AQA, Edexcel, OCR

A Level

A Level Physics

MECHANICS: Solid Mechanics

(Answers)

Name:

Mathsmadeeasy.co.uk

Total Marks: /30

1. Figure 1 shows three plots of force, F, against extension, x. Measurements were taken during loading and unloading.

Total for Question 1: 15

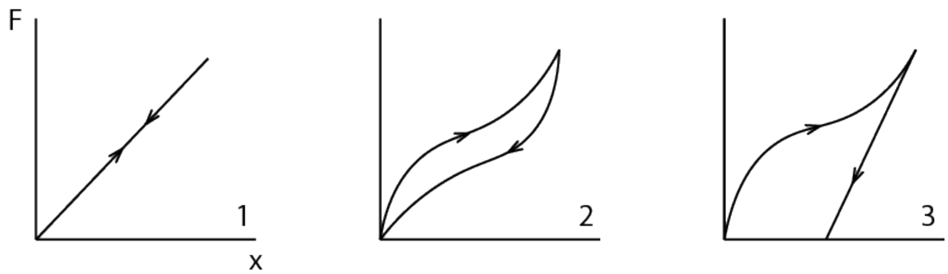

Figure 1: Plot of stress against strain for a typical metal. Elastic and plastic regions of deformation are indicated by the dashed line. Circles represent key points of the curve.

(a) These plots are associated with a shopping bag, a piece of wire and an elastic band. Assign a material to each graph. [3]

Solution:
Left: wire
Middle: rubber band
Right: bag

(b) What is represented by the area underneath a graph of force against extension? [1]

Solution: Work done/energy stored.

(c) The Hookean material deforms according to the equation $F = -kx$ (Hooke's Law). Show that the elastic strain energy stored when it is stretched is $\frac{1}{2}kx^2$. [2]

Solution:
Work done stretching a spring = average force × displacement = $\frac{1}{2}Fx = \frac{1}{2}(-kx)x = -\frac{1}{2}kx^2$
Energy stored is that which can be recovered by undoing this work i.e. $\frac{1}{2}kx^2$

A cylindrical, Hookean wire has a diameter of 3 mm, a length of 1 m and a mass of 64 g when it is not being loaded. An applied force of 10 N is required to induce an extension of 2 cm.

(d) What is the density of the wire? [2]

> **Solution:** 9054 kgm^{-3}

(e) When extended by 10 cm what is the elastic strain energy stored in the wire? [3]

> **Solution:** 2.5 joules

(f) If the wire were coiled to form a spring, and this was used to suspend a mass, describe how energy would be transferred between kinetic, gravitational potential and elastic strain forms when the mass moves up and down. [4]

Solution:
Total energy is always conserved.
At the top of its range, kinetic energy and elastic strain energy are zero; all energy is GPE. As the mass falls, its initial GPE is transferred to elastic strain energy and kinetic energy. Kinetic energy is at a maximum half way through the fall. At the bottom, GPE is zero, kinetic is zero; all energy is elastic strain.

2. Figure 2 is a typical stress strain graph for a metal.

Total for Question 2: 15

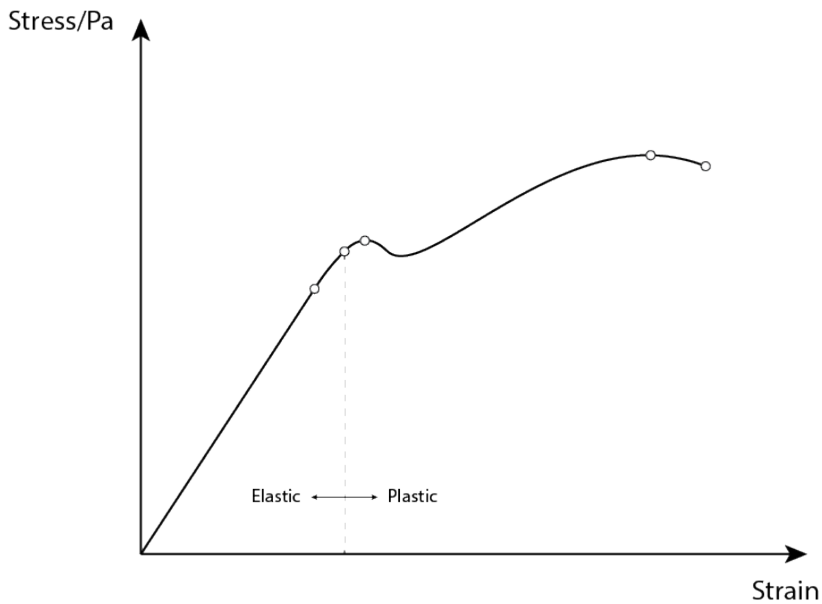

Figure 2: Plot of stress against strain for a typical metal. Elastic and plastic regions of deformation are indicated by the dashed line. Circles represent key points of the curve.

(a) Define tensile stress and tensile strain. [2]

> **Solution:**
> Tensile stress: applied force per unit cross-sectional area, $\sigma = F/A$
> Tensile strain: extension per unit of original length, $\epsilon = \Delta l/l_0$

(b) What are meant by the terms elastic and plastic deformation? [2]

> **Solution:** Elastic deformation: deformation after which the material returns to its original dimensions.
> Plastic deformation: deformation after which the material does not return to its original dimensions i.e. deformation is permanent.

(c) Label each circle on the plot above with **one** of the following terms: *ultimate tensile stress, elastic strain energy, limit of proportionality, breaking stress, Young's modulus, elastic limit, yield stress.* Note that not all terms need be used. [5]

> **Solution:** From L to R:
> limit of prop., elastic limit, yield stress, ultimate tensile stress, breaking stress.

Ahmed wants to know the Young's modulus ($E = \sigma/\epsilon$) of copper. He generates a graph like that above using a piece of copper wire whose original length and diameter were 1 m and 1 mm, respectively. The Young's modulus he calculates is 10×10^{10} Pa.

(d) Outline a simple method Ahmed could have used, detailing the apparatus used, the measurements taken and the the way in which the data is analysed. [3]

> **Solution:**
> Experimental setup: clamp holds one end of wire; a marker is attached to the wire at an appropriate point (the distance between the clamp and marker is the original length); a ruler is fixed to the surface as a reference with zero at the marker; the other end of the wire is then weighted using a known mass; extension measured using the marker; repeat final two steps for incrementally greater weights.
> Measurements: extension, x, for incrementally increasing loads, F, original length, l_0, original wire diameter, d.
> Plot of stress ($4F/\pi d^2$) against strain (l/l_0). Gradient is E.

(e) The limit of proportionality was plotted when the extension measured 1 cm. Assuming that the line goes through (0,0) and is linear between there and this point, calculate the applied force when this measurement was taken. [3]

> **Solution:** 250π N