1.3.4 Behaviour of Springs and Materials

AS Physics at Beechen Cliff

Introduction

The modern world around you works because we understand how various materials behave under different conditions. This allows us to design machinery; vehicles; in fact everything that we now take for granted. By testing materials we can investigate their properties and use them to our advantage.

By carrying our various experiments and completing the tasks in this booklet you will investigate some of these material properties.

Learning Objectives

- ✓ **State** the unit of density.
- ✓ Use measurements to **calculate** the density of regular and irregular shaped solids.
- ✓ **Describe** the relationship between force and extension for a spring obeying Hooke's Law.
- ✓ **Compare** the extension of combinations of springs in series and parallel.
- ✓ **Select** and **apply** the equation $F = kx$ where k is the force constant of the spring or the wire.
- ✓ **Determine** the area under a force against extension (or compression) graph to find the work done by the force.
- ✓ **Derive** and **use** the equations for elastic potential energy stored in a spring.
- ✓ **Describe** how deformation is caused by a force in one dimension and can be tensile or compressive
- ✓ **Define** and use the terms:
    - Elastic limit
    - *Stress*
    - *Strain*
    - *Young's Modulus*
    - *Ultimate Tensile Strength* (*breaking stress*).
- ✓ Carry out an experiment to determine the Young modulus of a metal in the form of a wire.
- ✓ **Define** the terms *elastic deformation* and *plastic deformation* of a material.
- ✓ **Recognise** the shapes of the stress against strain graphs for typical ductile, brittle and polymeric materials.

Task 1

Describe, in detail, how you would find the density of a small metal cube and a glass marble.

State any equations you would need to use along with units.

Task 2

Complete **Practical 1.3.4 – 1** to calculate the density of the regular and irregular objects.

Record all measurement to an appropriate number of significant figures.

Task 3

You are to investigate the behaviour of a spring that obeys Hooke's Law. Follow the instructions for **Practical 1.3.4 – 2.** You are to investigate the behaviour of a spring that obeys Hooke's Law.

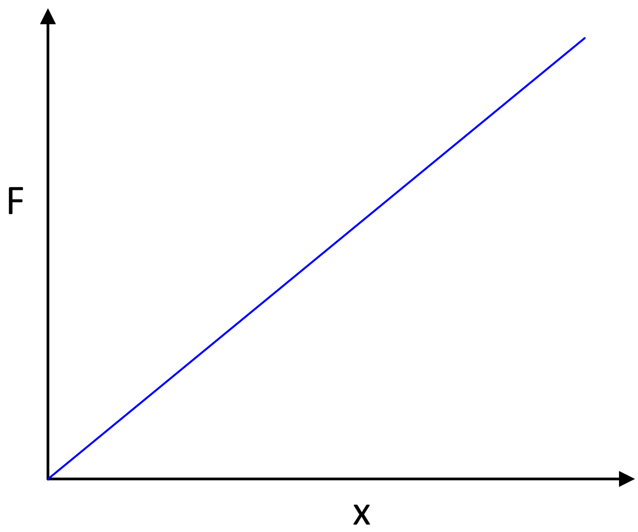
Once you have recorded your results you are to plot a graph and calculate the gradient.

Force / N	Length / m	Extension / m
0		0

The gradient is called the Spring Constant, k. Spring Constant = ________ Nm^{-1}

Task 4

On the following graph predict the results you would record for two of the same springs connected in parallel and also in series.



Justify why you made this prediction.

Task 5

Complete **Practical 1.3.4-3** and plot a graph of your results.

Comment on your results and relate these to your predictions. Explain any observations.

Task 6

If the energy stored in a spring is equal to the area under the line on a Force-Extension graph, derive the two equations for elastic potential energy stored by a spring.

E_p =

E_p =

Task 7

Explain the difference between a tensile and compressive force.

Task 8

SAFETY GLASSES MUST BE WORN DUE TO THE DANGER OF BREAKING WIRE

Set up the apparatus for **Practical 1.3.4 – 4**. Write up your experiment with a diagram and description of your method you used to obtain accurate results.

Task 9

From the graph that you have drawn, obtain a value for the Young's Modulus of Copper and state its unit.

Task 10

Draw a stress-strain curve for mild steel and mark on the elastic limit and the ultimate tensile strength.

Task 11

Write out the equations for Stress, Strain and Young's Modulus with appropriate units.

$\sigma =$

$\varepsilon =$

$E =$

Task 12

Draw a diagram of how a Vernier scale can be used to give a more precise value of E.

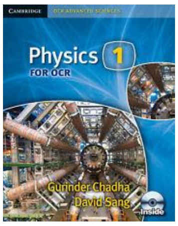
Task 13

Investigate the extension of a rubber band with **Practical 1.3.4 – 5**. Plot a graph showing how materials like rubber behave when loaded and unloaded.

Task 14

Go to www.memrise.com and search for the course 'BCS Behaviour of Springs'.

Further Learning



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Khan Academy Springs and Hooke's Law

- Intro to springs and Hooke's Law
- Potential energy stored in a spring
- Spring potential energy example

Your Extra Notes

Please use this space to add any further notes you may find useful.

Questions

All questions must be answered with a diagram, equations used, full working and the answer given to an appropriate number of significant figures with units.

1. A brick has mass of 3.0kg and dimensions 25 x 10 x 8cm. Calculate:
    a. Its volume
    b. Its density in kgm^{-3}
    c. Is your value for the density likely to be too high or low? State your reasons.

2. A steel spring is extended by 25cm using a weight of 15N. Calculate the spring constant.

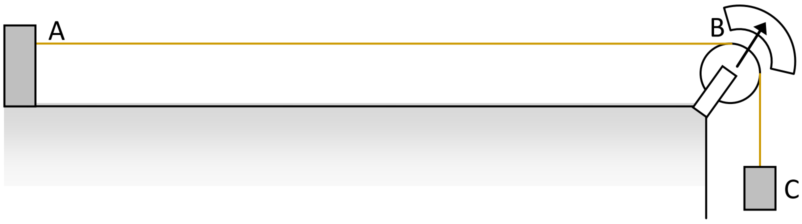
3. A mass of 11kg is suspended from a ceiling by a 2m aluminium wire of diameter 2mm. Calculate:
    a. The extension produced
    b. The elastic energy stored in the wire
    $E_{Al} = 7 \times 10^{10}$ Pa

4. The maximum upward acceleration of a lift of total mass 2500 kg is 0.5 ms^{-2}. The lift is supported by a steel cable which has a maximum safe working stress of 1.0×10^{8} Pa. What is the minimum cross sectional area of the cable that should be used?

5. For an elastic wire under tension, under certain conditions, there is a relationship between the *applied stress* and the *strain produced*. Explain the meaning of the terms in italics, their relationship and the conditions that must be fulfilled.

6. A 1mm wide nylon guitar string is 62.8 cm long and is tuned by stretching it 2.0cm. Calculate:
    a. The tension
    b. The elastic energy stored in the spring
    $E_{nylon} = 2 \times 10^{9}$ Pa

7. The diagram shows the apparatus used to measure the extension in a thin wire. A copper wire (A = $1mm^2$) is clamped at A and passes over a pulley or radius 6mm. This carries a pointer that points to a scale graduated in radians. Distance AB is 2.00m. Loads are attached to the free end, C.



Load / kg	0	1	2	3	4	5	6	7	8
Scale reading θ in rad	0.00	0.027	0.053	0.080	0.107	0.138	0.176	0.242	0.434

    a. For each load work out the tension in the wire in N, the extension in the wire in mm (given by rθ). Plot a graph of tension (y-axis) vs extension (x-axis)
    b. Describe the shape of this graph. State what you would expect to see if the wire was unloaded 1kg at a time.
    c. Calculate the value of Young's Modulus for Copper.

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