Challenge #6
Solar Panel Challenge 2

Due Tuesday, May 5

On February 1, 2020 Occidental College hosted the Second Technical Workshop. During the Solar Car Building Workshop, students built a balsa wood solar powered car. This challenge is also based on that workshop, and focuses on measuring the output of a single PV cell.

Students that didn't attend that session can still do this challenge, as the resources below and on the attached worksheet will help explain the information you need to complete the challenge.

This is the second of our solar panel challenges.

Challenge Details:

- This challenge focuses on solar panels with the goal of understanding how to interpret IV and PV curves, as well as using Google Sheets (and other spreadsheet software).
    - It is a bit more difficult than challenge 2, however if you follow the instructions carefully this challenge will not be as hard as it first seems.
    - This is by far the longest worksheet, but you will see that most of the space is taken up by pictures and graphs.
    - You'll need access to the following link and Google Sheets (free access with any Google account).
    - https://www.pveducation.org/pvcdrom/solar-cell-operation/iv-curve

This activity is worth 200 points. You will earn points based on the percentage of answers you get correct.

Responses can be emailed to Julie Miller Kalbacher at jamiller@mwdh2o.com Make sure to include your name and school name on your responses.

Good luck with this challenge and with all of your schoolwork.

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A current (I) vs. voltage (V) curve, or IV curve, of a solar panel displays the different possible current and voltage output combinations. Specifically, the current is plotted on the y-axis and the voltage is plotted on the x-axis.
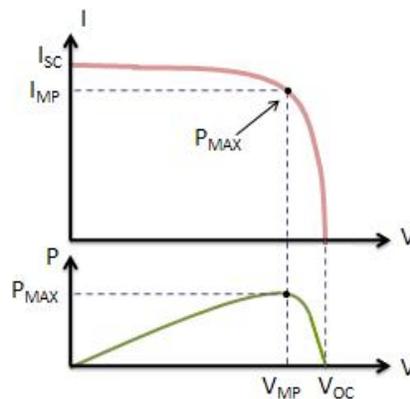
Current, Voltage and Power Curves. Figure from https://www.samlexsolar.com/learning-center/solar-panels-characteristics.aspx.

The maximum amount of current is produced when there is a short circuit between the positive and negative terminals. In this case, there is no resistance in the circuit and the voltage in the circuit is zero. On the other hand, the maximum voltage is achieved when there is a break in the circuit. In this case, the resistance is infinitely high and the current is zero. Those two values give the endpoints of the graph.

From the IV curve, the values of power can be determined. Furthermore, a power vs. voltage (PV) curve could also be plotted. In a DC (direct current) circuit, the power (in watts, W) is the product of the current (in amps, A) and voltage (in volts, V).

$$P = I \times V$$

At the bend of the IV curve, there is a point corresponding to the maximum power output. This is called the Maximum Power Point (MPP) or P_{max}. The corresponding values of voltage and current at MPP are represented by V_{mp} and I_{mp}, respectively.

Workshop #6: Solar Panels Worksheet

To begin, follow the link: https://www.pveducation.org/pvcdrom/solar-cell-operation/iv-curve and scroll down to the Light Biased IV Curve Calculator.

Part 1: Obtaining and Plotting IV Curve

In this experiment, you'll be acquiring simulated IV data and processing it in Google Sheets. Once you're on the website linked above, scroll down to the calculator and change the light generated current (I_L) to 3 A. This is the maximum current that is generated when the solar cell is exposed to light. We're using 300K (27°C or 81°F) for the approximate temperature outside on a warm day. You'll be mainly changing the voltage and recording the output current on the right.

Light Biased IV Curve Calculator

Input Parameters

Dark Saturation Current, I_0 = 1e-10 A
Light Generated Current, I_L = 3 A
Ideality Factor, n = 1
Temperature, T = 300 K
Voltage, V = 0.65 V

Results

Current, A = -5.3082 A

1. Start plugging in values between 0.00-0.65 V. What happens to values of the current?

   _____
   _____

2. Why? _____

   _____

Define some of the variables used in the calculator:

3. Dark Saturation Current: _____

   _____
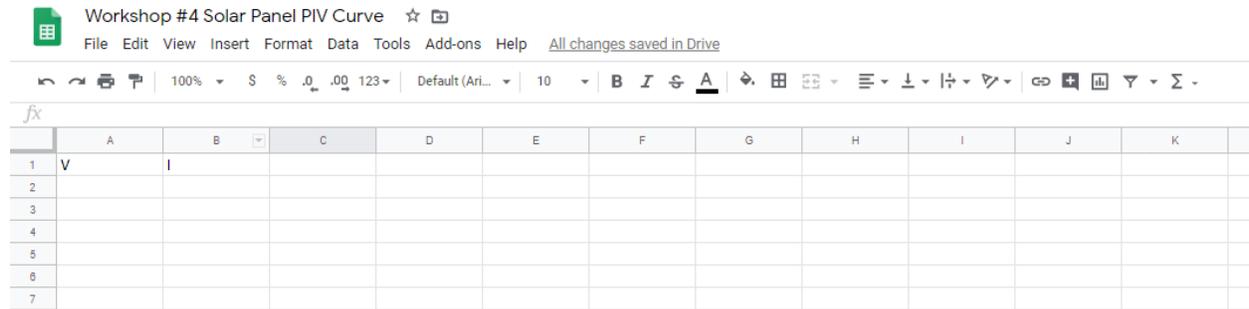
4. Light Generated Current: _____

   _____

5. Ideality Factor: _____

   _____

Now let's record and plot the values to form an IV plot in Sheets. Before we do, set up the first column for voltage and second column for current.

To make things easier, you can have Sheets help you label your input voltage values. Starting from Column (Col) A Row 2 going downward, fill out 0, 0.05, and 0.1. Hold and drag to select these three cells.
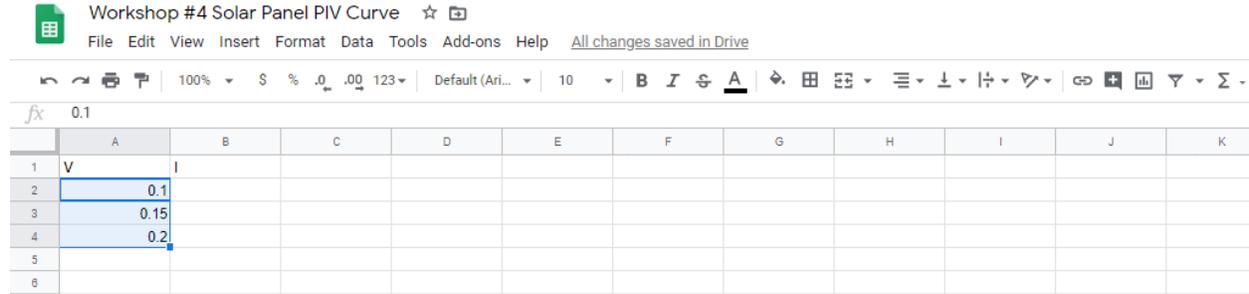
Then click and hold the square at the bottom right of the selection and drag downwards to Row 12. You should have values from 0 to 0.5 in 0.05 increments. In Col A Row 13 and 14, fill out 0.51 and 0.52, respectively. Select cells Col A from Rows 12-14 and drag the bottom right square downward to Row 24. In Col A Row 25, type in "0.623666".

Plug in these voltage values into the calculator and record the output current values in Col B. You should end up with something like this.
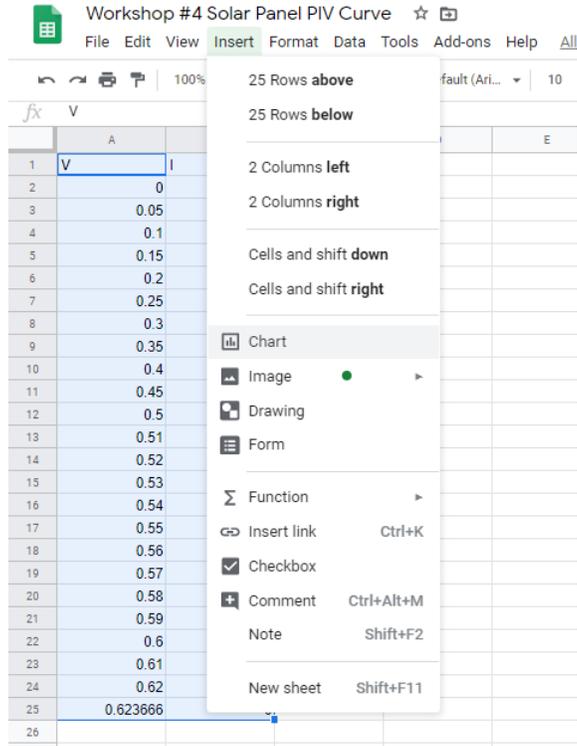

Now let's graph the data. Hold and drag from Col A Row 1 to Col B Row 25 to select the data. Then click on "Insert" above the toolbar and select "Chart".

You should see a plot of the data pop up. We should probably change the title of the graph to be more informative. Double click on the title, which is currently "I vs. V", and change it to "IV Curve for Solar Cell"
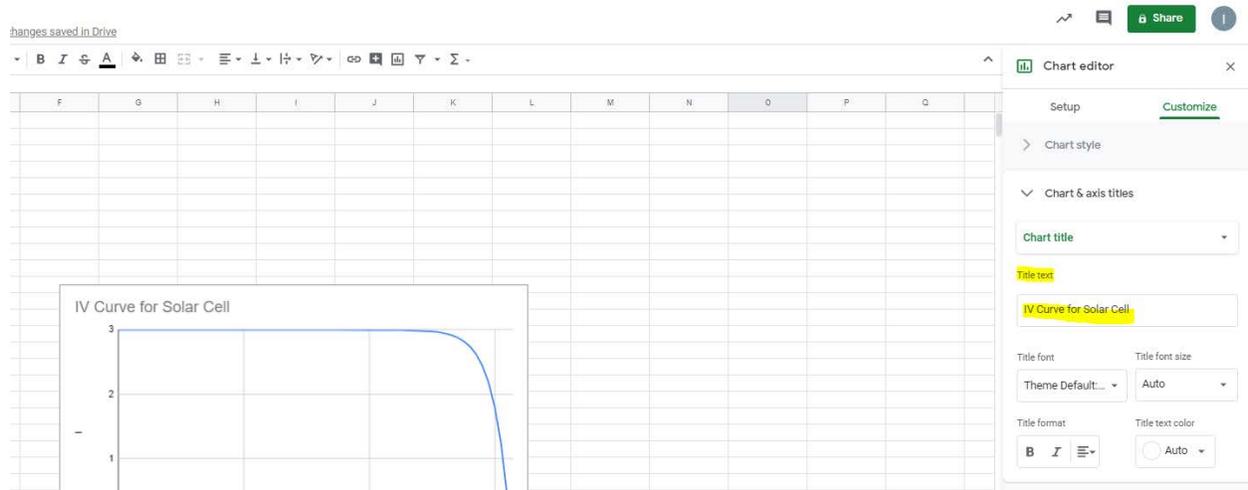
Part 2: Calculating and Plotting PV Curve

Now that you've successfully made an IV curve, let's try to calculate and overlay a PV curve. Instead of painstakingly calculating by hand the product of voltage and current to find power repeatedly, Sheets can do that for you easily. Label the third column as "P". In Col C Row 2, type in "=", select Col A Row 2, type "*", select Col B Row 2, and press enter. You have just used a formula to calculate the product of two cells.
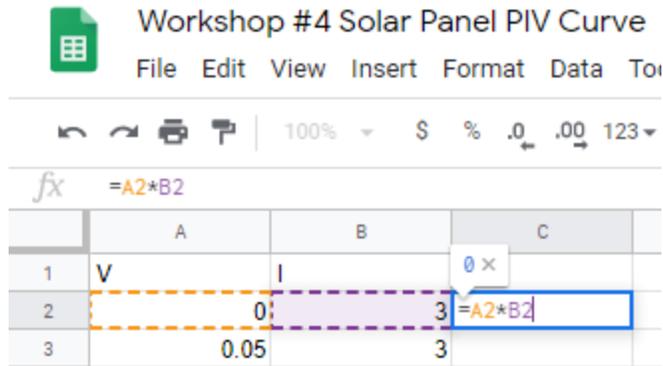
Select Col C Row 2 and drag the bottom right square downward until you reach the end of the data list. You should see a new list of numbers appear that are the different values of power.


To plot the PV curve overlaid with the IV curve, select the entire data set including the headers in Row 1. Then go to Insert>Chart. Now you should see two lines appear in the plot. Change the plot name to "IV and PV Curves for Solar Cell" (refer to previous instructions if necessary).

Now we want to find the maximum power point (MPP). To adjust the plots for this, we'll need to modify the axes. Set the PV curve to a second axis by double clicking anywhere on the curve and selecting "Right axis" in the "Axis" dropdown menu.
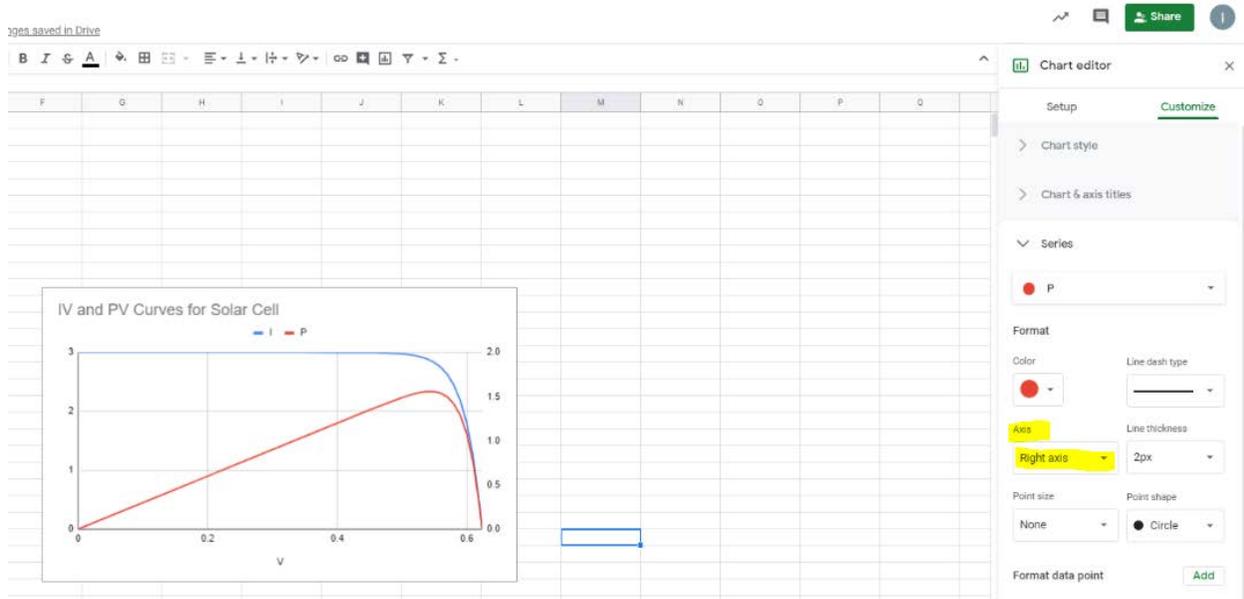
Modify the scale of the axes so that the PV curve intersects the IV curve around the MPP. Double click anywhere on the left Y-axis, and set the "Min" to 0 and "Max" to 3.5. Then double click anywhere on the right Y-axis, and set the "Min" to 0 and "Max" to 1.7.
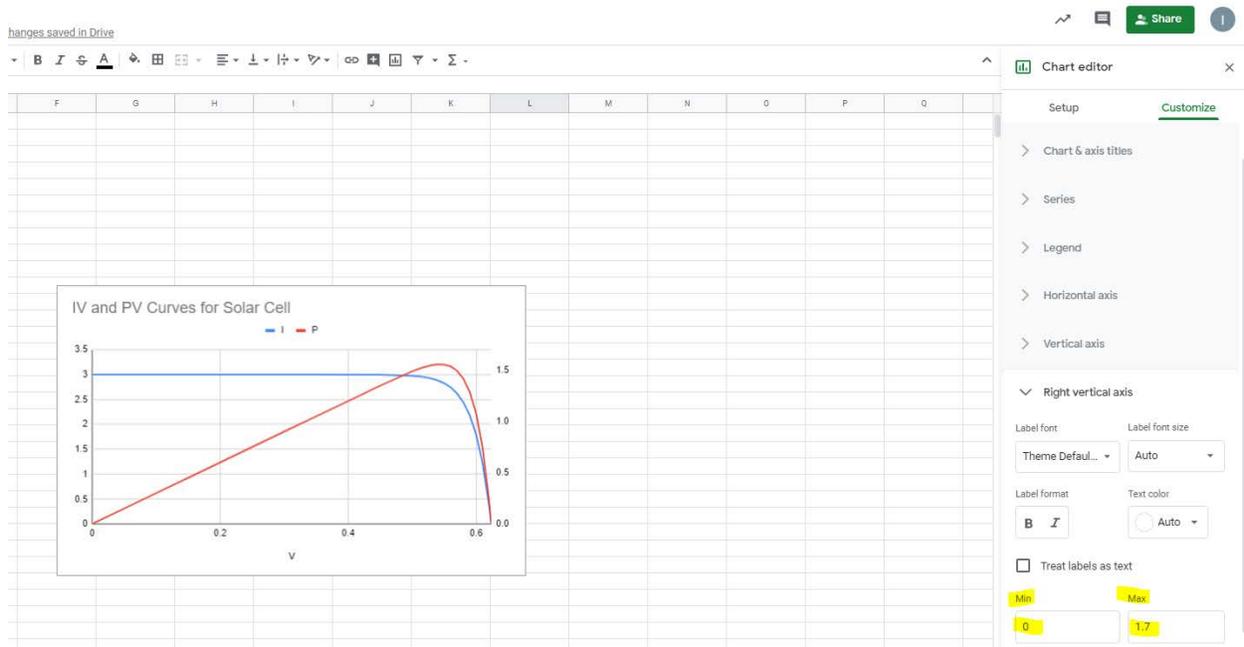
6. According to the plot, what is the power value at the MPP? _____

_____

7. For the power value stated above, what are the corresponding voltage and current values?

_____

After you identified the MPP, let's label the data point. We'll assume the MPP is 1.556 W when the voltage is at 0.54 V. First, we should highlight that specific data point by enlarging the plot marker. Double click anywhere on the PV curve and select "Add" next to "Format data point".

A new menu will appear in the middle of the spreadsheet for you to select the specific data point. We want to select "P: 0.54" for the value of P (power) at voltage 0.54 V.

B I S A ◆. ⊞ ⊞▾ ≡▾ ↨▾ ↕▾ ▽▾ ⊖ ➕ ⊞ ▼▾ Σ▾

	F	G	H	I	J	K	L

IV and PV Curves for Solar C...

Select data point   ✕

Click an item on the chart or select one from the drop down.

Data point

P: 0.5

P: 0.51

P: 0.52

P: 0.53   Cancel

P: 0.54

P: 0.55   ⌐ 0.0

P: 0.56

P: 0.57

P: 0.58

P: 0.59

A new submenu should pop up in the Chart Editor underneath "Format data point". Crank up the "Point Size" to "10px" by selecting it in the dropdown menu. Now the MPP data point marker should be much larger.
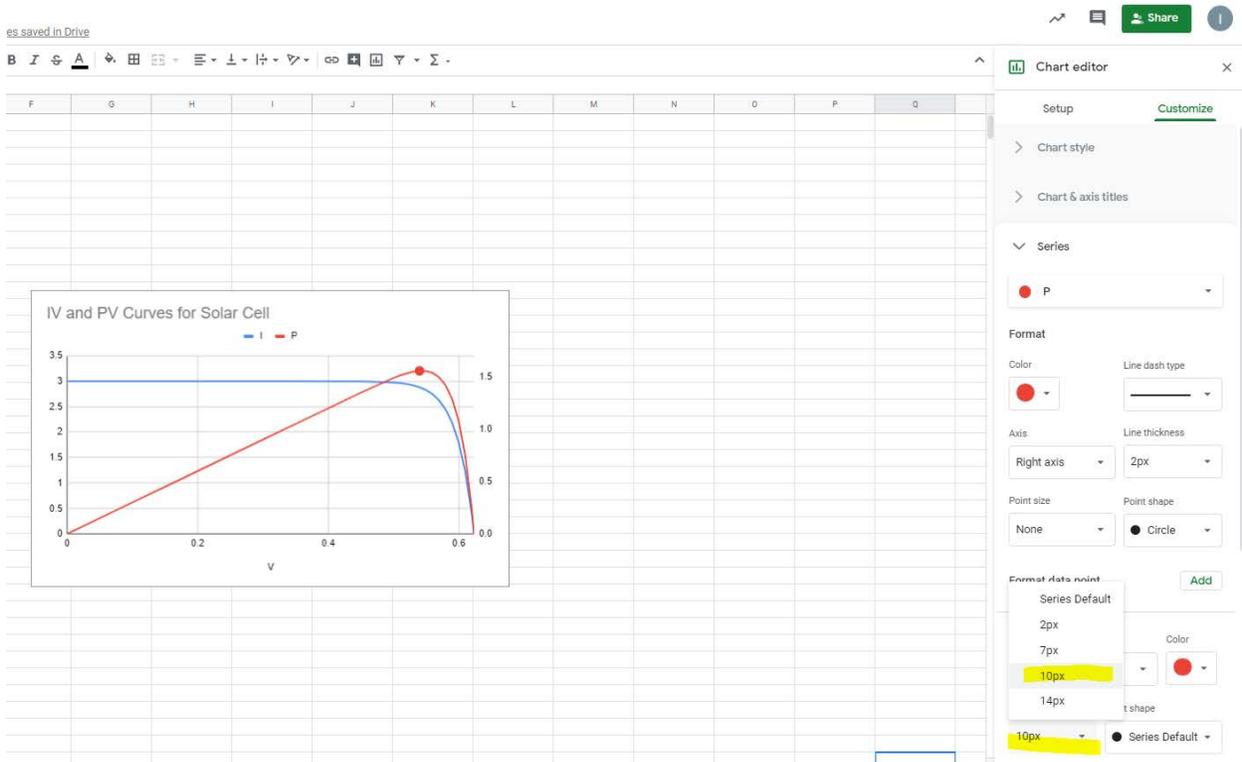
To label the power value at the MPP, we need to manually insert a text box. Go to Insert>Drawing to pull up the following menu. Select the textbox option (the left highlight with the letter in T in a box) and drag to make a small square in the middle of the menu. Center the text in the box by clicking on the alignment menu (the right highlight) and selecting center. Then type out "1.556 W".
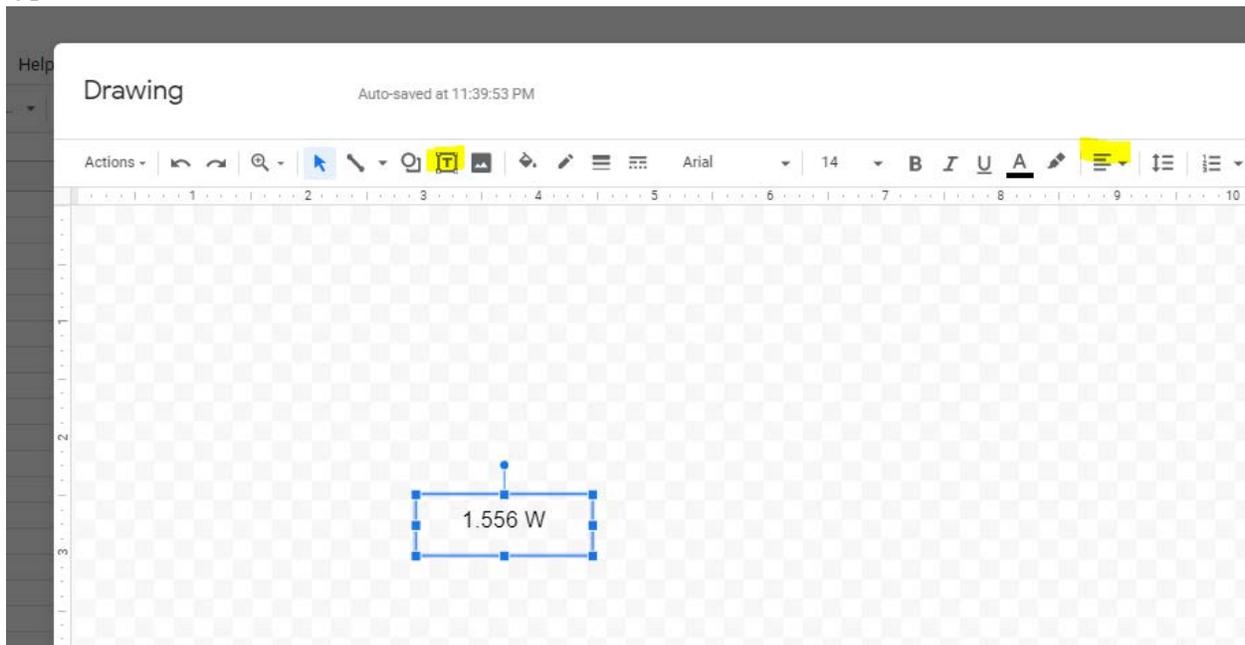
Click on "Save and Close" on the top right of the Drawing menu. The textbox should now appear near your graph. Drag it so that it is close to the MPP point that you just enlarged.

IV and PV Curves for Solar Cell
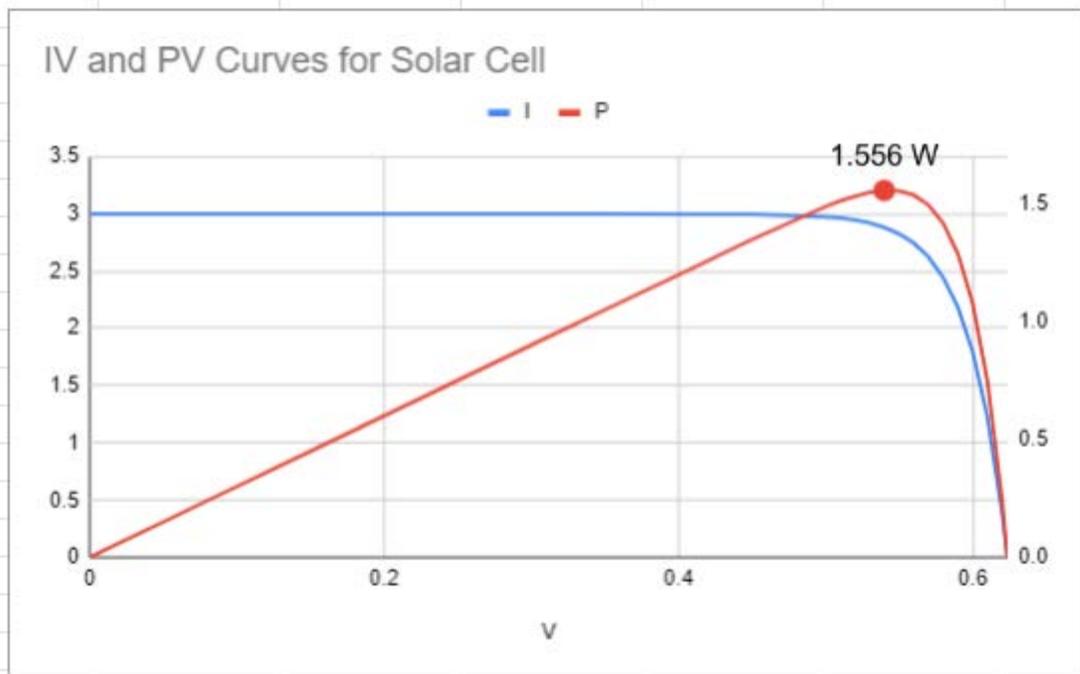
Congratulations! You just determined the MPP of a solar cell from the IV and PV plots that you made.

It's probably best to take a screen shot of you graph which also shows your input values. Your submission for this challenge should include the screen shot along with the answer to the questions in this worksheet.