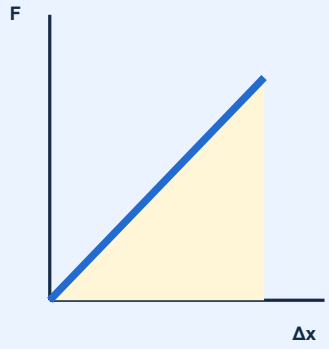
PEARSON EDEXCEL IAL PHYSICS | UNIT 1

LESSON 1.2.4

Elastic Strain Energy and Material Behaviour

Work done deforming a sample is transferred into elastic strain energy. On a force-extension graph, that energy is the area under the curve.

ENERGY UNDER THE GRAPH



area = elastic strain energy

THE CORE RELATIONSHIPS

ANY FORCE-EXTENSION CURVE

W = area under graph

unit: J

LINEAR LOADING

$E_{el} = 1/2\ F\ \Delta x$

triangle area

HOOKE'S LAW FORM

$E_{el} = 1/2\ k(\Delta x)^2$

when F = kx

FOLLOW THE ENERGY

1 EXTERNAL WORK

A force moves through an extension.

2 ENERGY STORED

The deformed sample stores strain energy.

3 ENERGY RETURNED

Elastic unloading can transfer it back.

GRAPH RULE

Gradient gives stiffness k. Area gives stored energy. These are different graph operations, so always check what the question asks for.

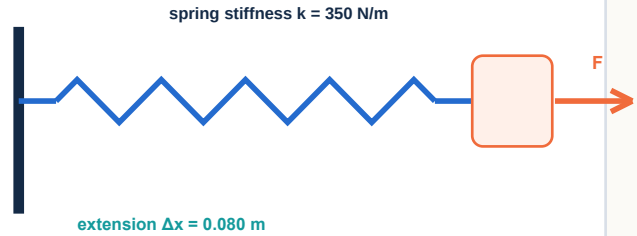
VALIDITY CHECK

Use the triangle formula only when the force-extension graph is a straight line from the origin. For a curved graph, estimate the whole area beneath it.

1 A complete elastic energy calculation

For a Hookean spring, find the final force first. Then calculate the triangular area under the force-extension graph.

SPRING DATA



GIVEN

$k = 350\ N\ m^{-1}$

$\Delta x = 0.080\ m$

The spring obeys Hooke's law.

CALCULATE IN THREE STEPS

1 FINAL FORCE

$F = k\Delta x$

$= 350 \times 0.080 = 28\ N$

2 TRIANGLE AREA

$E_{el} = 1/2\ F\Delta x$

$= 1/2 \times 28 \times 0.080$

3 ENERGY STORED

$E_{el} = 1.12\ J$

$= 1.1\ J$ to 2 s.f.

THE SAME RESULT FROM k

$$E_{el} = 1/2\ k(\Delta x)^2 = 1/2 \times 350 \times (0.080)^2 = 1.12\ J$$

Both methods calculate the same triangular area under the graph.

WHAT CHANGES THE ENERGY?

DOUBLE THE EXTENSION

Energy becomes four times larger because Eel is proportional to extension squared.

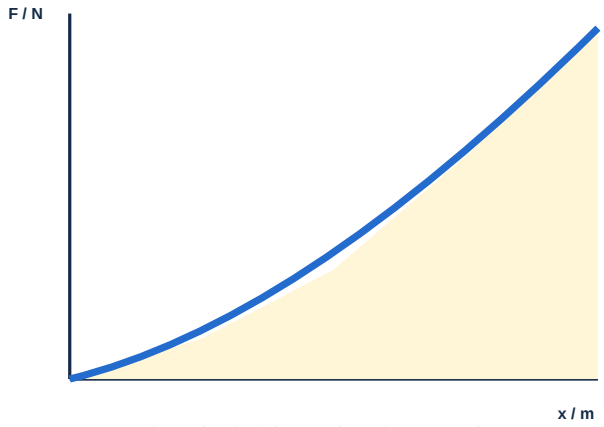
DOUBLE THE STIFFNESS

At the same extension, energy doubles because Eel is proportional to k.

2 Curved graphs and material behaviour

For non-linear loading, divide the area into simple shapes. Loading and unloading paths reveal energy recovery and dissipation.

ESTIMATING A NON-LINEAR AREA



estimate the shaded area using strips or trapezia

MEASURED VALUES

x / cm	0	1	2	3	4
F / N	0	3	8	15	24

TRAPEZIA

$\Delta E = 1/2\ (F_1 + F_2)\Delta x$

Convert each 1 cm interval to 0.010 m.

$E_{el} \approx 0.015 + 0.055 + 0.115 + 0.195 = 0.380\ J$

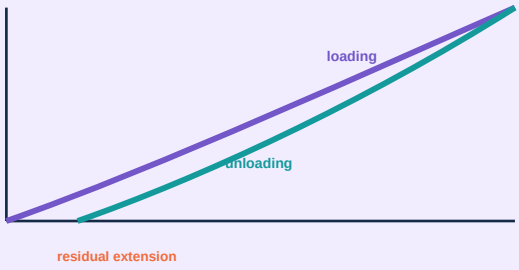
READING MATERIAL BEHAVIOUR

ELASTIC RETURN



If unloading retraces the loading path, the stored energy is returned and the sample regains its original length.

ENERGY DISSIPATION



EXAM CHECK

State whether the graph is linear before choosing a formula. Show SI conversions and label an estimated area with the unit joule.