Cratering (Part 1)

Lab Notebook

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Course:	PHYS 13100 2
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Initial observations

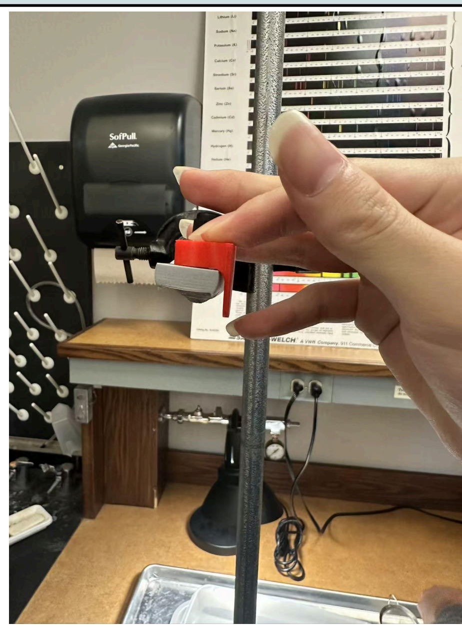
As your group begins, what do you notice? What things will be important to keep in mind as you design and conduct the experiment? What (if anything) do you learn from the group discussion that informs how you will take data?

It is hard to maintain the surface of a sand completely flat during all trials in the experiment. Though we have efforts in smoothing it, there are inevitably fluctuations on the surface. This first may cause extra unconsidered uncertainty to the measurement of the height and the effect can be bigger at small height. Secondly, the interaction of the mass with a smooth or not smooth surface may have different mechanism that we are not able to explain and predict.

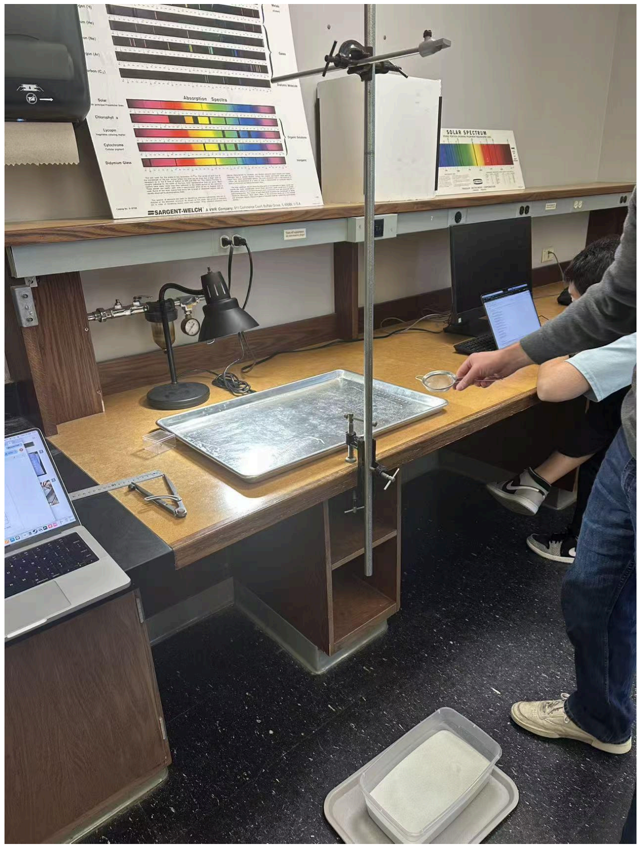
As shown in the graph, the edge of the circle trace due to the impact is not a clear border. Thus, during the measurement, there may be extra random uncertainty. It is also hard to locate where is the diameter too. 5.5

Collecting data and plotting

Record your data here, and make sure to plot as you go. Use this space also to record observations and thoughts, including details about your procedure (including pictures, if it would help) and how you are minimizing (and quantifying) your uncertainties.



We set the distance from the surface of the sand to the clip on the iron structure to the height we want to measure. We release the mass using the magnetic device shown in the image above. It will stick the iron ball and release it when taken away so that we avoid the force of our hand impacting the releasing of the iron ball. Afterwards, we measure the diameter of the circular trace due to the impact using a compass and a ruler. After each trial, we shake the sand and use the ruler to smooth the surface.

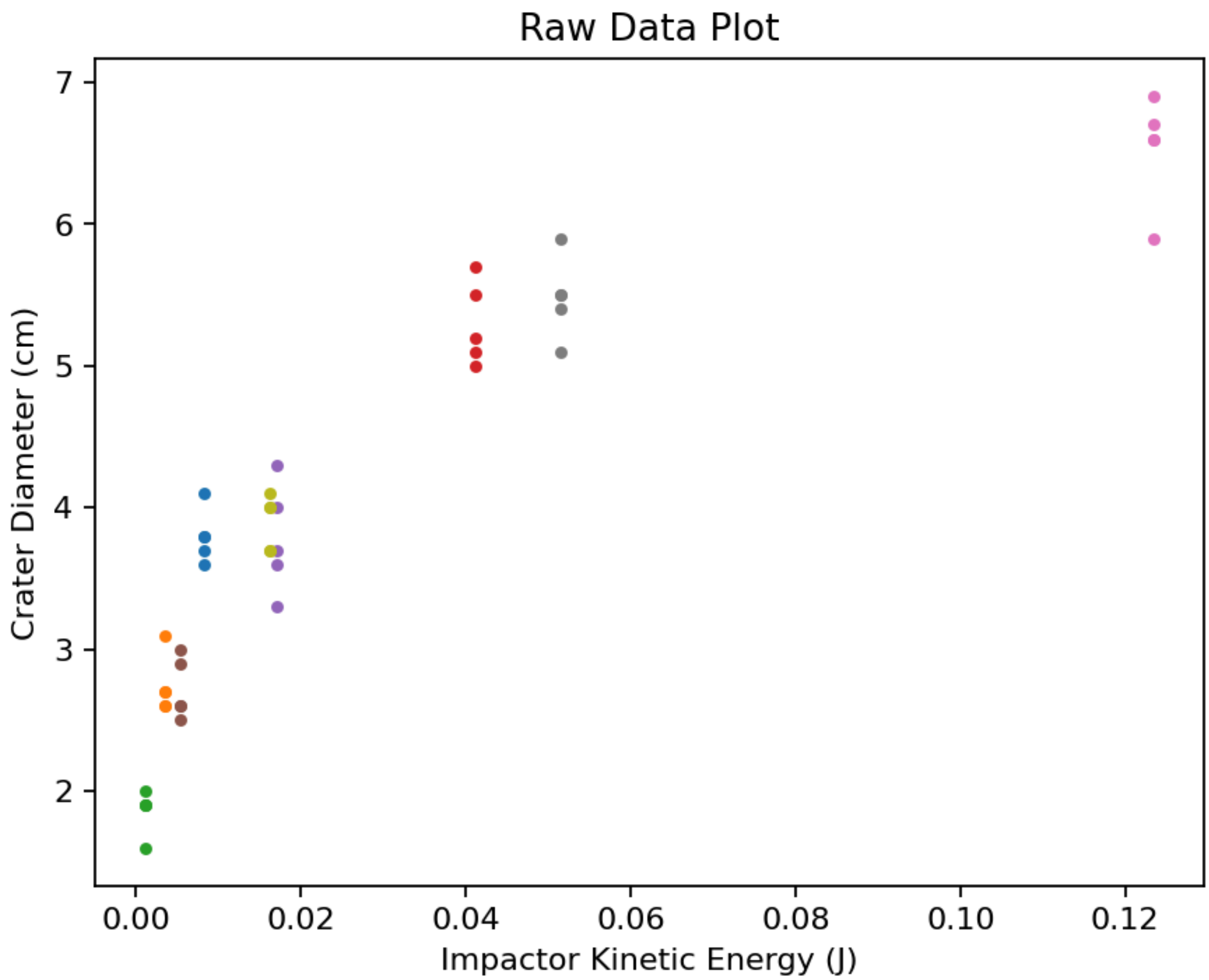


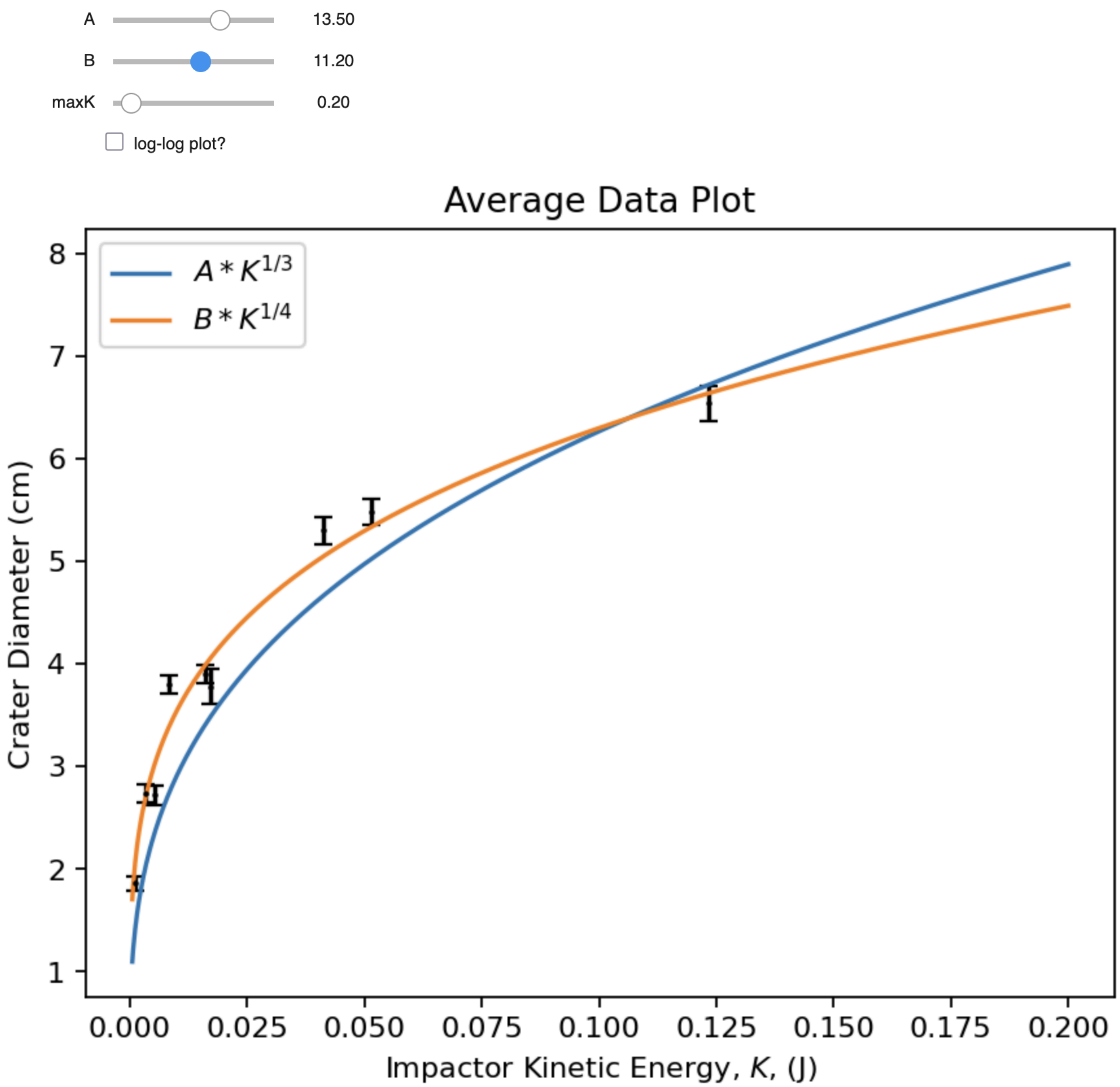
At the tallest height, we shift the sand to the ground. The mass sometimes fell to the side of the box. In such cases, we do the trial again.

Height (cm ± 0.05 cm)	*Trials (#)*	*Diameter Measurement (cm ± 0.1 cm)*		
		Mass (g ± 0.1g)		
		8.4	*3.5*	*1.1*
10.0	*1*	*3.7*	*2.6*	*2.0*
	2	*3.8*	*2.7*	*1.9*
	3	*4.1*	*2.7*	*1.6*
	4	*3.6*	*3.1*	*1.9*
	5	*3.8*	*2.6*	*1.9*
50.0	*1*	*5.5*	*3.3*	*2.6*
	2	*5.7*	*3.6*	*2.5*
	3	*5.2*	*4.3*	*2.6*

	4	*5.0*	*4.0*	*2.9*
	5	*5.1*	*3.7*	*3.0*
150.0	*1*	*5.9*	*5.5*	*4.0*
	2	*6.6*	*5.4*	*4.1*
	3	*6.6*	*5.9*	*4.0*
	4	*6.7*	*5.5*	*3.7*
	5	*6.9*	*5.1*	*3.7*

Shared Google Colab:
https://colab.research.google.com/gist/yaoshiiscool/92106dce1a4ee7666c245b5b75faf48d/cratering.ipynb


Raw Data Plot
Crater Diameter (cm)
Impactor Kinetic Energy (J)
7
6
5
4
3
2
0.00
0.02
0.04
0.06
0.08
0.10
0.12



Based on the two graphs, it appears that the 1st Model ($BK^{1/4}$) fits better with the data as for equal A and B, the orange line representing the Ejection model appears to intersect with more of our plotted bars to suggest that the results of the model are closer to the results of the experiment.

Cratering (Part 2)

Lab Notebook

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Course:	PHYS 13100 2
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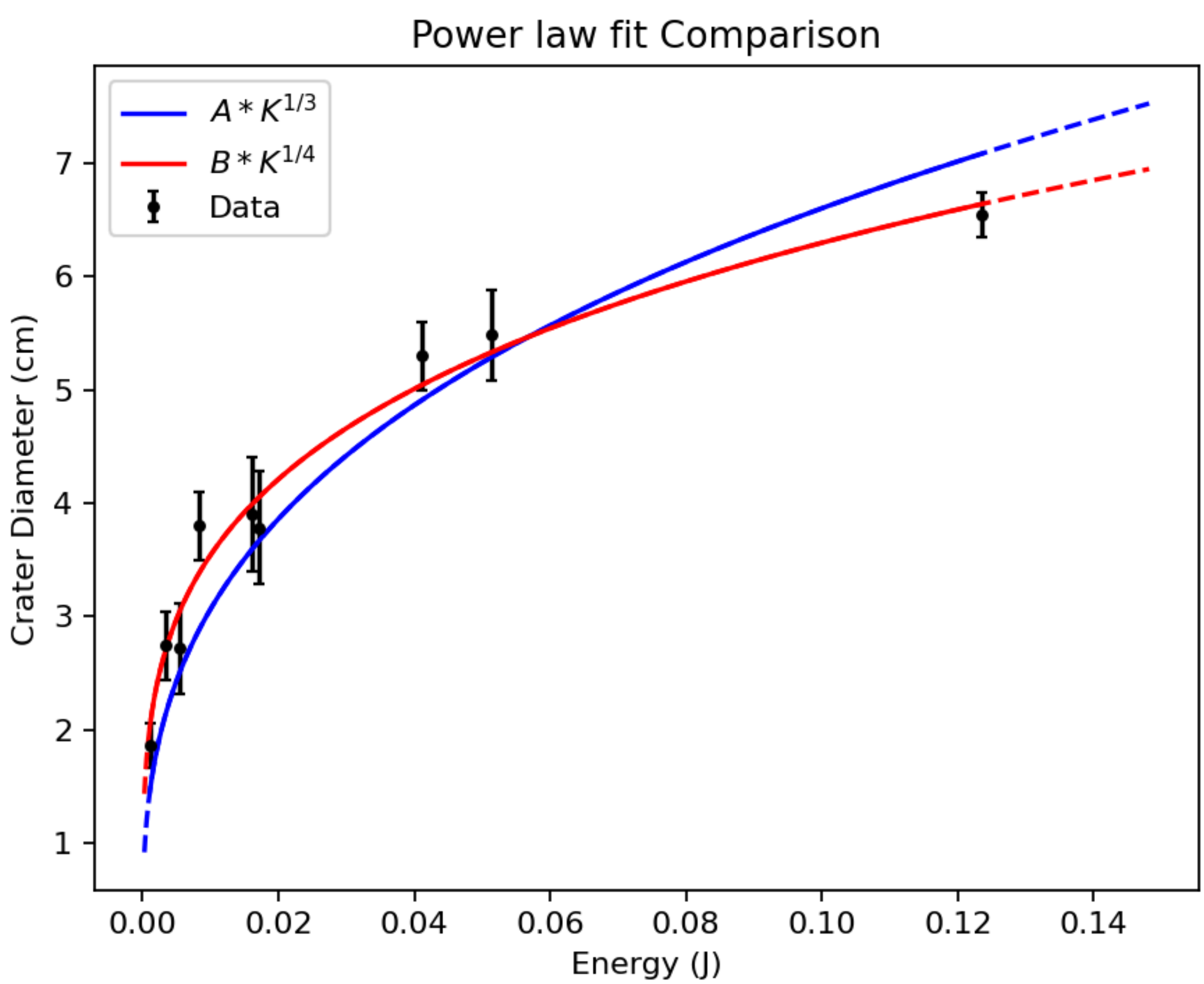
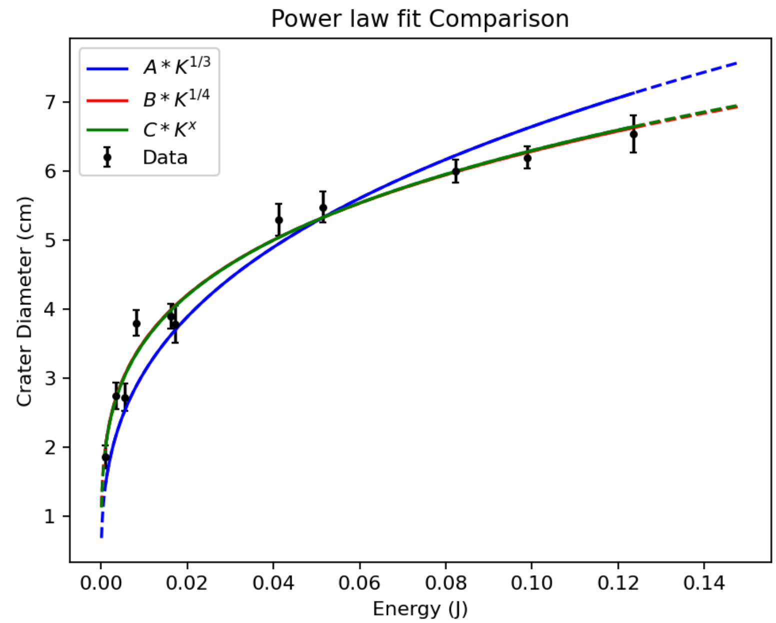


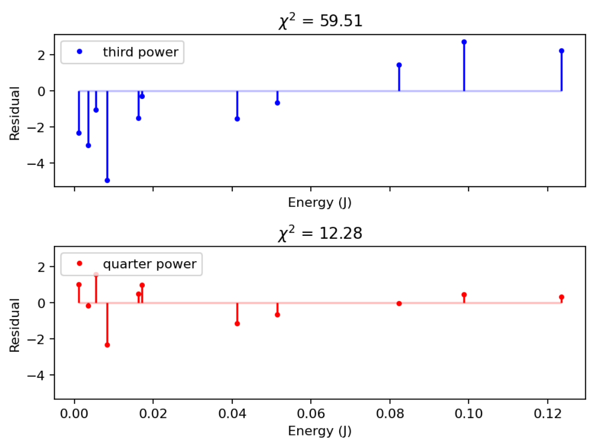
For model 1 (blue line), the reduced chi-square is 3.44. From the graph, we can conclude that it is not a result of overly small uncertainty, but a result of the model not agreeing with the data. Currently, the fit of the second model (red line) has a calculated reduced chi-square 0.60 and we can see a clear gap between the point with the biggest KE and the second biggest. Thus, using the same method as the previous experiments, we are doing more measurements to fill in the gap. The data we collected in today's lab is shown in the following table.

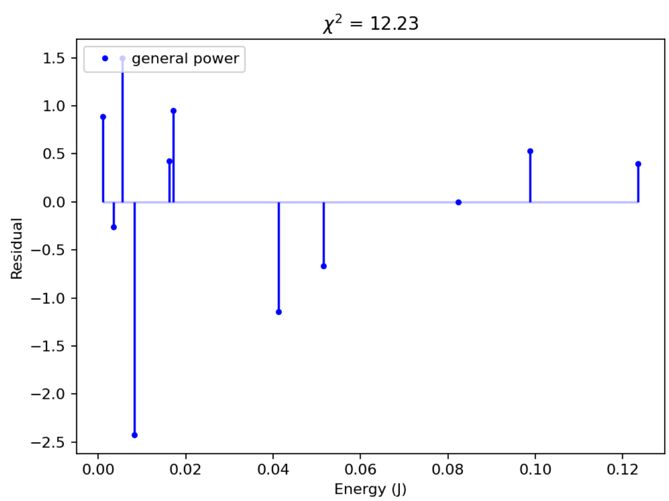
We select the new mass and height with estimation of the kinetic energy.

Height (cm ± 0.05 cm)	*Trials (#)*	*Diameter Measurement (cm ± 0.1 cm)*
		Mass (g ± 0.1g)
		8.4
100.0	*1*	*5.9*
	2	*6.1*
	3	*5.9*
	4	*5.9*
	5	*6.2*
120.0	*1*	*6.1*
	2	*6.2*
	3	*6.2*
	4	*6.1*
	5	*6.4*

Afterwards, we find our reduced chi-square to be even smaller. We found out that it is the result of overly estimated uncertainty, so instead of the statistical uncertainty calculated by our hand, we use the standard error function in the google code instead. However, since the standard error is too small, and make the reduced chi-square too big, we add the measurement uncertainty of 0.1cm to it, which turns out a chi-square of 1.23, showing agreements. The fittings, parameters and results are shown in the following images copied from the google collab.


Power law fit Comparison
$A * K^{1/3}$
$B * K^{1/4}$
$C * K^{x}$
Data
Crater Diameter (cm)
Energy (J)


χ^2 = 59.51
third power
Residual
Energy (J)
χ^2 = 12.28
quarter power
Residual
Energy (J)


χ^2 = 12.23
general power
Residual
Energy (J)

```
quarter_fit, quarter_err, quarter_chisq, quarter_dof = data_fit(['B'], [1], quarter_pow
                                     Energy, Crater_Width_Average, Crater_Width_Uncertainty)
```

```
FIT: D = A*K^(1/3)
-----
Converged with chi-squared: 59.51
Number of degrees of freedom, dof: 10
Reduced chi-squared (chi-squared/dof): 5.95

Parameter    | Best fit values:         | Uncertainties in the best fit values:
A            | 14.3223                  | 0.1822

FIT: D = B*K^(1/4)
-----
Converged with chi-squared: 12.28
Number of degrees of freedom, dof: 10
Reduced chi-squared (chi-squared/dof): 1.23

Parameter    | Best fit values:         | Uncertainties in the best fit values:
B            | 11.1846                  | 0.1417
```

Next, let's plot the fits to see how they look compared to the data

```
  ax.legend()
  plt.show()
```

```
FIT: D = C*K^x
-----
Converged with chi-squared: 12.23
Number of degrees of freedom, dof: 9
Reduced chi-squared (chi-squared/dof): 1.36

Parameter    | Best fit values:         | Uncertainties in the best fit values:
C            | 11.2685                  | 0.4133
x            | 0.2524                   | 0.0111
```

☐ log-log plot?

Below is the data for the trial we did together.
Mass used: 66.7g = 0.0667kg
Height: 8.63m
Calculated KE = 5.6410858J
Measurements:
1: 16.5 cm
2: 17.2cm
3: 18.0
4: 18.7 cm

Height (m ± 0.05 cm)	*Trials (#)*	*Diameter Measurement (cm ± 0.1 cm)*
		Mass (g ± 0.1g)

		66.7
8.63	*1*	*16.5*
	2	*17.2*
	3	*18.0*
	4	*18.7*

We try to use our model to predict the width of the crater, and it is shown in the following image.

```
print("general-power prediction: ", D_gen, "+/- ", dD_gen, "cm")
```

```
Enter an energy (in J) to see what your models predict for the crater diameter: 5.6410858
1/3-power prediction:  25.49576536599417  +/-  0.3242732946811734 cm
1/4-power prediction:  17.23704560766189  +/-  0.2184002530250408 cm
general-power prediction:  17.438646654970448  +/-  0.6396835561771812 cm
```

We can see from the ¼-power prediction and the general-power prediction that the results are similar to the measurements.

```
Parameter    | Best fit values:          | Uncertainties in the best fit values:
C            | 11.2685                   | 0.4133
x            | 0.2524                    | 0.0111
```