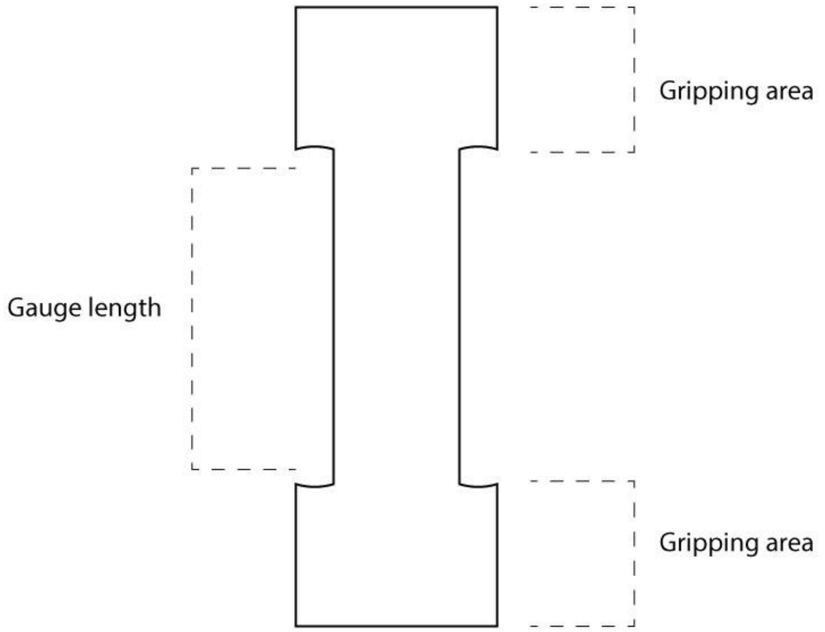
ENGR 298: Engineering Analysis and Decision Making – Tensile Strength Testing

Dr. Jason Forsyth
Department of Engineering
James Madison University

Today, We Break Things



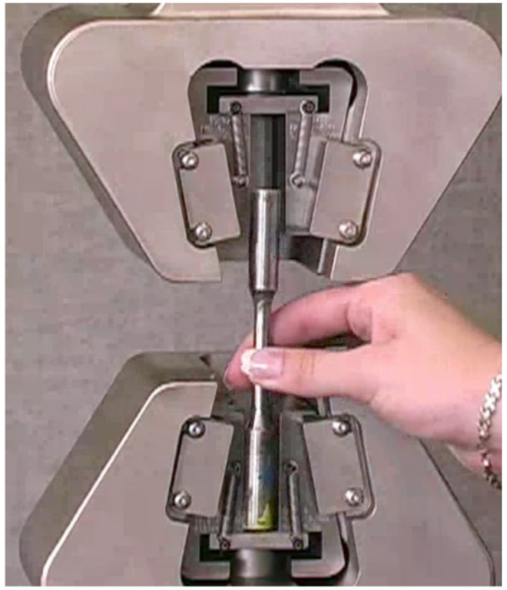


Figure 6. Insert specimen from front.

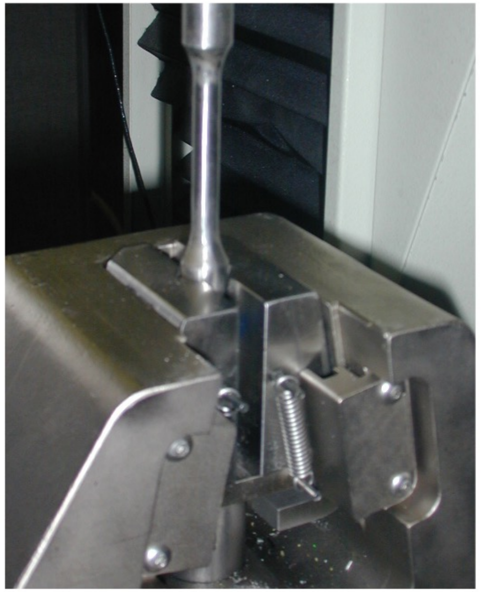


Figure 7. Install in lower grip.

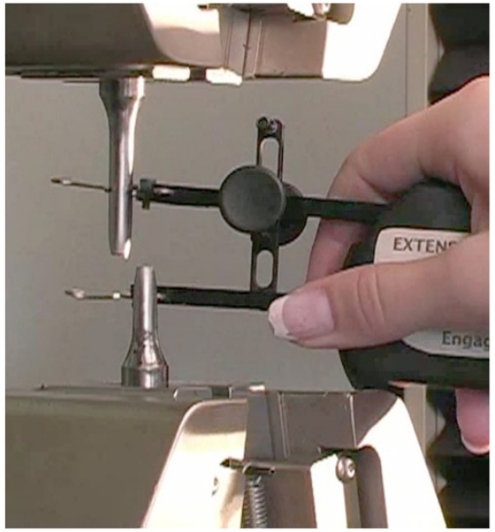
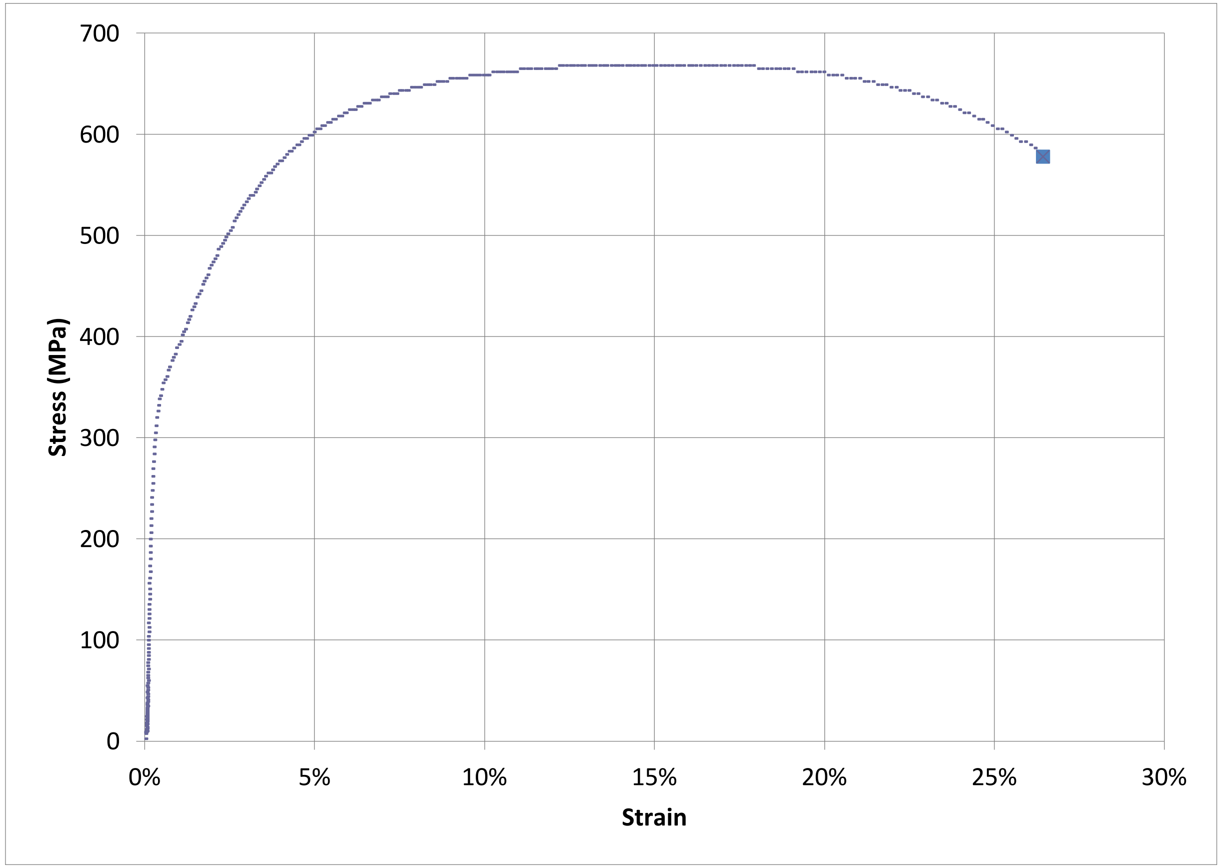
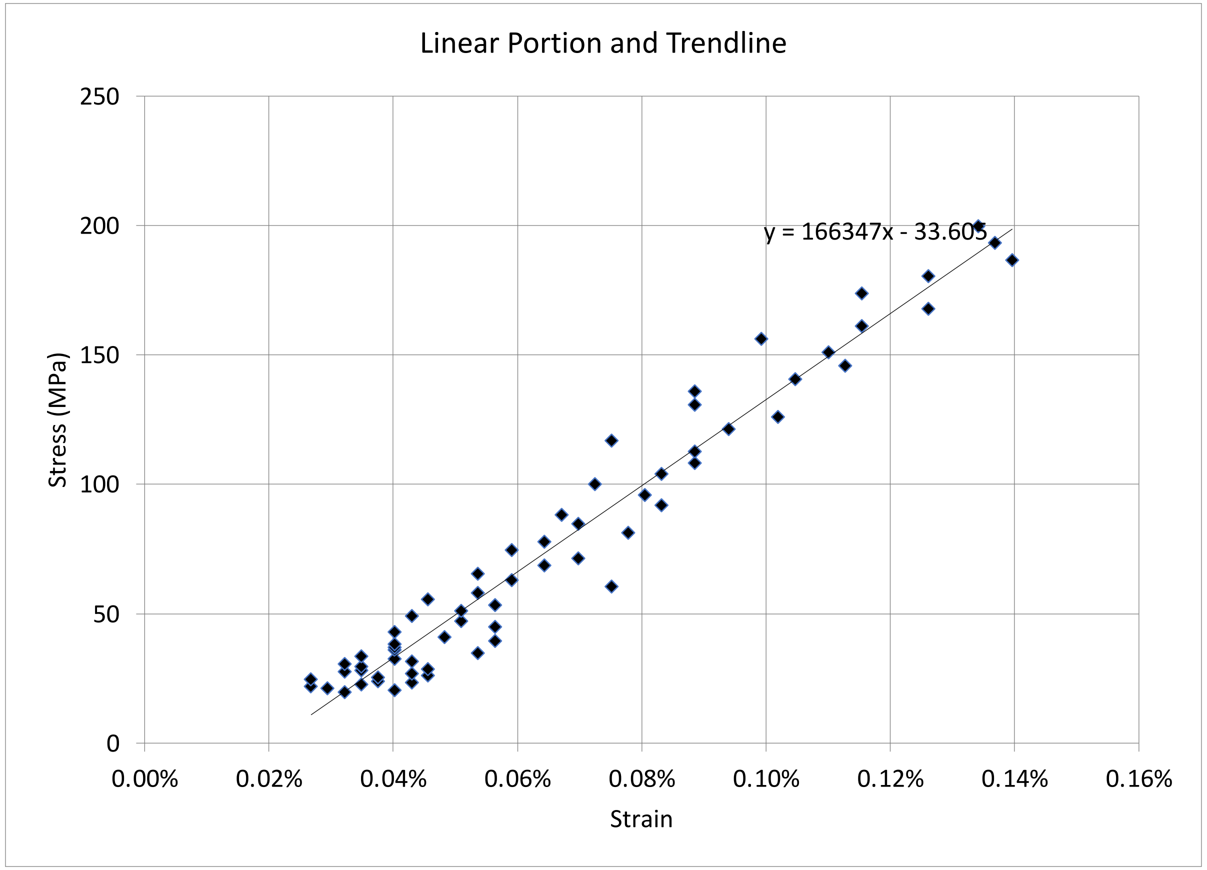


Figure 12. Push the extensometer to the right to remove.

Figure 13. Place the extensometer on its hanger.

Stress – Strain Curves and Modulus





A1 | f_x System ID

	A	B	C	D
1	System ID		4483J11304	
2	Method name only		Tension_Round_NEW	
3	Test type		Tension	
4	Sample file name		C01A1045CR	
5	Last test date		Monday, February 7, 2022	
6	Last test time		11:03:11 AM	
7	Course		CEE300	
8	Lab Section Number		AB01	
9	Group		A	
10	Material		STEELS1045	
11	Heat Treatment		CR	
12	Other Information			
13	Crosshead Speed	(mm/min)	4	
14	Geometry		Circular	
15	Gage Diameter	(mm)	7.25	
16	Grip Diameter	(mm)	12.78	
17	Rockwell Hardness		96.3	
18	Rockwell Scale		HRB	
19	Extensometer Gage Length	(mm)	25.4	
20	Final Gage Diameter	(mm)	5.54	
21	Fracture Notes and Location		Cup and cone. Necking.	
22	Notes During Test			
23				
24	Results Table 1			
25			1	
26	Maximum Force	(kN)	32.53	
27	Maximum Strain	(%)	16.14	
28				
29	Time	Displacem	Force	Strain 1
30	(s)	(mm)	(kN)	(mm/mm)
31	0	0	-0.03398	1.77E-07
32	0.5	0.03	0.5951	5.24E-05
33	1	0.06	1.286	8.8E-05
34	1.5	0.1	1.702	0.000184
35	2	0.13	2.03	0.000195
36	2.5	0.16	2.325	0.000229
37	3	0.2	2.582	0.000354
38	3.5	0.23	2.816	0.000424
39	4	0.26	3.039	0.000364

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201 Talbot Laboratory

Talbot Lab at the University of Illinois

Lab Coordinator: David Farrow, Ph.D.
E-mail: dfarrow@illinois.edu
Phone - (217) 333-8133
FAX - (217) 244-0720

Mailing Address:

MTIL
306 Talbot Lab, MC-236
104 S. Wright Street
Urbana, Illinois 61801-2958

Steel bar bending test

Show informative links (column at left)

Looking for student testing data or help files? Go here...

Entrance to Talbot Laboratory

Entrance to 201 Talbot Laboratory

https://mtil.illinois.edu/

What information is generated from these machines?

- **Metadata**: test day/time, material type, sample diameter, hardness…

- **Time series information**:
    - Time (seconds)
    - Displacement (mm)
    - Force/Load (kN)
    - Strain (mm/mm)

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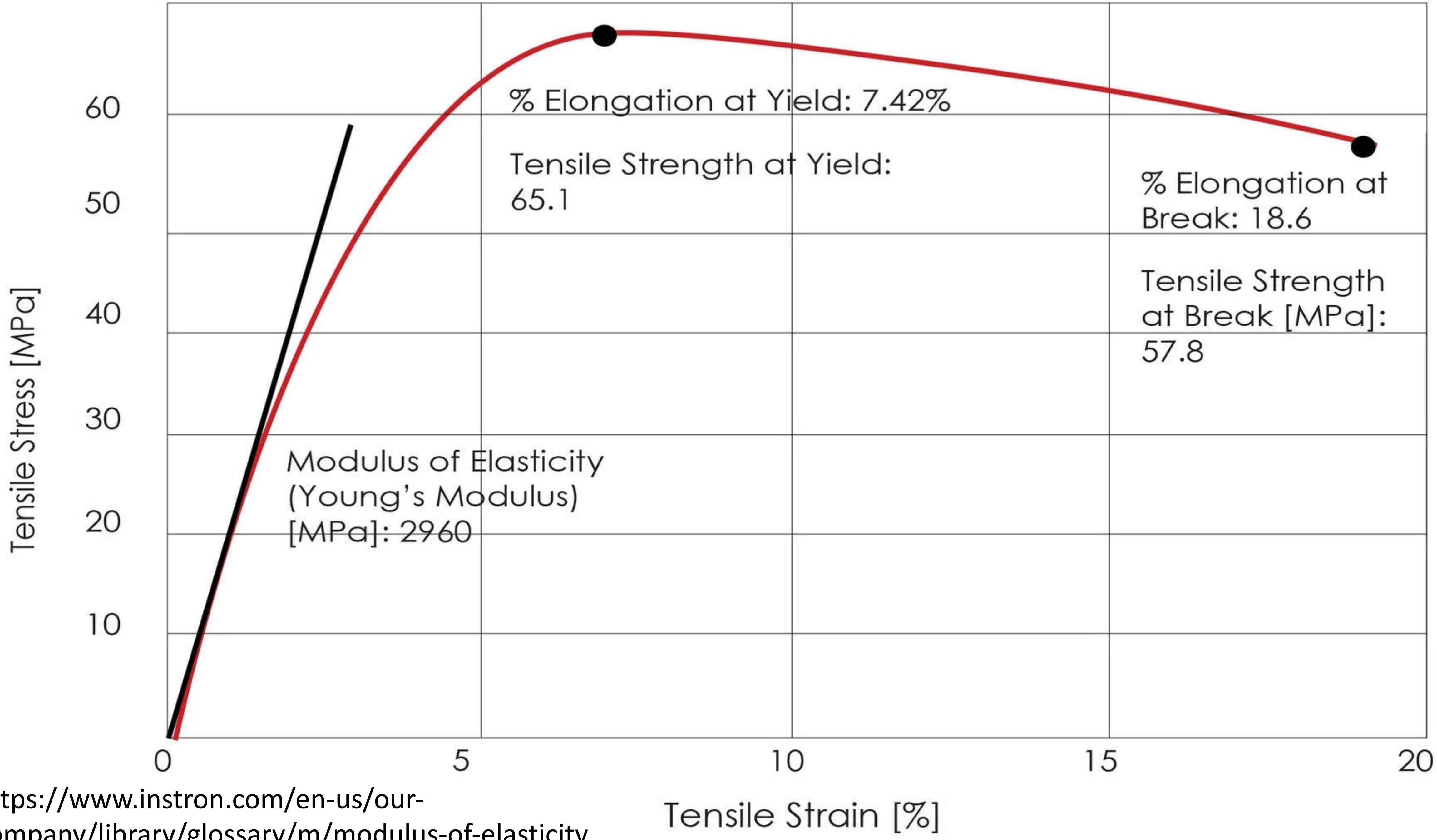
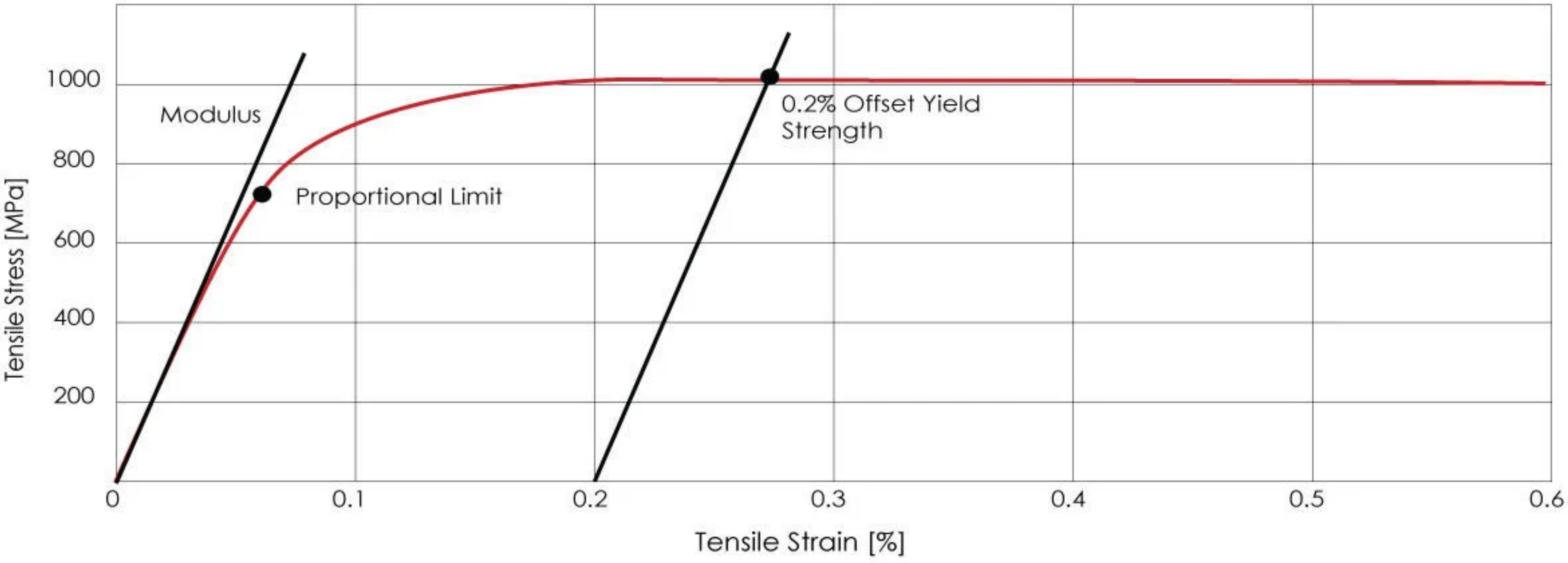
35	2	0.13	2.03	0.000195
36	2.5	0.16	2.325	0.000229
37	3	0.2	2.582	0.000354
38	3.5	0.23	2.816	0.000424
39	4	0.26	3.039	0.000364

What can we calculate from this information?

- **Ultimate Tensile Strength**: the maximum stress experienced by the sample (link)
- **Fracture Strain**: the maximum strain experienced by the sample
- **Elastic Modulus**: measure of materials resistance to change before permanent damage (link).
- **Yield Strength**: an approximation of the elastic limit. Slightly beyond the elastic point and may have plastic strain (link)



https://www.instron.com/en-us/our-company/library/glossary/m/modulus-of-elasticity



https://www.instron.com/en-us/our-company/library/glossary/o/offset-yield-strength

If you have 5x of these samples to do, would you use Excel?

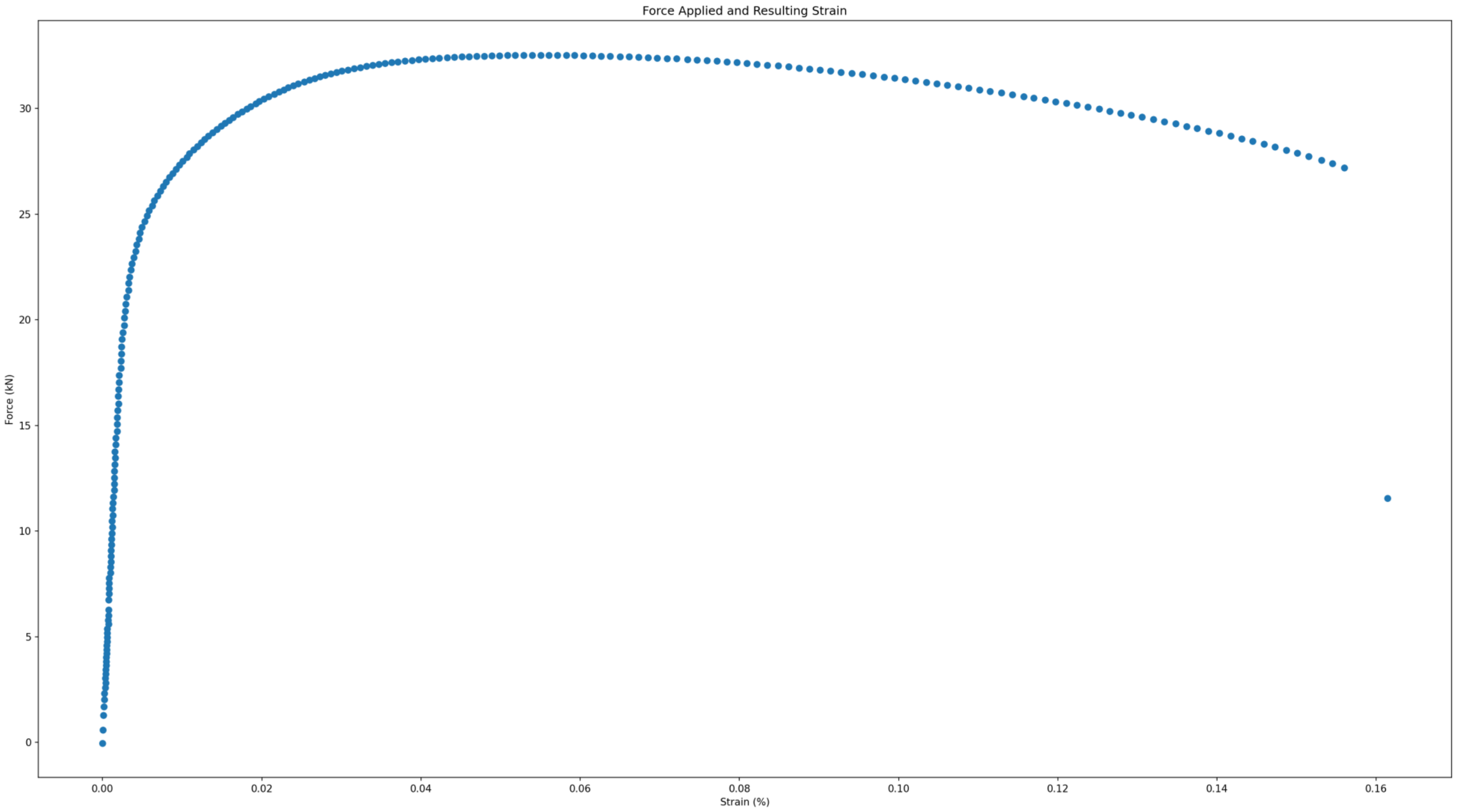
What about 500x?

Tensile Testing in Python

- File format from Instron is odd; Instructor will provide parser that extracts sample diameter (mm), time (s), force (kN), displacement (mm), and strain (%).

- Student solution will calculate:
  - **Stress** (MPa) = Load (N) / **Area** (mm^2)
  - **Ultimate Tensile Stress** (MPa) and **Fracture Strain** (%)
  - **Elastic Modulus** via Secant Modulus @ 40%
  - Yield Strength via 0.2% offset (in-progress)

Consider a plot of Load/Force (kN) Versus Strain. How would you calculate Stress (MPa)? What do you need to know? How would you do this in Python?



It’s pretty simple if it’s all in Numpy…

Numpy Array

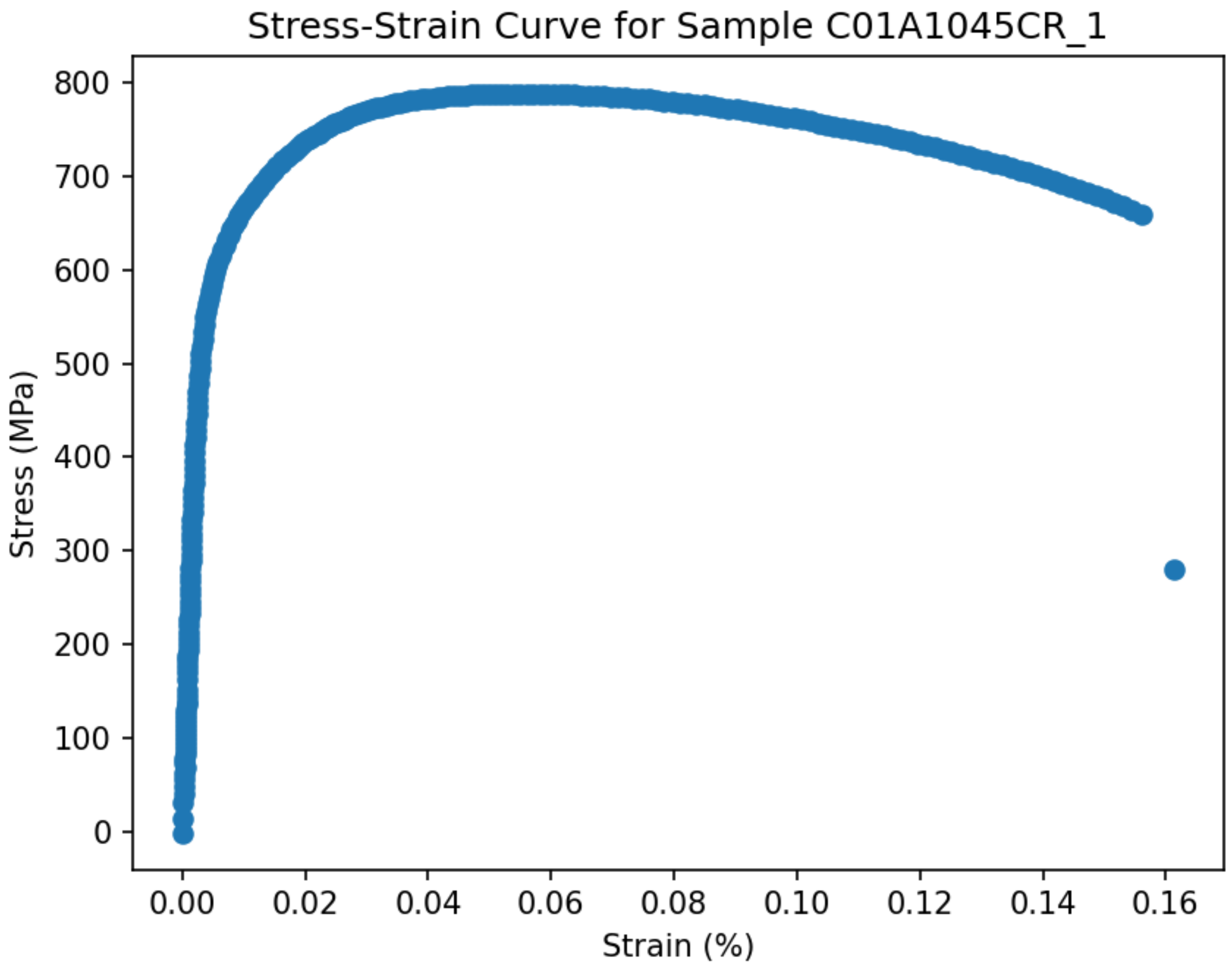
Numpy Array

```python
# calculate stress (MPa) from load (kN) and cross-sectional area
stress = force / cross_sectional_area * 1000

return stress
```

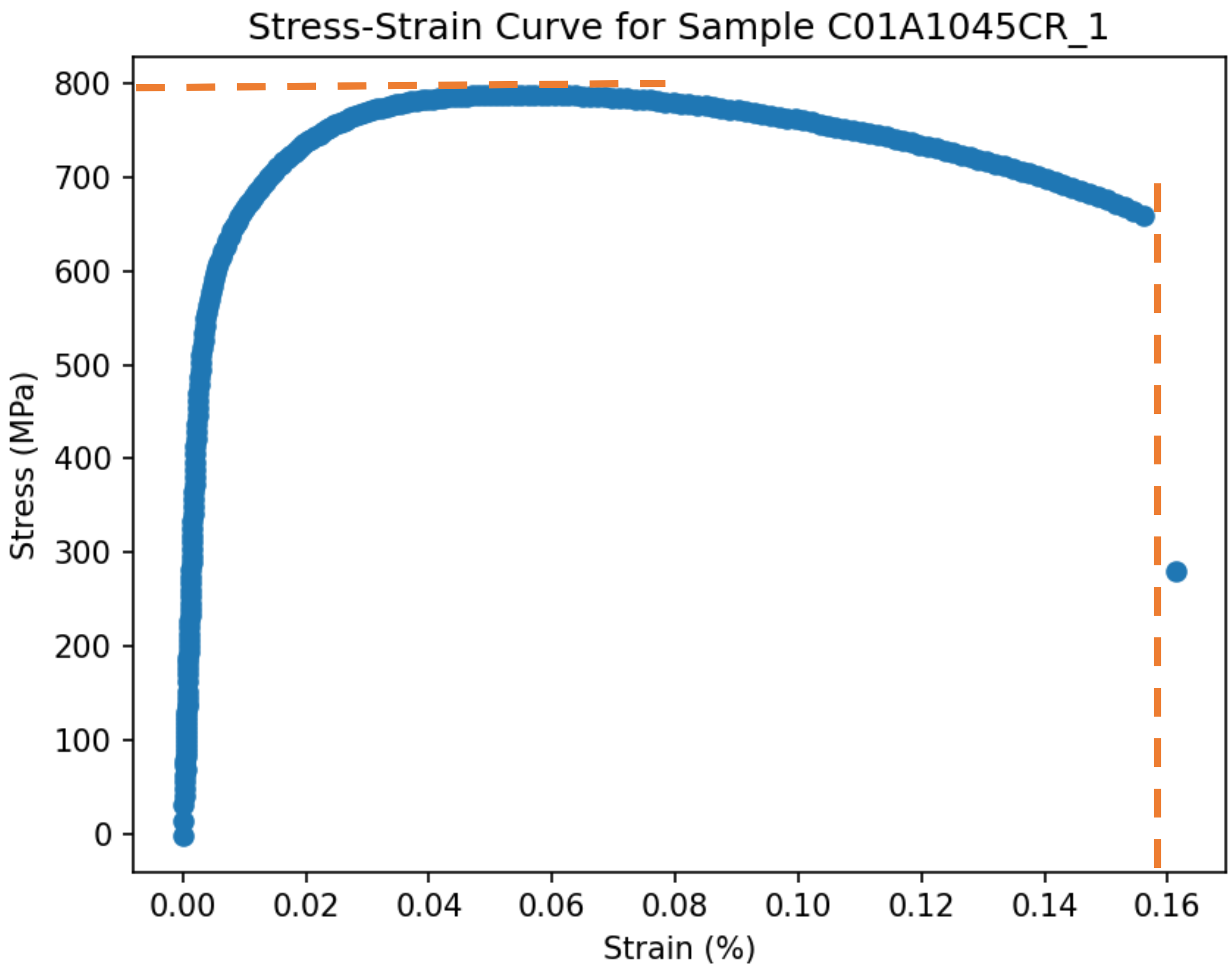
Constant

Stress (MPa) = Load (N) / **Area** (mm^2)

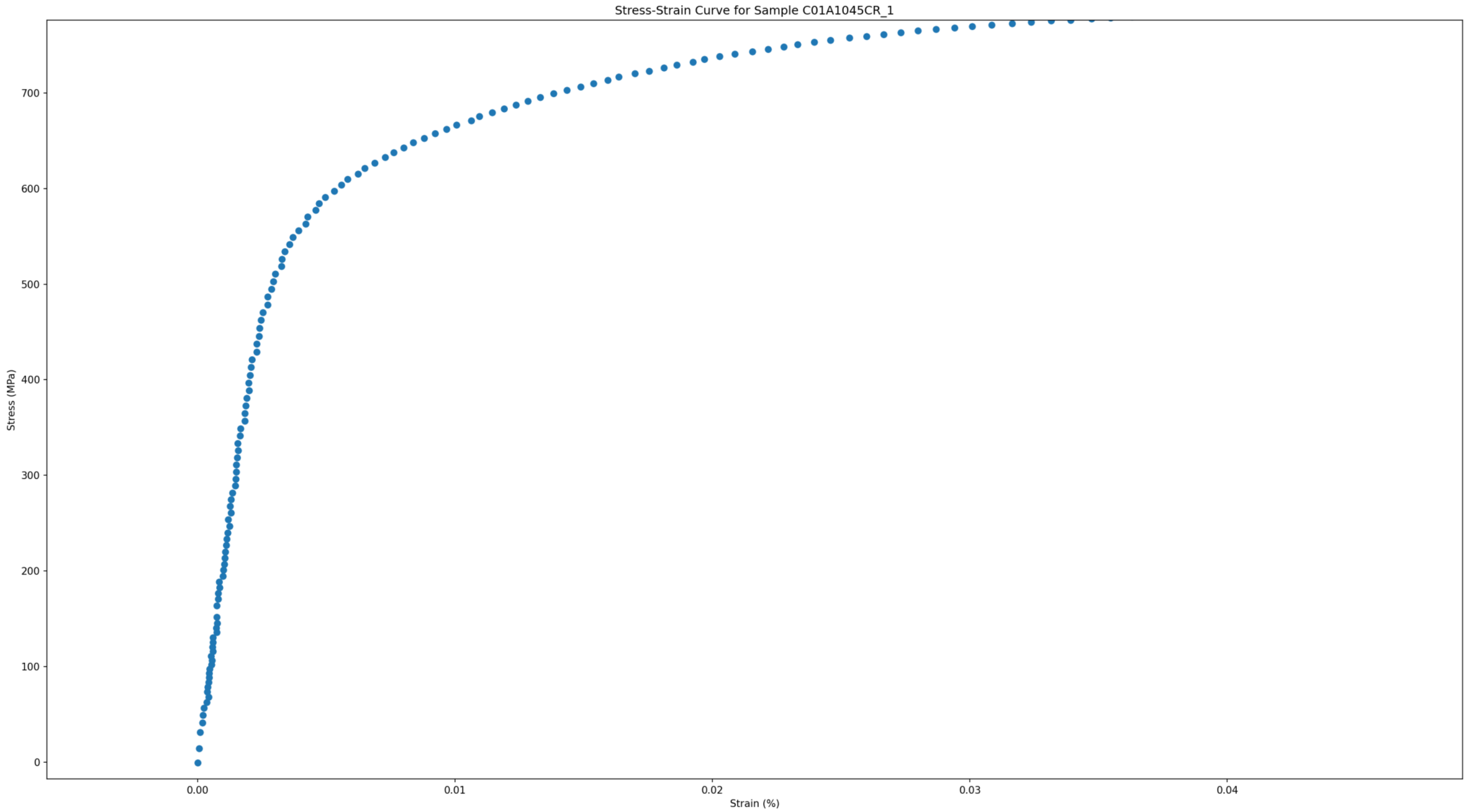


Stress-Strain Curve for Sample C01A1045CR_1
800
700
600
500
400
300
200
100
0
Stress (MPa)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
0.16
Strain (%)

If Stress and Strain are both numpy arrays, how would you find the max Stress and Strain?



What about the linear region for modulus?

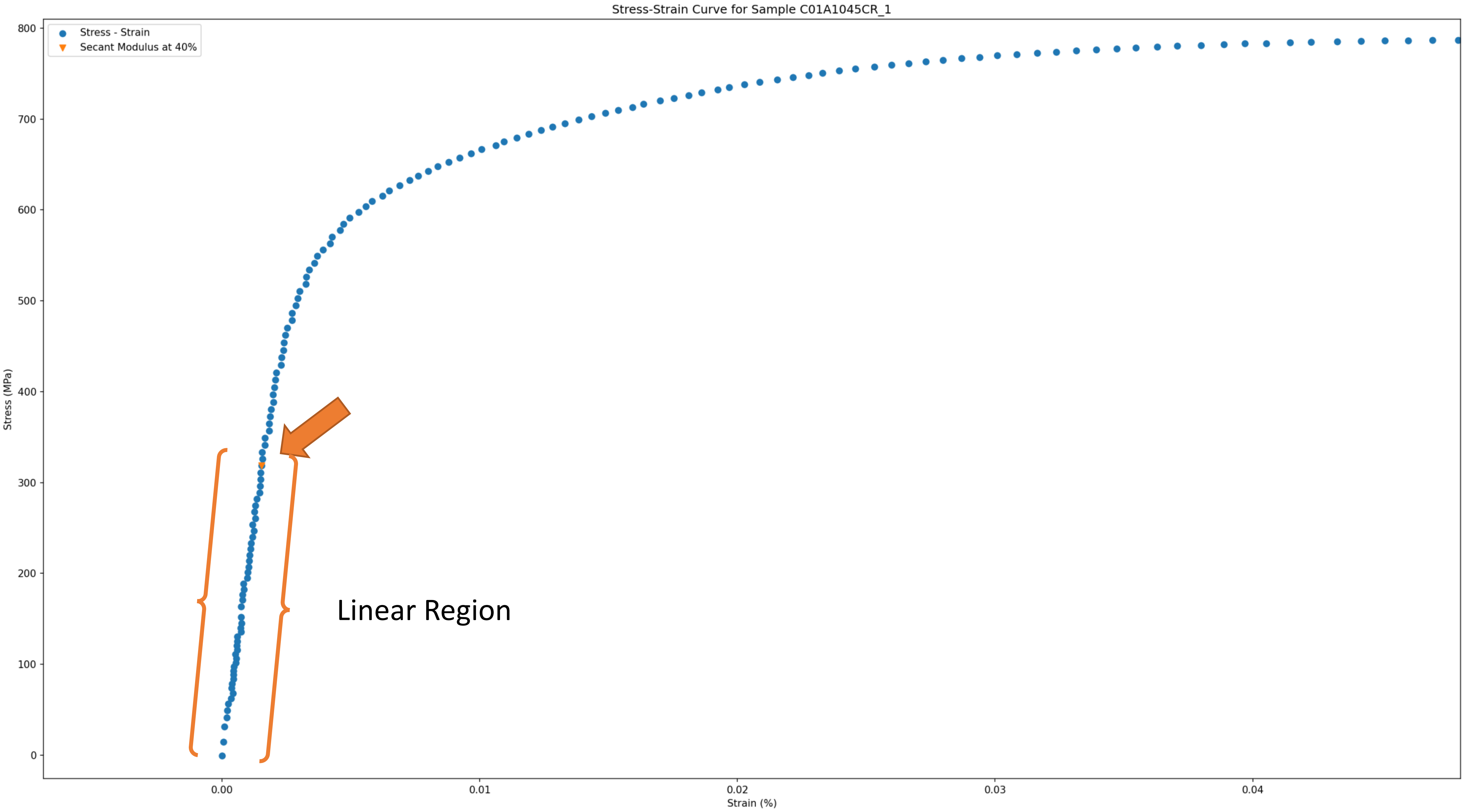


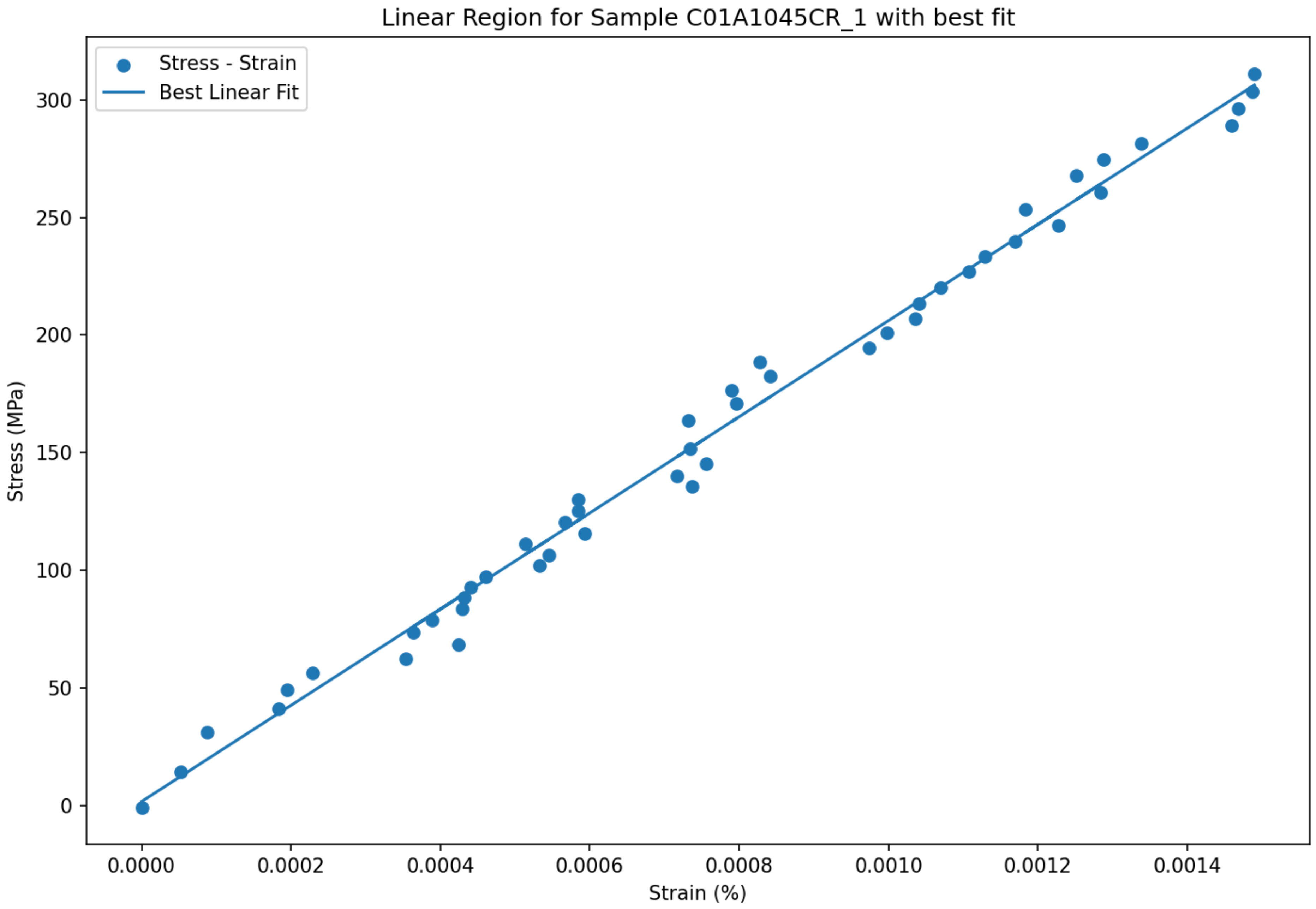
Thankfully Dr. Castaneda has a method…

1. Identify the point on the curve that is at 40% of the maximum stress (Secant at 40% of max strain).

2. Isolate the “linear region” between that point and the origin.

3. Perform linear best fit on region to identify slope (modulus) and intercept

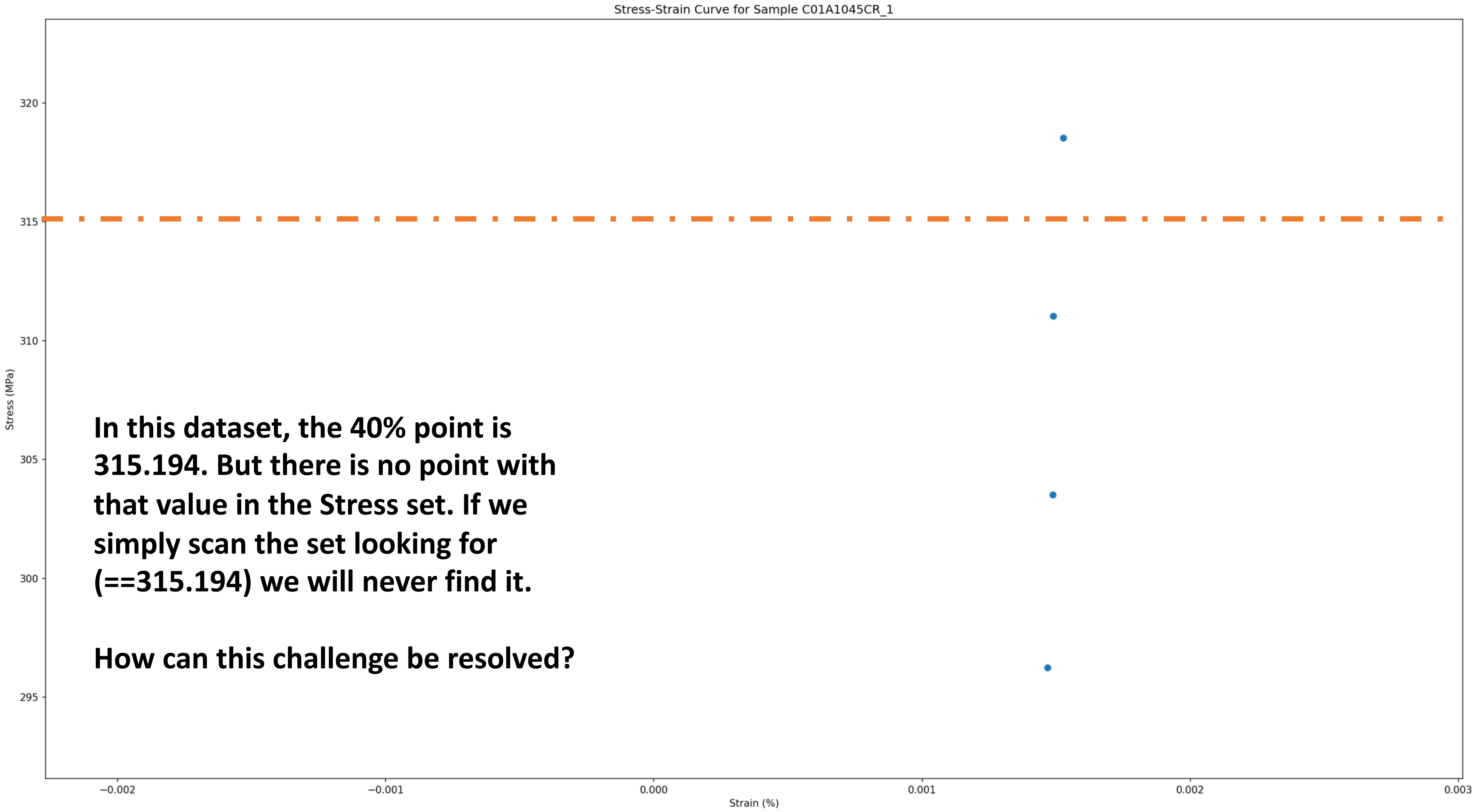

Stress-Strain Curve for Sample C01A1045CR_1
Stress - Strain
Secant Modulus at 40%
Stress (MPa)
Strain (%)
Linear Region
0
100
200
300
400
500
600
700
800
0.00
0.01
0.02
0.03
0.04


Linear Region for Sample C01A1045CR_1 with best fit
Stress - Strain
Best Linear Fit
Stress (MPa)
300
250
200
150
100
50
0
0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
0.0014
Strain (%)

How might we do these steps in Python…

- Identify the point on the curve that is at 40% of the maximum stress (Secant at 40% of max strain).

- Finding the value of the point (0.4 of max()) is easy, but we can’t just scan all the points to look for that exact value… What if it doesn’t exist?



In this dataset, the 40% point is 315.194. But there is no point with that value in the Stress set. If we simply scan the set looking for (==315.194) we will never find it.

How can this challenge be resolved?

Options for Finding the Closest Point

- **Option #1**: Scan the whole Stress list. Track the current index and how far apart the current value is from the 40% point. Return the index where the distance is least. (Very non-Pythonic)

- **Option #2**: Subtract the 40% point from all Stress points in the array. Use numpy.argmin() to find the INDEX with the minimum value.

Index: 0	1	2	3	4
Value: 7	9	3	-2	3

Minimum of the array would return (-2). Argmin would return 3; which is the location of the minimum

Thankfully Dr. Castaneda has a method…

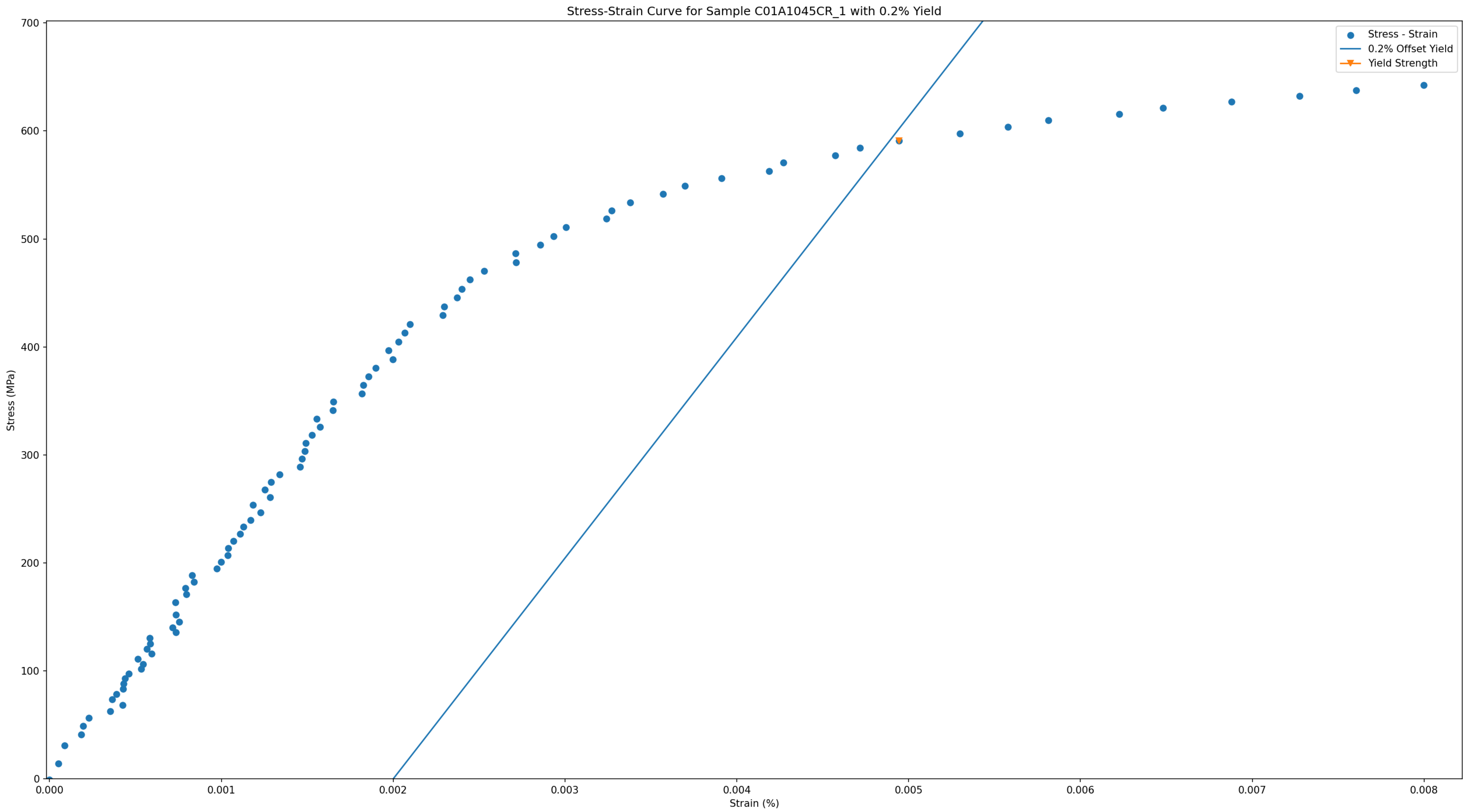
1. Identify the point on the curve that is at 40% of the maximum stress (Secant at 40% of max strain). ☺

2. Isolate the “linear region” between that point and the origin.
   1. Previous method just returned the index of where the 40% value occurred. Use array slicing (array[0:1000]) to down select to linear region.

3. Perform linear best fit on region to identify slope (modulus) and intercept
   1. Use numpy.plotfit() on a single dimension

Going Forward

- Will finish up tensile strength on Friday (need confirmation with Dr. Castaneda on yield strength)
- Three templates on GitHub for Step 1, Step 2, and Full Solution. Do them in order and copy your code over between them.
- Will develop Gradescope submission due later next week.


Stress-Strain Curve for Sample C01A1045CR_1 with 0.2% Yield
Stress - Strain
0.2% Offset Yield
Yield Strength
Stress (MPa)
Strain (%)
0
100
200
300
400
500
600
700
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008