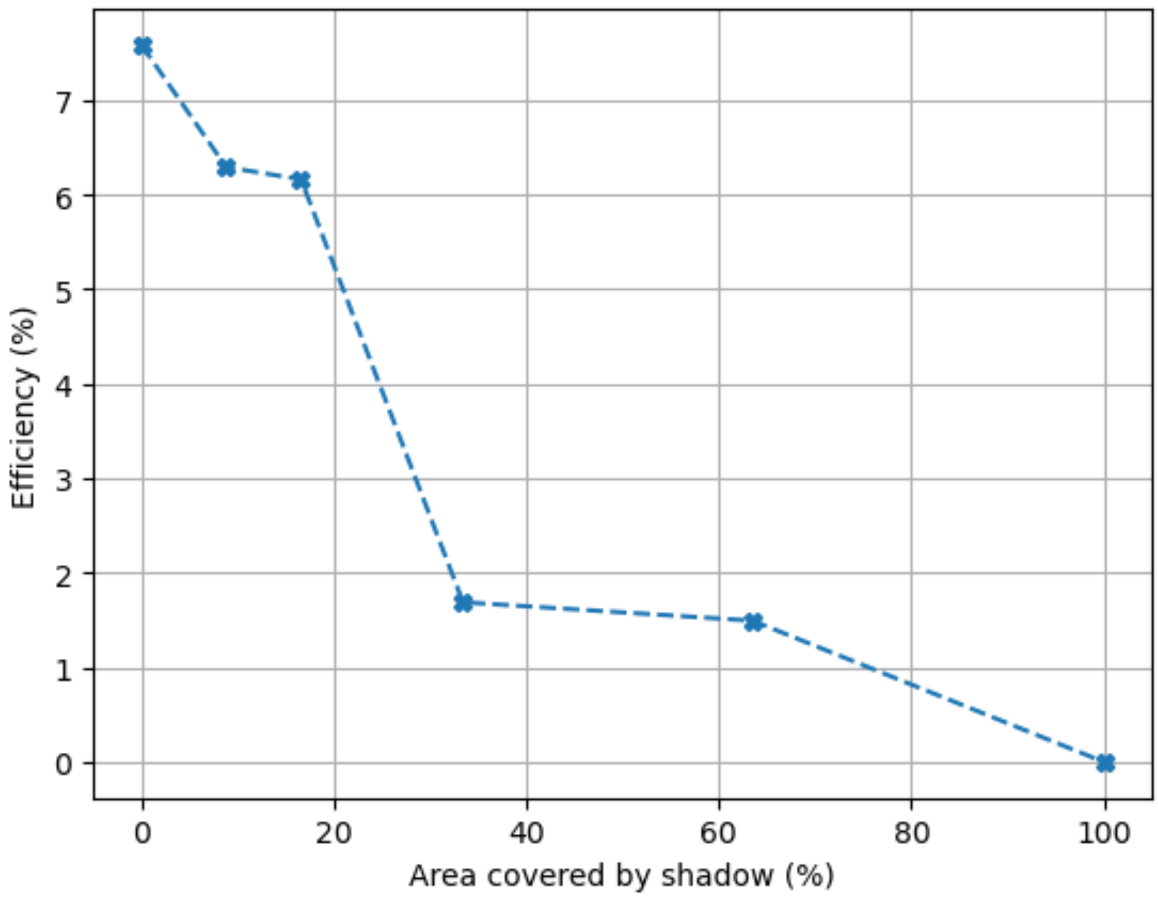
In [25]:
```
plt.plot(areas,current_areas,'X--')
plt.xlabel("Area covered by shadow (%)")
plt.ylabel("Power (W)")
plt.grid()
plt.show()
```



Using [http://rain.ttu.edu/tech/1-output/mesonet.php (http://rain.ttu.edu/tech/1-output/mesonet.php)](http://rain.ttu.edu/tech/1-output/mesonet.php) to find expected power.

In [4]:
```
expected_power = ((666+691)/2)*(area_sp*0.0001)
effeciency_areas = 100*(power_areas / expected_power)
```

In [5]:
```
plt.plot(areas,effeciency_areas,'X--')
plt.xlabel("Area covered by shadow (%)")
plt.ylabel("Efficiency (%)")
plt.grid()
plt.show()
```



The results make sense because of the flat angle of the solar panel.

Conclusion