CEE 300 / TAM 324: Lab 1 Tension Test Worksheet

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General note:

- Use space as needed. The answer length is <u>not</u> suggested by the space.
- <u>Format</u> graphs and tables as described in Lab 0 lectures. Include descriptive captions.
- Very briefly describe your results and trends.
- Read 'Analysis of results' section in the lab manual for hints.

Q1 (15 pts). Construct a diagram of engineering stress vs. strain for each of the materials tested using plotting software, e.g. Excel, MATLAB, OriginPro, etc. The tab-delimited ASCII data files contain, in order, the crosshead position, the load, the strain, and the time. (For details, see lab manual Appendix B). For ductile materials, select one strain scale such that only the elastic portion of the curve is emphasized; use the data in this range to determine modulus of elasticity. Then select a second strain scale that allows the entire curve to be included on your plot. For brittle materials, one scale is usually sufficient. Additionally, superimpose the stress-strain diagram for each material onto a single graph (with the exception of PMMA) using an appropriate strain scale.

<u>Answer:</u>

Cast Iron:

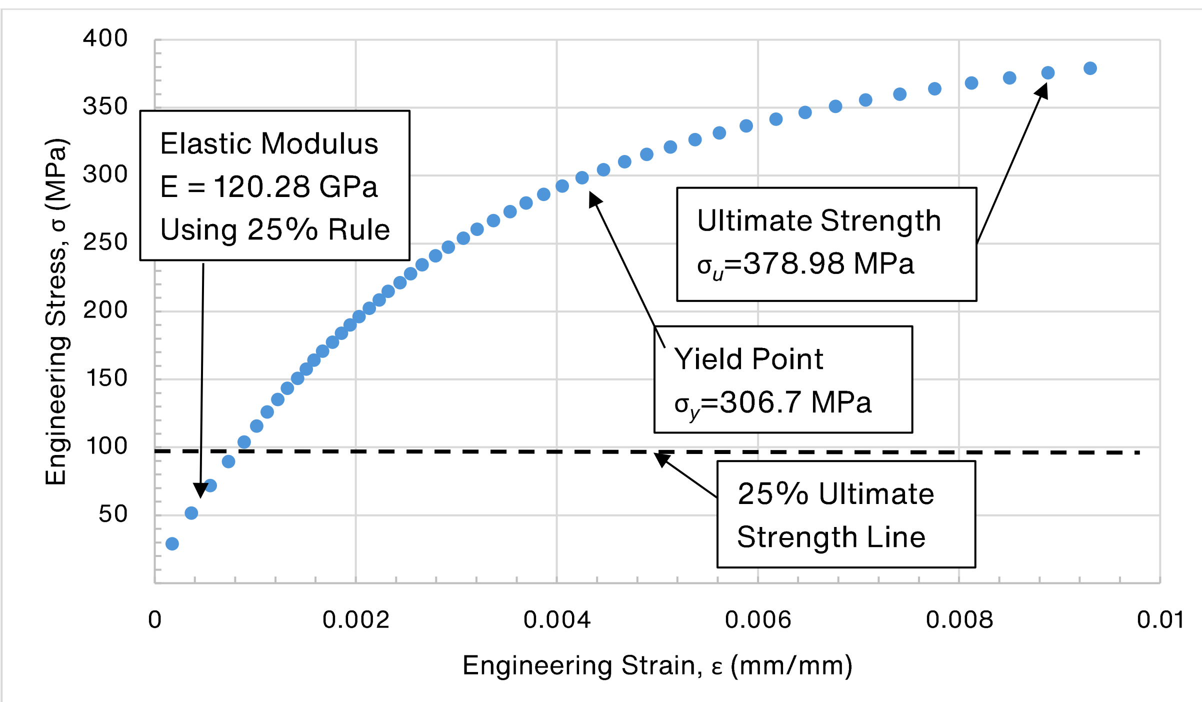

Figure 1: Engineering Stress and Strain Diagram for Grade 40 Gray Cast Iron (UNS F12801) in Tension

1018 Steel:

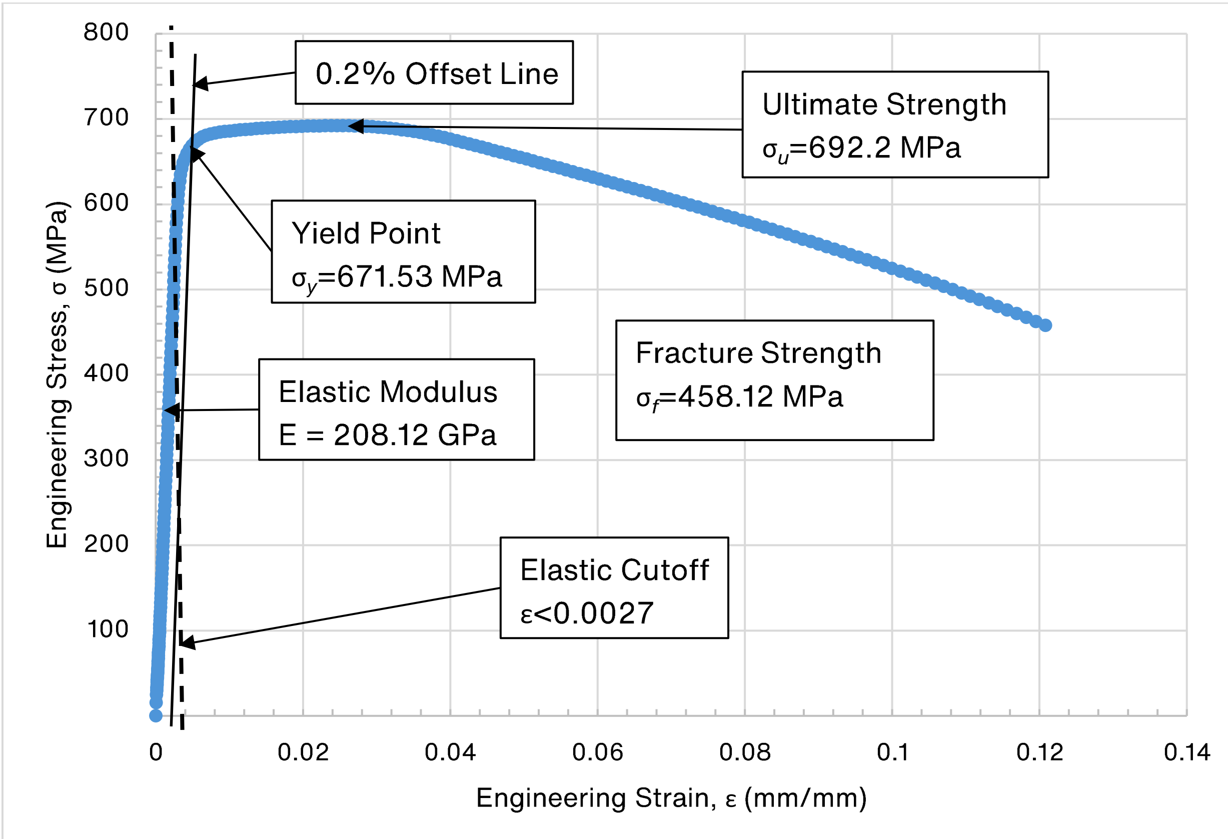

Figure 2: Engineering Stress and Strain Diagram for AISI 1018 Steel (UNS G10180) with Cold-Rolled Heat Treatment in Tension

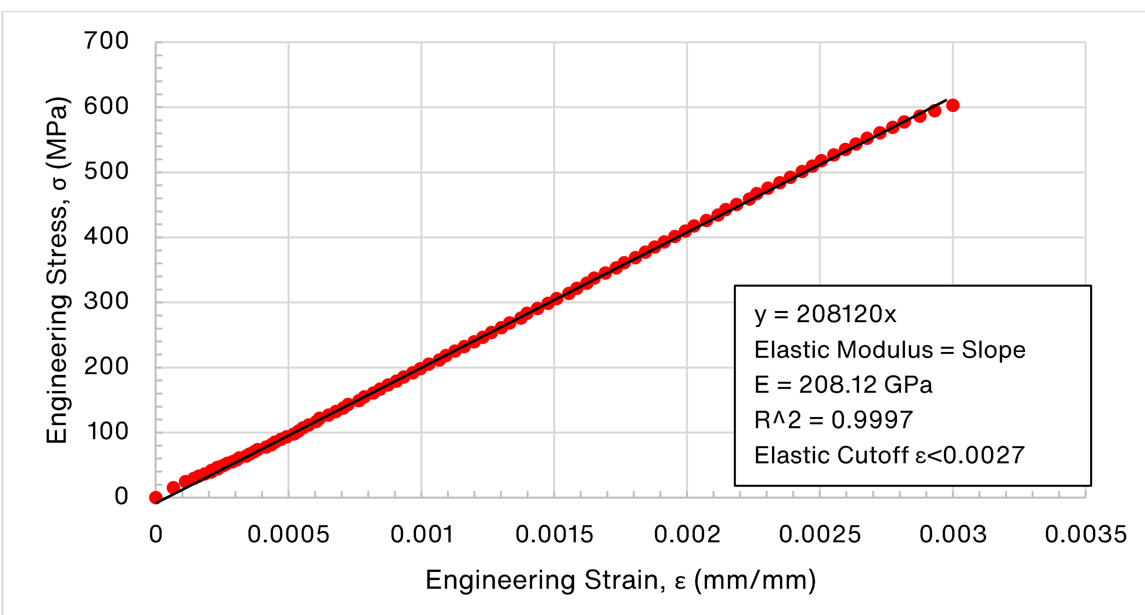

Figure 3: Elastic Region of Engineering Stress and Strain Diagram for AISI 1018 Steel (UNS G10180) with Cold-Rolled Heat Treatment in Tension

1045 Steel Cold-rolled:

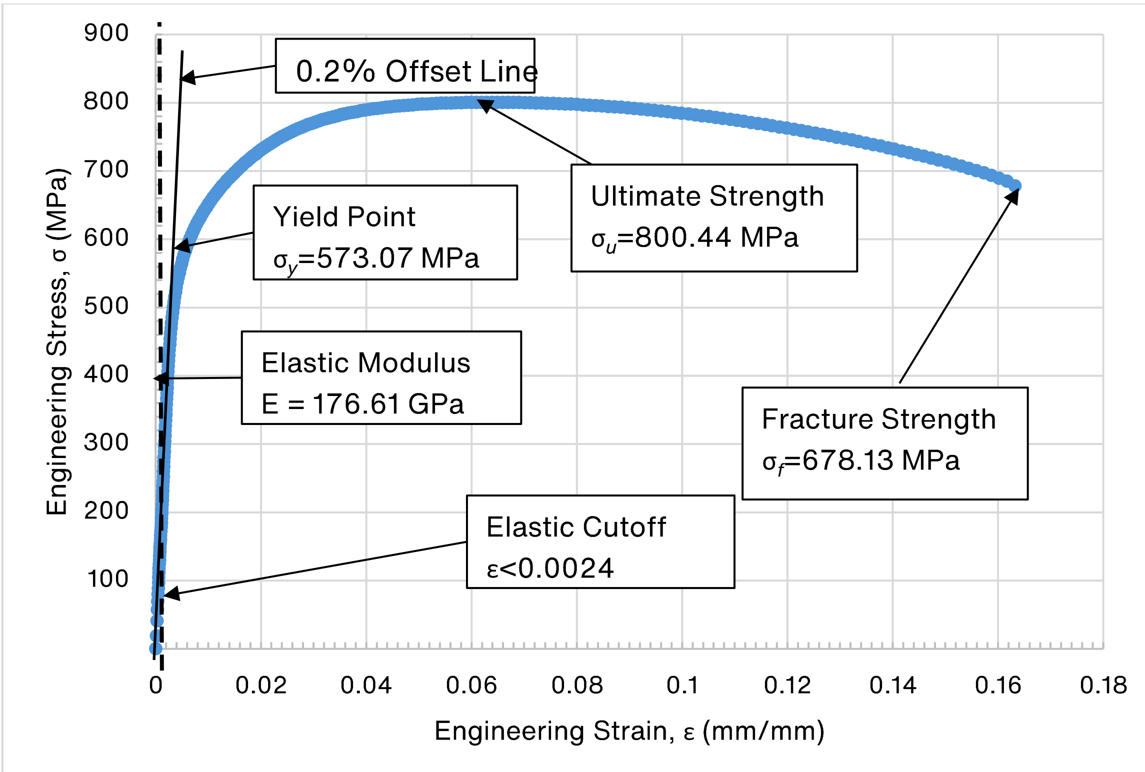

Figure 4: Engineering Stress and Strain Diagram for AISI 1045 Steel (UNS G10450) with Cold-Rolled Heat Treatment in Tension

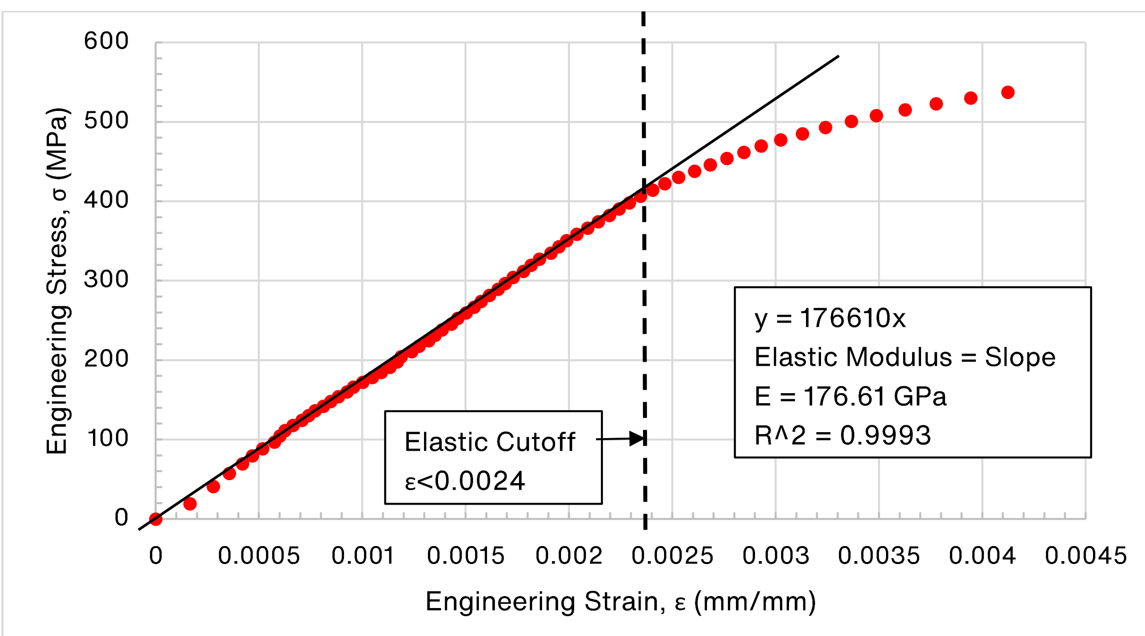

Figure 5: Elastic Region of Engineering Stress and Strain Diagram for AISI 1045 Steel (UNS G10450) with Cold-Rolled Heat Treatment in Tension

1045 Steel Normalized:

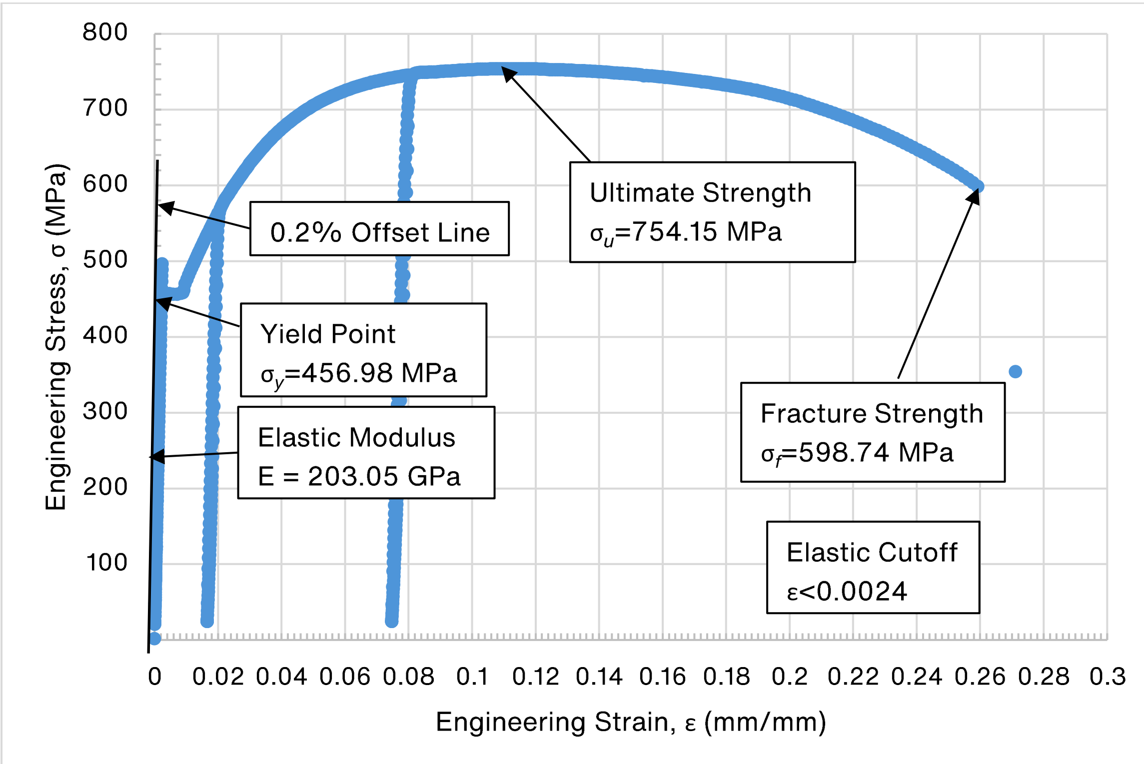

Figure 6: Engineering Stress and Strain Diagram for AISI 1045 Steel (UNS G10450) with Normalized Heat Treatment in Tension

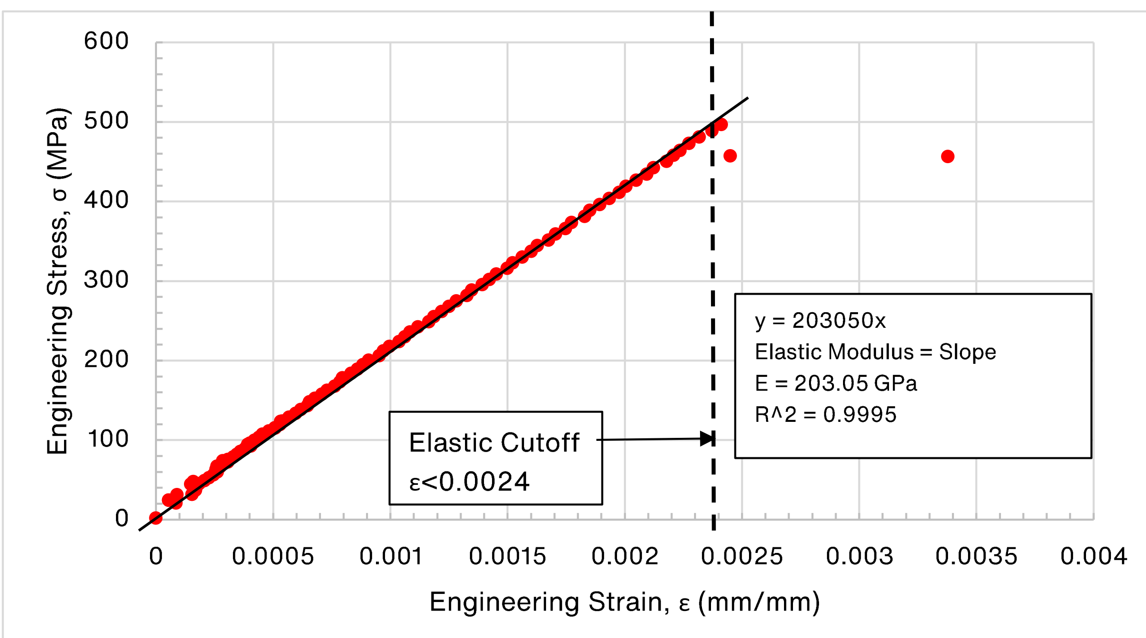

Figure 7: Elastic Region of Engineering Stress and Strain Diagram for AISI 1045 Steel (UNS G10450) with Normalized Heat Treatment in Tension

7075 Aluminum:

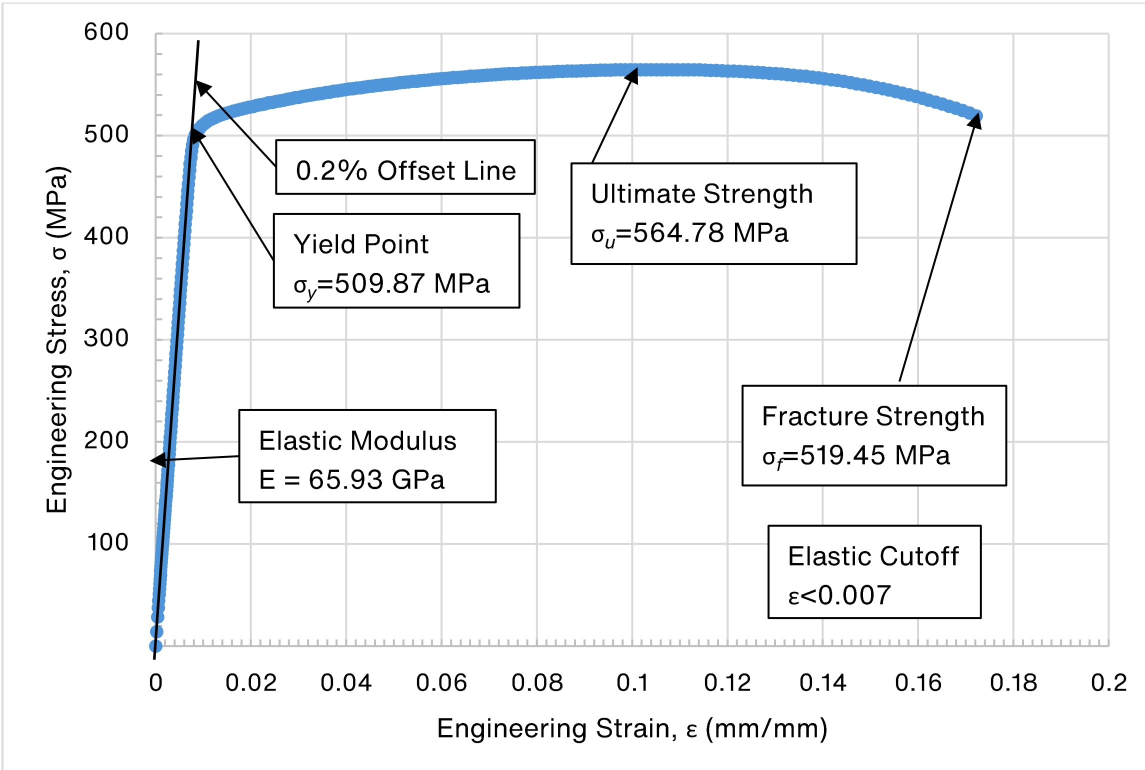

Figure 8: Engineering Stress and Strain Diagram for 7075 Aluminum Alloy (UNS A97075) in Tension

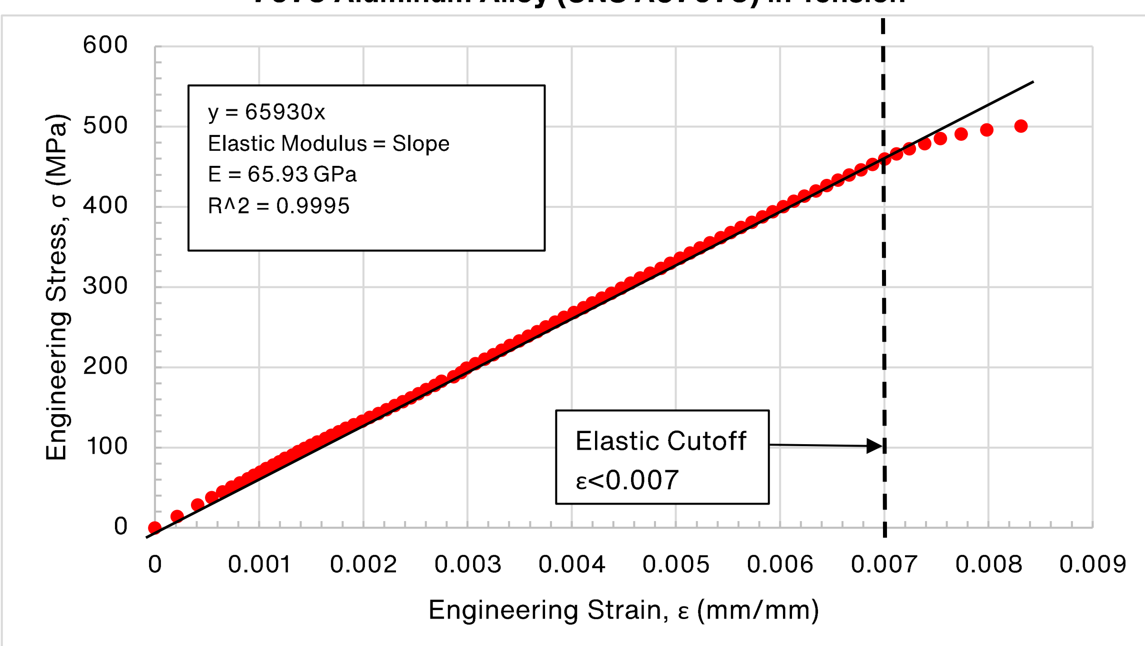

Figure 9: Elastic Region of Engineering Stress and Strain Diagram for 7075 Aluminum Alloy (UNS A97075) in Tension

304 Stainless Steel:

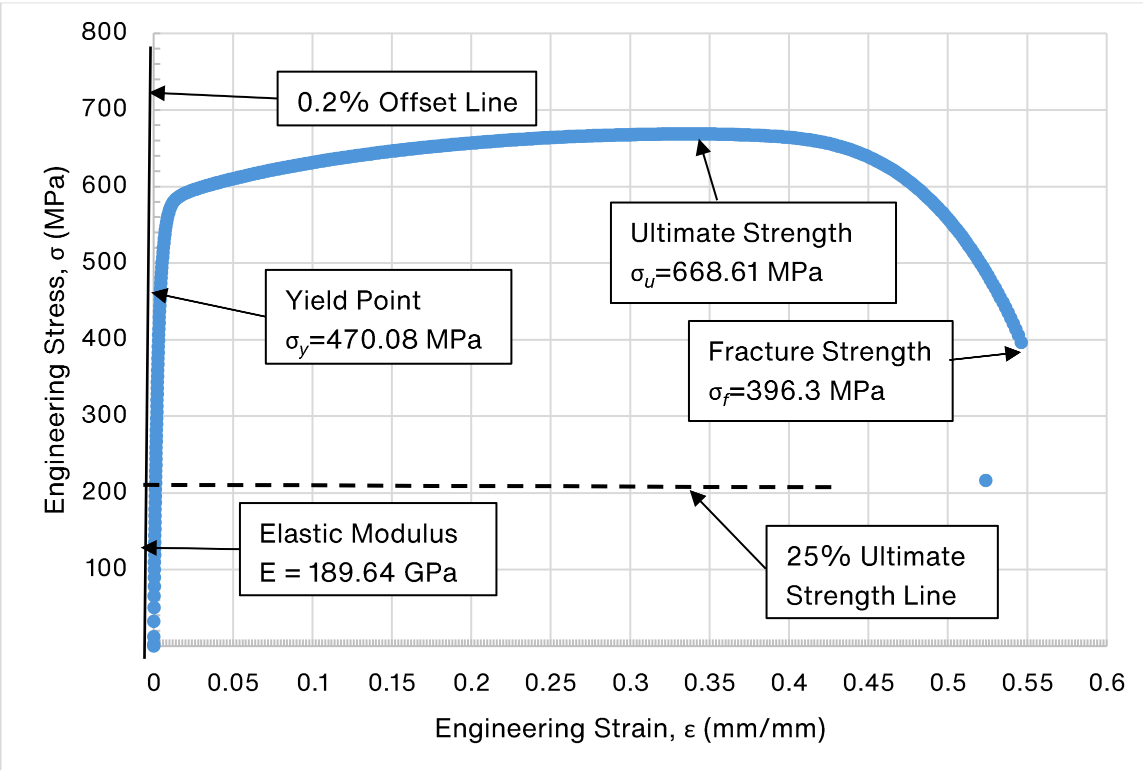

Figure 10: Engineering Stress and Strain Diagram for SAE 304 Stainless Steel (UNS S30400) in Tension

PMMA:

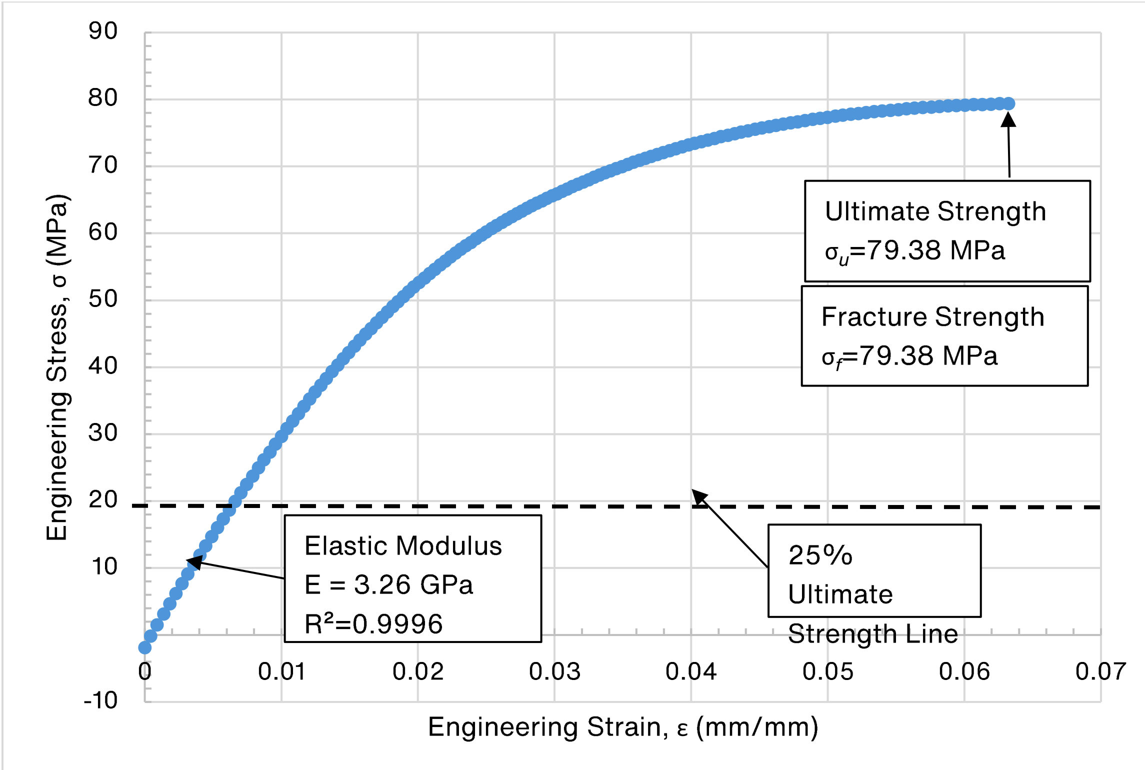

Figure 11: Engineering Stress and Strain Diagram for Poly(methyl-methacrylate) (PMMA) in Tension

Diagram overlay:

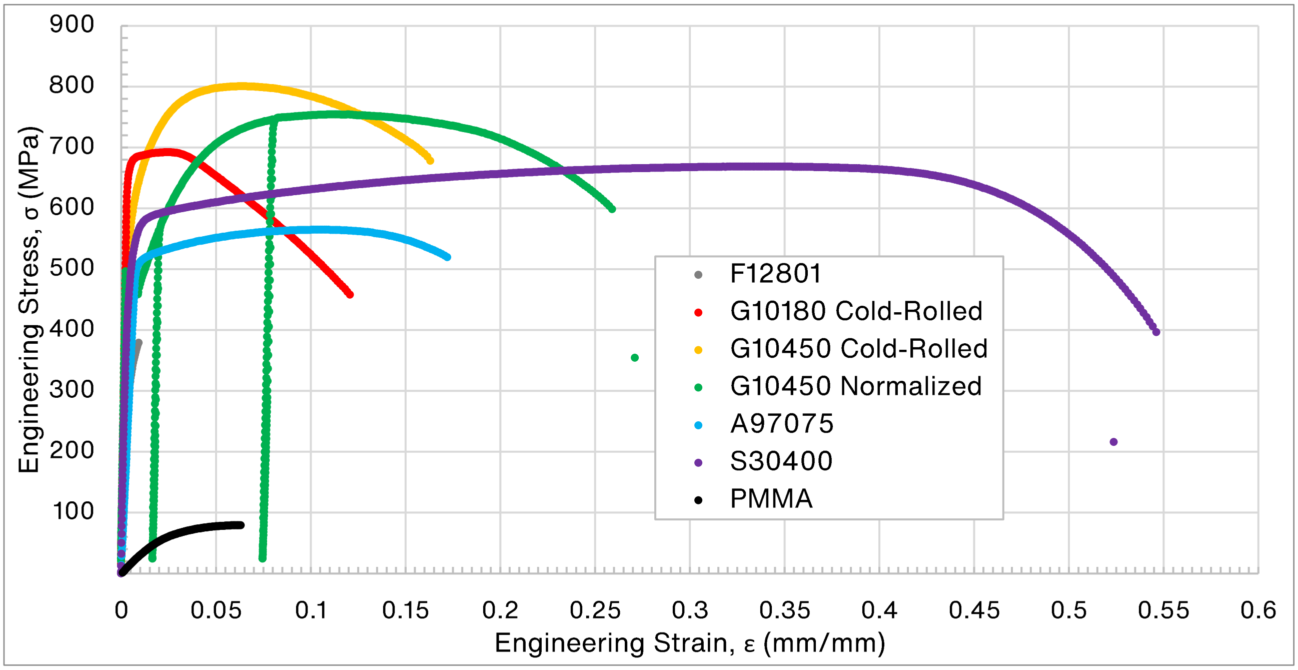

Figure 12: Engineering Stress and Strain for Class 40 Gray Cast Iron (UNS F12801), AISI 1018 Steel (UNS G10180) Cold Rolled, AISI 1045 Steel (UNS G10450) Cold Rolled, AISI 1045 Steel (UNS G10450) Normalized, 7075 Aluminum Alloy (UNS A97075), SAE 304 Stainless Steel (UNS S30400), and Poly(methyl-methacrylate) in Tension Tests

Brief discussion of results and trends:

Q2 (6 pts). Complete Table 1. See instructions below the table.

Table 1—Tensile mechanical properties

Measurement or property			Material						
Quantity	Symbol	Units	Cast iron	1018 Steel	1045 Steel Cold-rolled	1045 Steel Normlz'd	7075 Alum.	304 S. S.	PMMA
Initial data									
Diameter	d_0	mm	7.08	7.12	7.12	7.19	7.13	7.17	8.17
Cross-sectional area	A_0	mm^2	39.41	39.88	39.81	40.60	39.93	40.41	62.09
Strength									
Yield load	P_y	kN	12.07	26.78	22.81	18.56	20.36	19.01	2.62
Max. load	P_{max}	kN	14.92	27.56	32.59	30.62	22.55	27.45	4.03
Shape changes during deformation	—	—	No Change	Necking	Necking	Necking	Necking	Necking	No Change
Description of fracture surface	—	—	Cup & Cone	Cup & Cone	Cup & Cone	Cup & Cone	Cup & Cone	Cup & Cone	Flat
Hardness									
Rockwell hardness	HRB	—	102.3	93.5	93.5	88.6	86.7	101.3	
Ductility									
Gage length	l_0	mm	25.4						
Percent elongation	%EL	—	0.93	0.92		4.64	17.22		8.04
Final diameter	d_f	mm	7.09	5.03	0	5.18	4.99	3.46	8.01
Final area	A_f	mm^2	39.5	19.88	0	21.07	19.56	9.41	50.35

Percent reduction of area	%RA	—	0.28	50.13	50.1	48.1	51.0	76.71	3.88
	Mechanical properties derived from stress–strain diagram								
Young's modulus	E	GPa	140.98	213.4	176.61	207.93	74.58	189.64	2.73
Yield strength	$\square_y$	MPa		569.8	573.07	462.6	489.5	470.08	
Ultimate strength	$\square_u$	MPa	758	692.2	800.44	800.72	519.94	668.61	133.84
Mechanical behavior (description)	—	—	Not Very Ductile	Less ductile	Less ductile	Ductile	Ductile	Very Ductile	Brittle

Instructions for Table 1:

i. From the stress–strain diagrams for each of the materials, compute: (a) the modulus of elasticity E, (b) the yield strength $\square_y$, and (c) the ultimate tensile strength $\square_u$. (Hints: For ductile materials without a clear yield point, the yield strength can be determined using a 0.2% offset strain. For brittle materials that exhibit non-linear stress-strain behavior, E can be determined using a secant line originating at 25% of ultimate stress.) The graphs in Q1 should indicate clearly the methods used to determine values of E, $\square_y$, and $\square_u$ for each material.

ii. Compute the percent reduction of area %RA, and find the percent elongation %EL, for each material, using the definitions

$$\%RA = \frac{A_0 \square A_f}{A_0} \square 100\%, \quad \%EL = \frac{l_f \square l_0}{l_0} \square 100\%.$$

Alternatively, for percent elongation, use the observed strain at failure.

Q3 (3 pt). Compare the yield strengths and the ultimate strengths of all materials tested. Did all the materials yield? Describe any differences in observed yield behavior.

Answer:

Some materials, like the gray cast iron and the PMMA did not have a defined yield point. Because these materials are classified as brittle, the materials did not experience plastic deformation before fracture.

The 304 stainless steel had a very continuous transition between elastic and plastic deformation. In fact, the entire elastic range had negative curvature, making linear approximation difficult. I used the 25% rule for 304 stainless steel.

The cold rolled steels and aluminum also had a more gradual transition between elastic and plastic. For these materials, the 0.2% method was used to determine the yield point.

The only material which had a defined yield point was the 1045 normalized steel.

Q4 (6 pt). For the as-received steel specimen (1045 cold rolled steel) only, superimpose a plot of the "true" stress σ_t vs. "true" strain ε_t <u>up to the point of maximum load</u>, on the same graph for the engineering stress–strain curve*. Be careful to use natural units for strain, and not percent values, when using the true-stress and true-strain formulas.

*True stress σ_t is based on the instantaneous area A. Thus, if it is assumed that plastic deformation occurs homogeneously at constant volume, i.e. $A_0 l_0 = A l$, then

$$\sigma_t = \frac{P}{A} = \frac{P}{A_0}\frac{A_0}{A} = \sigma \frac{l}{l_0} = \sigma(1+\varepsilon) .$$

The true strain ε_t is given by the integral of differential strains based on current length l, namely,

$$\varepsilon_t = \int_{l_0}^{l} \frac{dl}{l} = \ln \frac{l}{l_0} = \ln(1+\varepsilon) .$$

If the strain ε is small, there is little numerical difference between true and engineering values of stress and strain. Note that, once necking begins, the deformation is no longer homogeneous; therefore the stresses and strains become unknown functions of position within the necked region, and it is incorrect to refer to the true stress and the true strain.

<u>Answer:</u>

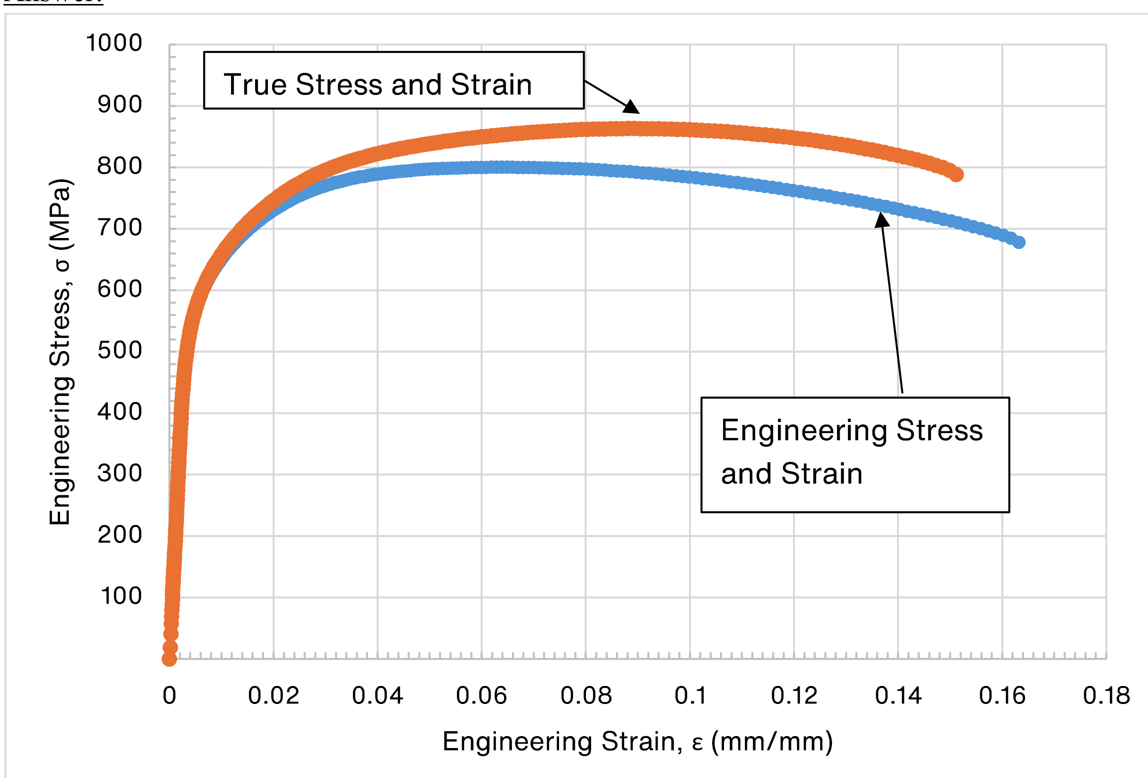

Figure 13: Engineering Stress and True Strain Compared with True Stress and True Strain for AISI 1045 Steel (UNS G10450) with Cold-Rolled Heat Treatment