

MATERIALS BY DESIGN

Elastic Modulus

An important materials property is termed the tensile elastic modulus, or Young's Modulus. This is usually given the symbol **E**. Loosely, the modulus is defined as the force you need to provide to elongate your material.

Measuring The Elastic Modulus

The elastic modulus is measured by pulling a sample of a material in a tensile testing machine, an instrument which measures force.

Let's define **stress**, denoted by the Greek letter σ (sigma), as the force (F) normalized by the cross-sectional area (A) of the material:

$$\sigma = F/A$$

Now attach an extensometer to the sample. The extensometer measures the change in length of the sample as it is being pulled.

Let's define **strain**, denoted by the Greek letter ϵ (epsilon), as the change in length of the fiber normalized by the initial length.

$$\epsilon = (l_1 - l_0) / l_0$$

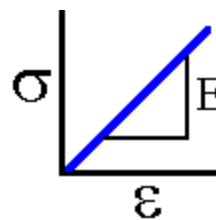
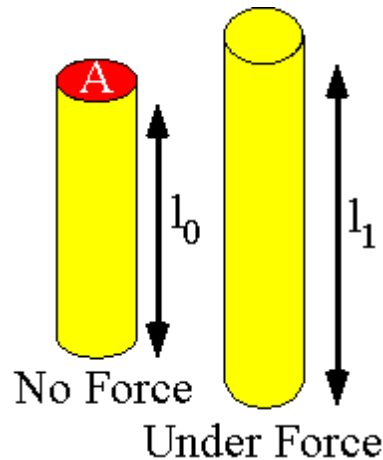
Now, plot stress versus strain. The slope of this line will give you the elastic modulus **E** of the material.

$$\sigma = E\epsilon$$

This technique applies for small forces which do not irreversibly stretch the material. The material is in the **elastic regime**.

Young's Modulus for Typical Materials

Material	Modulus (GPa)
<u>Ceramics, glasses, and semiconductors:</u>	
Diamond (C)	1000
Tungsten Carbide (WC)	450 -650



Silicon Carbide (SiC)	450
Aluminum Oxide (Al ₂ O ₃)	390
Beryllium Oxide (BeO)	380
Magnesium Oxide (MgO)	250
Zirconium Oxide (ZrO)	160 - 241
Mullite (Al ₆ Si ₂ O ₁₃)	145
Silicon (Si)	107
Silica glass (SiO ₂)	94
Soda-lime glass (Na ₂ O - SiO ₂)	69

Metals:

Tungsten (W)	406
Chromium (Cr)	289
Beryllium (Be)	200 - 289
Nickel (Ni)	214
Iron (Fe)	196
Low Alloy Steels	200 - 207
Stainless Steels	190 - 200
Cast Irons	170 - 190
Copper (Cu)	124
Titanium (Ti)	116
Brasses and Bronzes	103 - 124
Aluminum (Al)	69

Polymers:

Polyimides	3 - 5
Polyesters	1 - 5
Nylon	2 - 4
Polystyrene	3 - 3.4
Polyethylene	0.2 - 0.7
Rubbers	0.01 - 0.1

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