

**AQA, Edexcel, OCR**

**A Level**

# **A Level Physics**

**MECHANICS: Solid Mechanics  
(Answers)**

Name:



[Mathsmadeeasy.co.uk](http://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

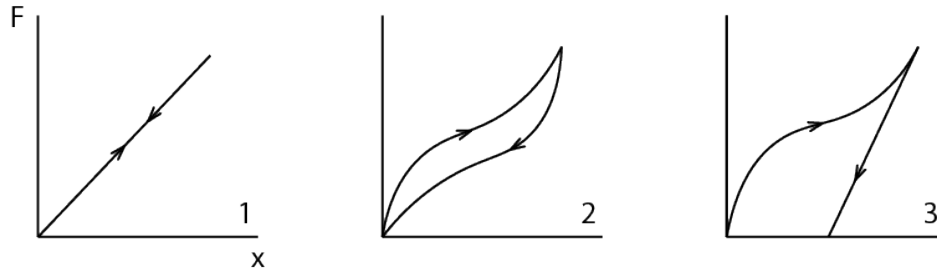


Figure 1: Plot of stress against strain for a typical metal. Elastic and plastic regions of deformation are indicated by the dashed line. Circles represent key points of the curve.

- (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  $\times$  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.  $\frac{1}{2}kx^2$



**MEGA LECTURE**

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:**  $9054 \text{ kgm}^{-3}$

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

[3]

**Solution:** 2.5 joules

[www.megalecture.com](http://www.megalecture.com)

- (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

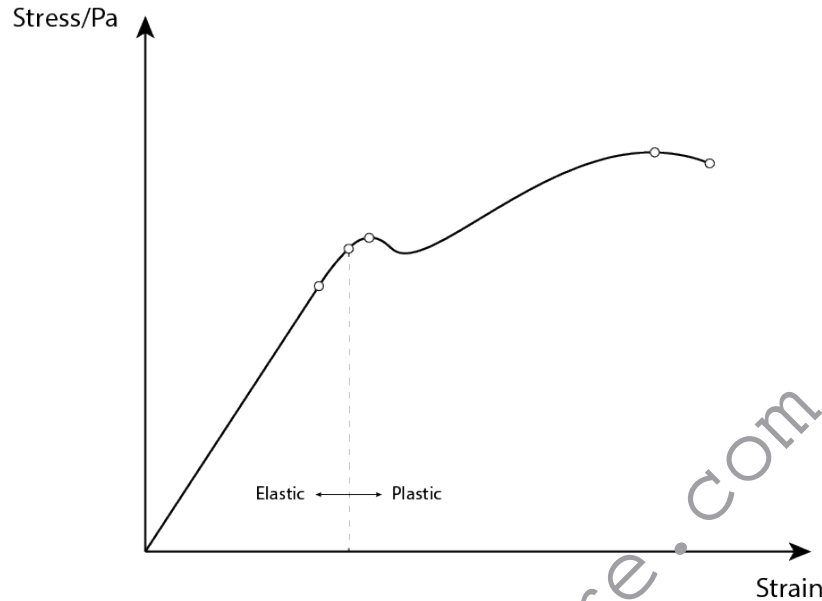


Figure 2: Plot of stress against strain for a typical metal. Elastic and plastic regions of deformation are indicated by the dashed line. Circles represent key points of the curve.

(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  $10 \times 10^{10}$  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:**  $250\pi$  N