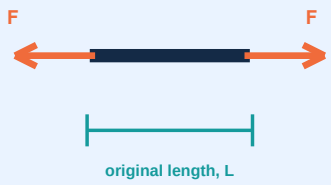
PEARSON EDEXCEL IAL PHYSICS | UNIT 1

LESSON 1.2.3

Stress, Strain and Young Modulus

Stress measures load per area. Strain measures fractional deformation. Young modulus links them in the linear elastic region.

TENSILE LOADING



extension = ΔL

THE THREE DEFINITIONS

STRESS

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

unit: Pa

STRAIN

$$\varepsilon = \frac{\Delta L}{L}$$

no unit

YOUNG MODULUS

$$E = \frac{\sigma}{\varepsilon}$$

unit: Pa

WHAT EACH QUANTITY NORMALISES

STRESS COMPARES LOAD WITH AREA

The same force produces greater stress when applied over a smaller cross-sectional area.

STRAIN COMPARES CHANGE WITH ORIGINAL LENGTH

The same extension represents less strain for a longer original sample.

OBJECT PROPERTY VS MATERIAL PROPERTY

Stiffness k depends on material and dimensions. Young modulus E describes the material itself, so samples of different shapes can be compared fairly.

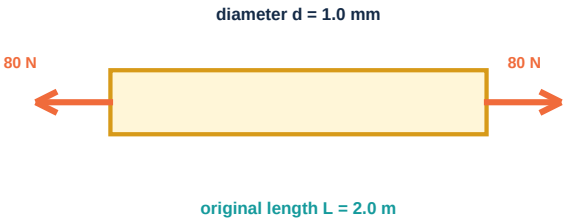
CORE HABIT

Convert every length and area to SI units before substituting. Squaring a diameter conversion is a common source of large errors.

1 A complete Young modulus calculation

Find cross-sectional area, then stress and strain, before dividing stress by strain. Keep every conversion visible.

STEEL WIRE DATA



GIVEN

$F = 80\ N$

$d = 1.0 \times 10^{-3}\ m$

$L = 2.0\ m,\ \Delta L = 1.0 \times 10^{-3}\ m$

CALCULATE IN THREE STEPS

1 AREA

$A = \pi d^2 / 4$

$= 7.85 \times 10^{-7}\ m^2$

2 STRESS

$\sigma = F / A$

$= 1.02 \times 10^{8}\ Pa$

3 STRAIN

$\varepsilon = \Delta L / L$

$= 5.0 \times 10^{-4}$

FINAL STEP

$$E = \frac{\sigma}{\varepsilon} = 2.04 \times 10^{11}\ Pa$$

A large E means a stiff material: more stress is needed for the same strain.

AREA TRAP

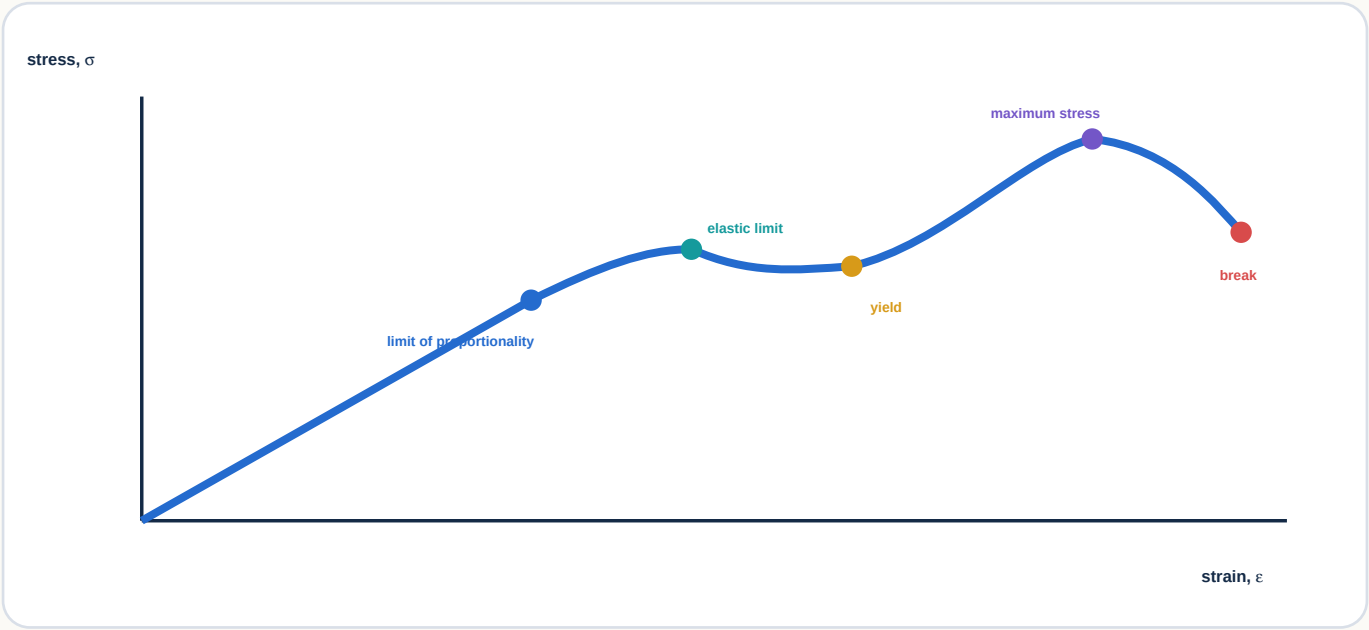
Use radius in $A = \pi r^2$ or diameter in $A = \pi d^2/4$. Convert millimetres to metres before squaring.

2

Stress-strain graphs and Young modulus

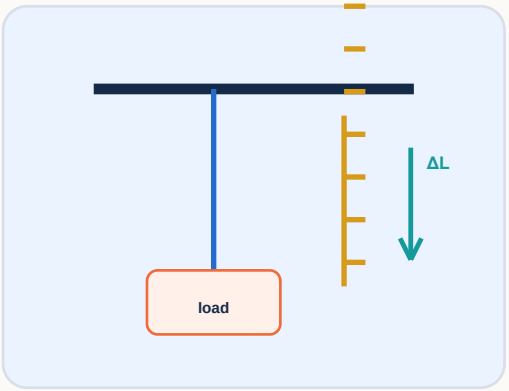
The initial gradient is Young modulus. Later regions show yielding, plastic deformation, maximum stress and breaking.

A DUCTILE MATERIAL



initial gradient of stress against strain = Young modulus, E

CORE PRACTICAL: DETERMINE YOUNG MODULUS



1. Measure diameter at several positions with a micrometer; calculate mean area.
2. Measure original length L and extension x for a series of loads F.
3. Stay within the proportional region and plot F against extension x.
4. Use E = (L/A) × gradient of the F against x graph.

EXPERIMENT QUALITY

DIAMETER

Small uncertainty is squared when area is calculated.

EXTENSION

Use a fixed pointer and read the scale at eye level.

STRAIGHT LINE

Use a best-fit gradient only in the proportional region.