Measurement of Young’s modulus using optical-lever method

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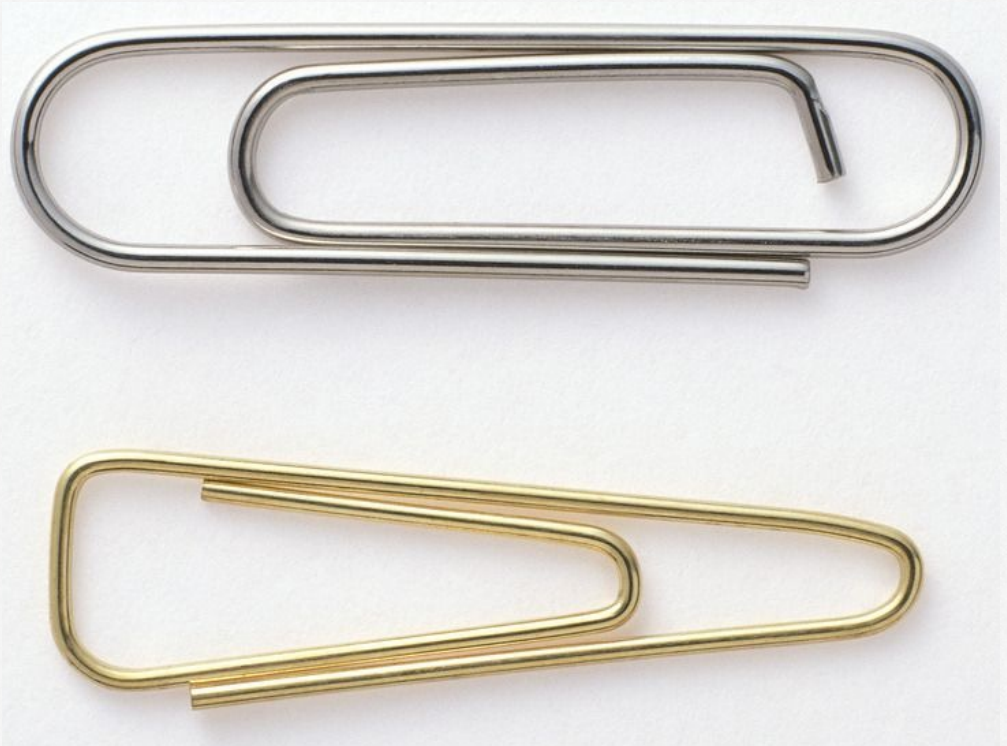
Trial Experiment

Rubber band



Pin

Questions?

How to… this property?

Quantify ?

Name ?

Measure ?

Name?

Young's Modulus

A mechanical property that measures the **stiffness** of a solid material.

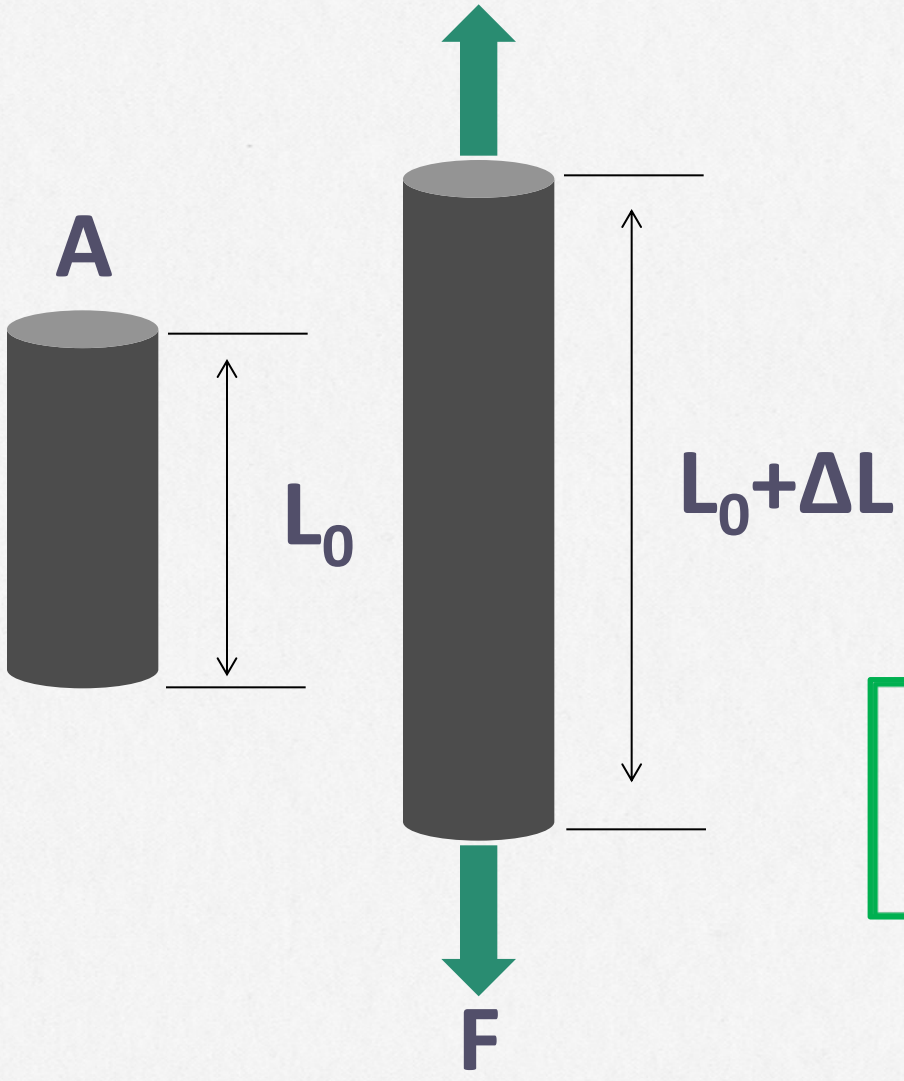
Stiffness

Resistance against deformation in response to an applied force.

Thomas Young

1773-1829
British polymath and physician
"The Last Man Who Knew Everything".
---by Andrew Robinson

Quantify?



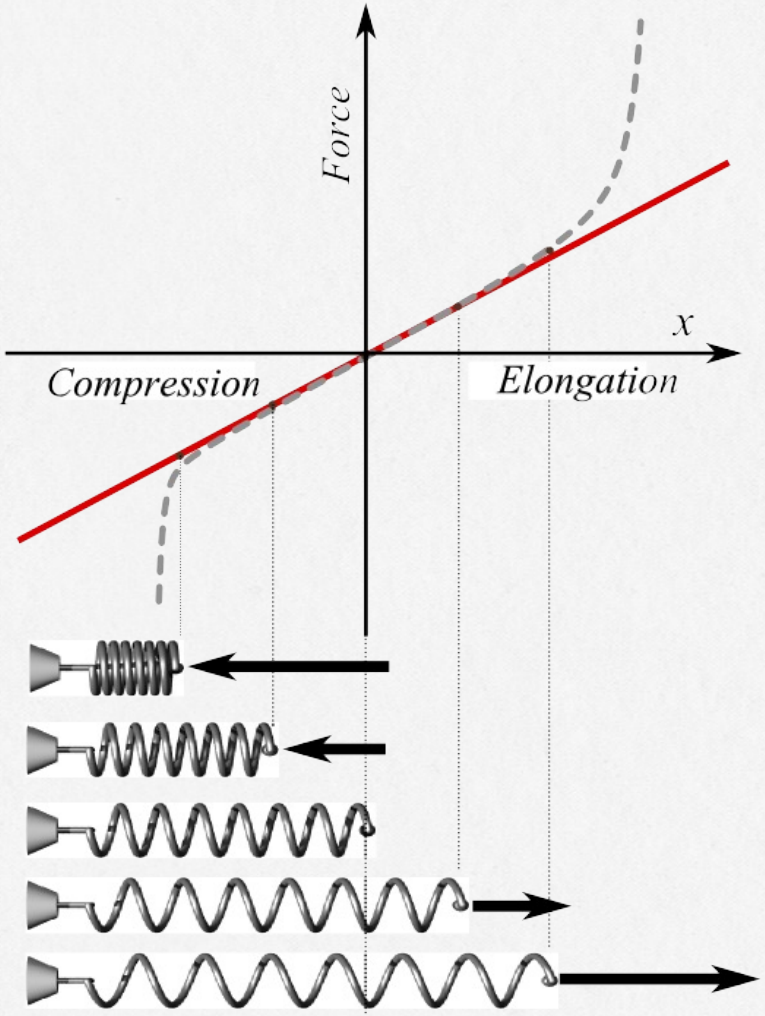
$$\text{Stress } \sigma = \frac{F}{A}$$

$$\text{Strain } \varepsilon = \frac{\Delta L}{L_0}$$

$$\sigma = E\varepsilon$$

$$\Longrightarrow E = \frac{\sigma}{\varepsilon} = \frac{F}{A}\frac{L_0}{\Delta L}$$

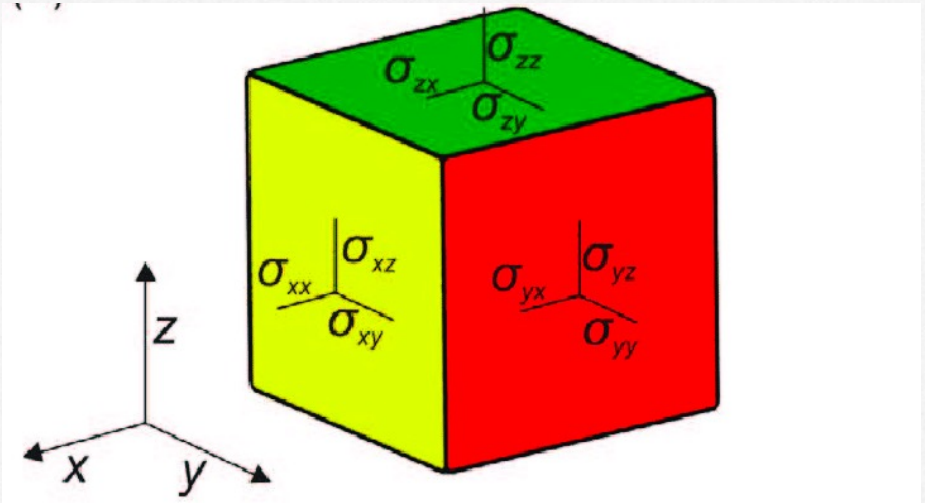
Linear Elasticity



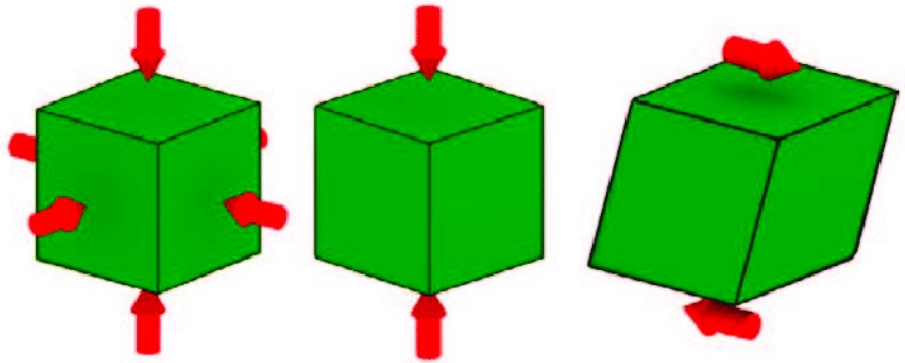
Hooke's law $F = kx$

Quantify?

$$\sigma_{ij} = C_{ijkl}\epsilon_{ij}$$



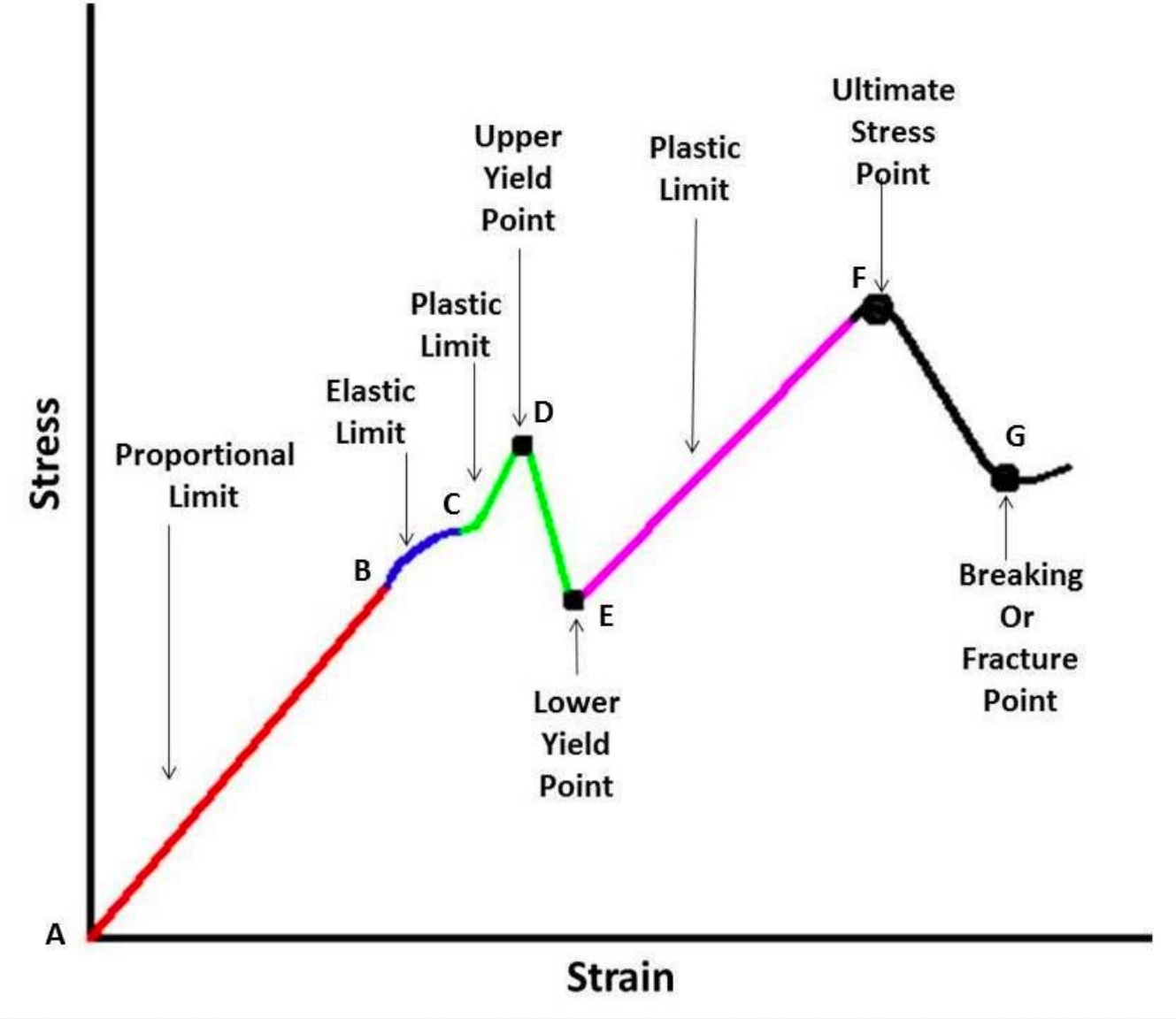
(b)

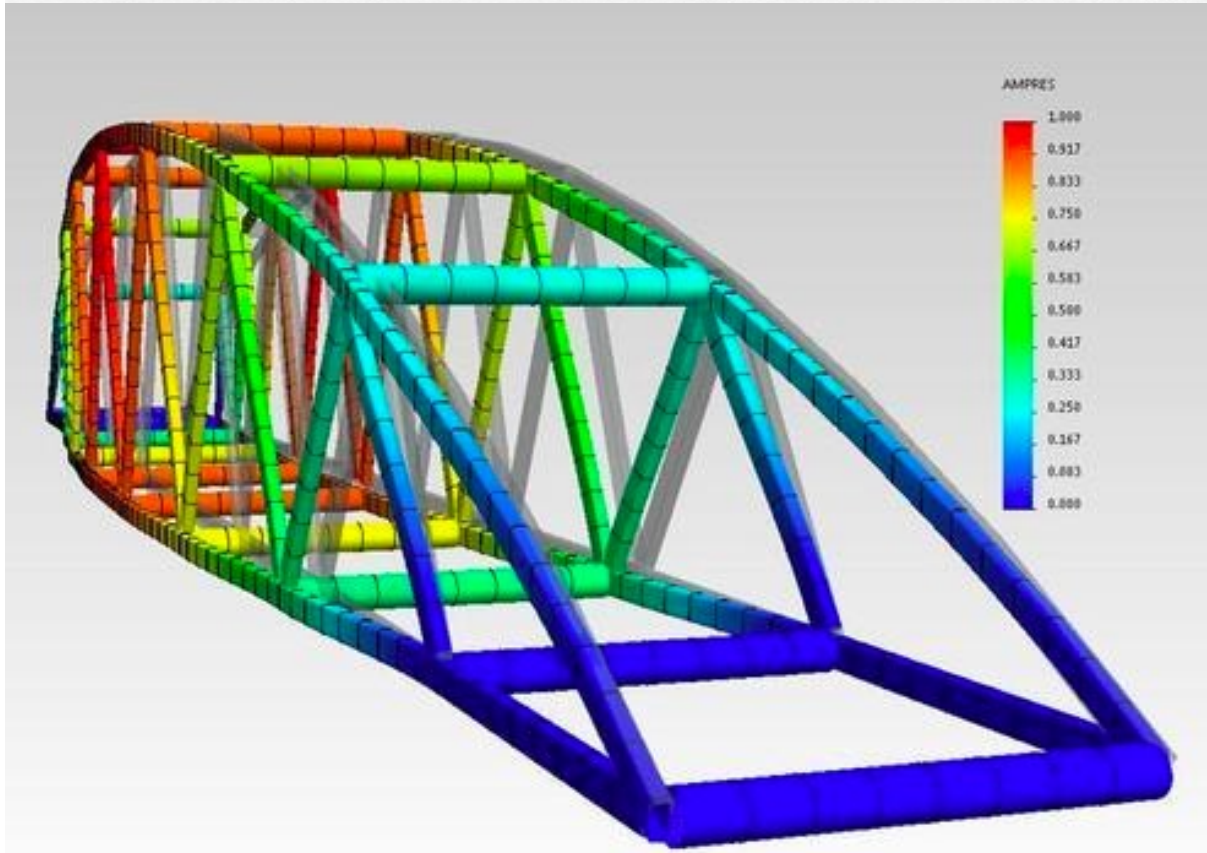


$$[c] = \begin{bmatrix} c_{1111} & c_{1122} & c_{1133} & c_{1123} & c_{1131} & c_{1112} \\ c_{2211} & c_{2222} & c_{2233} & c_{2223} & c_{2231} & c_{2212} \\ c_{3311} & c_{3322} & c_{3333} & c_{3323} & c_{3331} & c_{3312} \\ c_{2311} & c_{2322} & c_{2333} & c_{2323} & c_{2331} & c_{2312} \\ c_{3111} & c_{3122} & c_{3133} & c_{3123} & c_{3131} & c_{3112} \\ c_{1211} & c_{1222} & c_{1233} & c_{1223} & c_{1231} & c_{1212} \end{bmatrix}$$

$$= \begin{bmatrix} C_{11} & C_{12} & C_{13} & C_{14} & C_{15} & C_{16} \\ C_{12} & C_{22} & C_{23} & C_{24} & C_{25} & C_{26} \\ C_{13} & C_{23} & C_{33} & C_{34} & C_{35} & C_{36} \\ C_{14} & C_{24} & C_{34} & C_{44} & C_{45} & C_{46} \\ C_{15} & C_{25} & C_{35} & C_{45} & C_{55} & C_{56} \\ C_{16} & C_{26} & C_{36} & C_{46} & C_{56} & C_{66} \end{bmatrix}$$

Why?


Stress
Strain
A
B
C
D
E
F
G
Proportional Limit
Elastic Limit
Plastic Limit
Upper Yield Point
Lower Yield Point
Plastic Limit
Ultimate Stress Point
Breaking Or Fracture Point


AMPRES
1.000
0.917
0.833
0.750
0.667
0.583
0.500
0.417
0.333
0.250
0.167
0.083
0.000

Measure?

$$E = \frac{F}{A}\frac{L_0}{\Delta L}$$

ΔL is usually very small.

Measure?

$$E = \frac{F}{A}\frac{L_0}{\Delta L}$$

ΔL is usually very small.

$$\theta \approx tan\theta = \frac{\Delta L}{b}$$

$$2\theta \approx tan2\theta = \frac{x}{S}$$

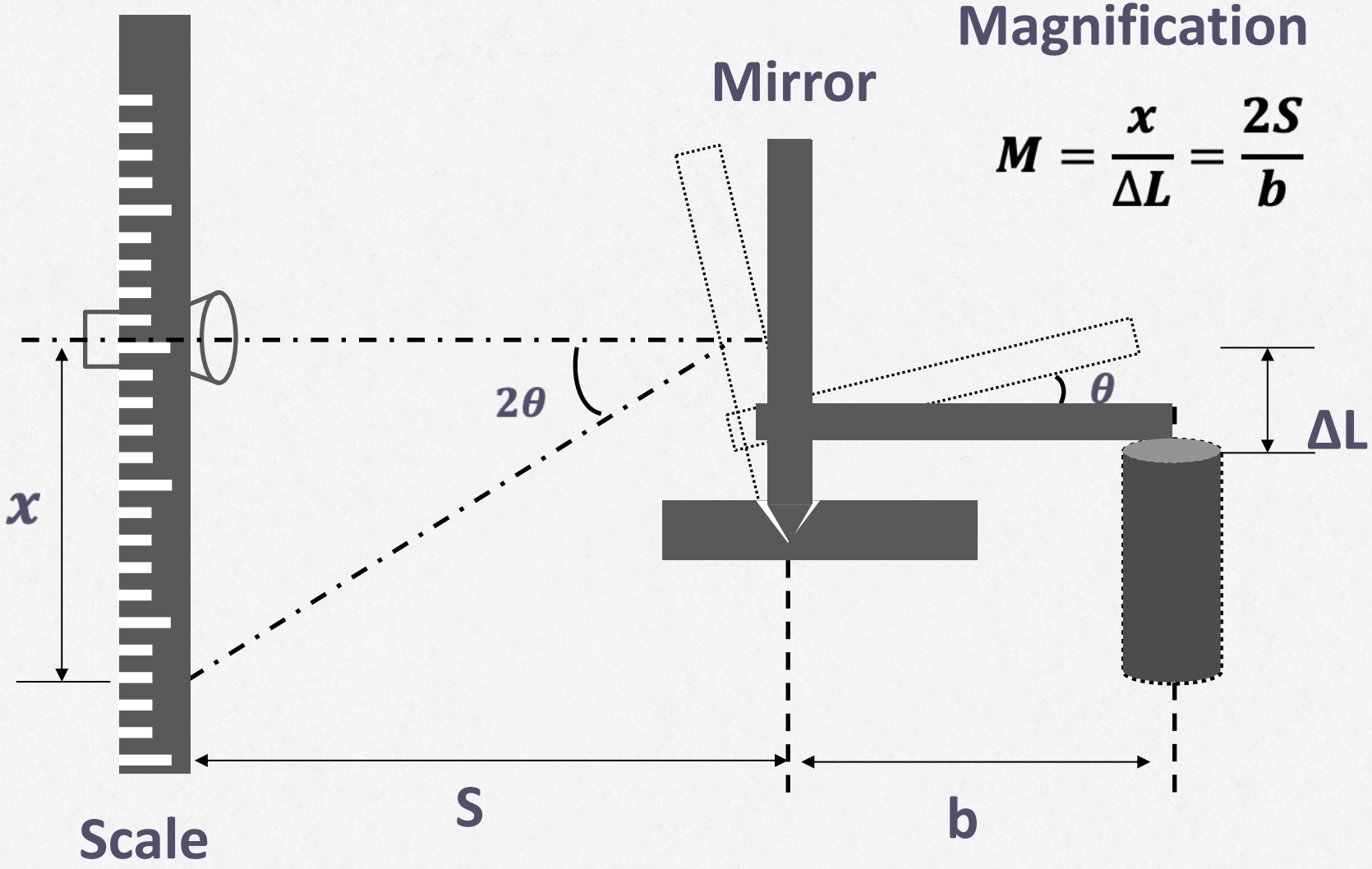
$$\Rightarrow \Delta L = \frac{bx}{2S}$$

$$\Rightarrow E = \frac{F}{A}\frac{2SL_0}{bx}$$

Optical Lever

Magnification

$$M = \frac{x}{\Delta L} = \frac{2S}{b}$$



Set-up

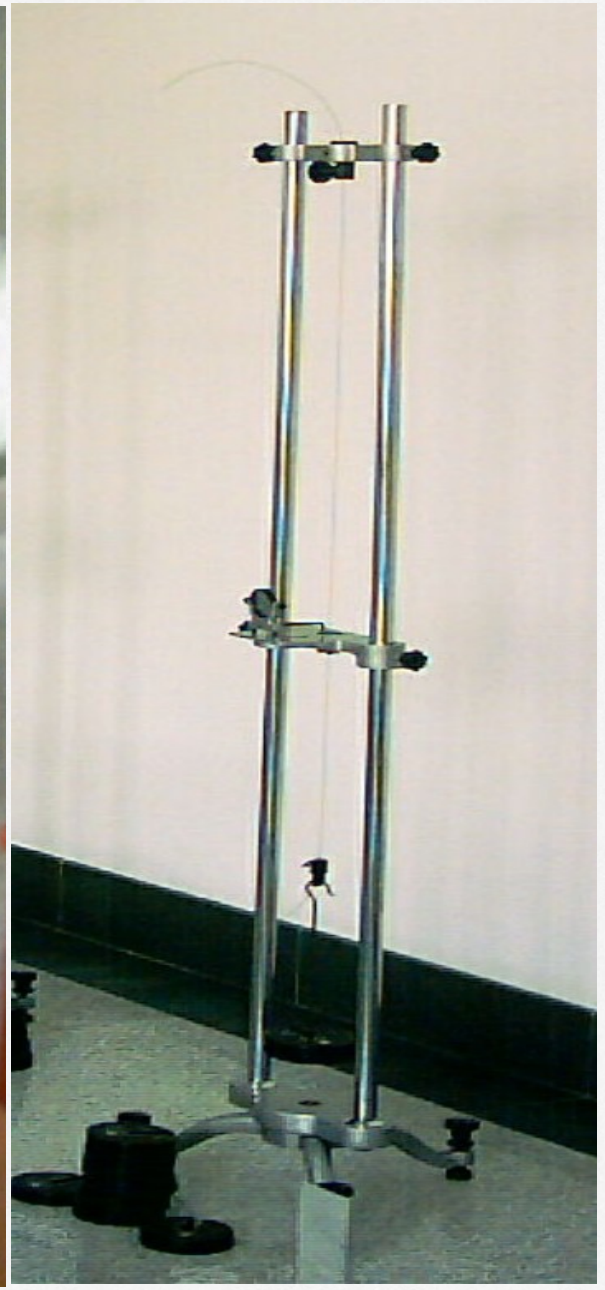
$$E = \frac{F}{A}\frac{2SL_0}{bx}$$

$$F = mg$$

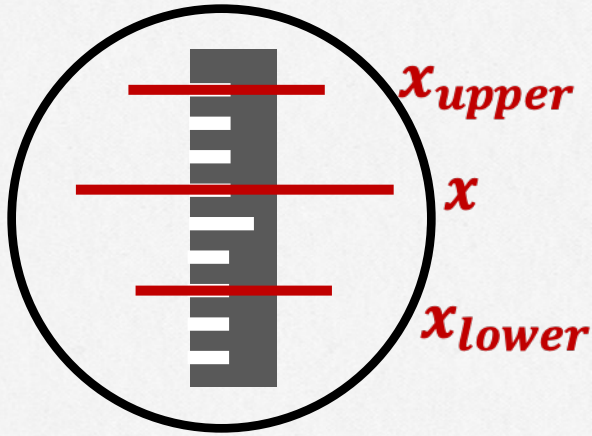
$$A = \pi d^2/4$$

$$E = \frac{8mg}{\pi d^2}\frac{SL_0}{bx}$$

$$S = \frac{|x_{upper} - x_{lower}|}{2} \times 100$$



$E_0 = 2.01 \times 10^{11}$ Pa



Measurement of Young's modulus using optical-lever method

Time for fun!

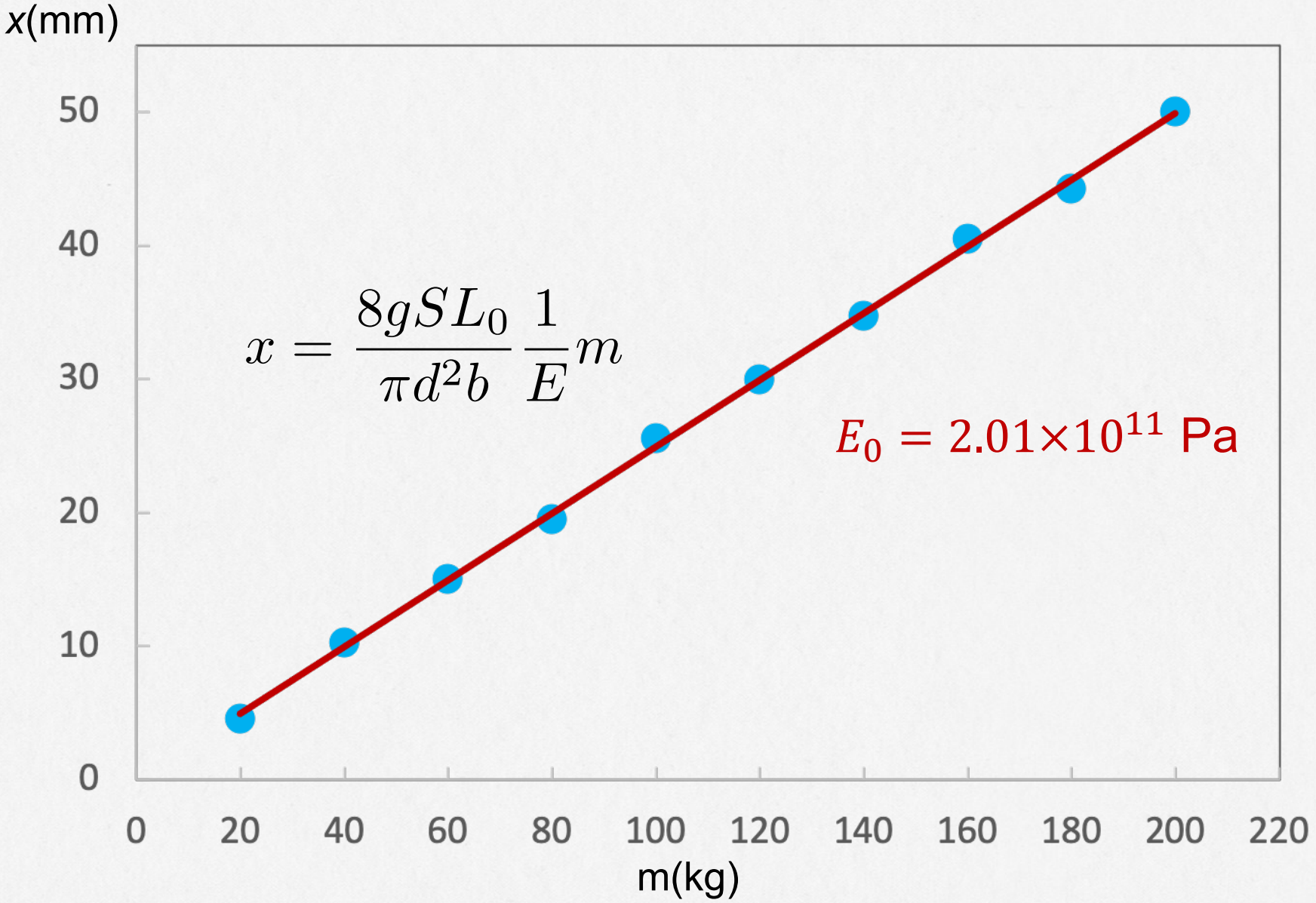
$$E = \frac{8mg}{\pi d^2}\frac{SL_0}{bx}$$

Appendix Table I: Experimental Raw Data

Basic parameters	d (mm)	L_0 (mm)	b (mm)	x_{upper} (mm)	x_{lower} (mm)
Young's Modulus	Load (kg)	x_1 (mm)	x_2 (mm)	x_3 (mm)	Mean x (mm)

Measurement of Young's modulus using optical-lever method

Data Analysis



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THANK YOU！