A Level Mechanics
Practice Test 1: Springs and Elasticity

Instructions:
Answer all questions. Show your working clearly.
Calculators may be used unless stated otherwise.
Draw clear diagrams where appropriate.
Time allowed: 1 hour 45 minutes

Section A: Hooke's Law and Spring Behaviour [35 marks]

Question 1 [**8 marks**]

(a) State Hooke's Law in words. [**2 marks**]

(b) Write the mathematical expression for Hooke's Law, defining all symbols used. [**2 marks**]

(c) Define the spring constant and state its SI unit. [**2 marks**]

(d) Explain what is meant by the elastic limit of a material. [**2 marks**]

Question 2 [**12 marks**] A spring has a natural length of 15.0 cm. When a force of 8.0 N is applied, the spring extends to a total length of 18.5 cm.

(a) Calculate the extension produced by the 8.0 N force. [**1 mark**]

(b) Determine the spring constant of this spring. [**3 marks**]

(c) Calculate the force required to extend the spring to a total length of 22.0 cm. [**3 marks**]

(d) Find the extension when a force of 15.0 N is applied to the spring. [**3 marks**]

(e) State one assumption you have made in your calculations. [**2 marks**]

Question 3 [**15 marks**] Two springs X and Y have spring constants of 150 N/m and 250 N/m respectively.

(a) The springs are connected in series and a force of 30 N is applied to the combination.

(i) Calculate the extension of spring X. [**2 marks**]

(ii) Calculate the extension of spring Y. [**2 marks**]

(iii) Find the total extension of the series combination. [**1 mark**]

(iv) Calculate the effective spring constant of the series combination. [**3 marks**]

(b) The same springs are now connected in parallel and the same 30 N force is applied.

(i) Calculate the extension of the parallel combination. [**3 marks**]

(ii) Find the effective spring constant of the parallel combination. [**2 marks**]

(iii) State which arrangement (series or parallel) is stiffer and justify your answer. [**2 marks**]

Section B: Elastic Potential Energy [40 marks]

Question 4 [10 marks]

(a) Define elastic potential energy. **[2 marks]**

(b) State the formula for the elastic potential energy stored in a spring and define all symbols. **[3 marks]**

(c) Explain how the area under a force-extension graph relates to the work done on the spring. **[3 marks]**

(d) State the principle of conservation of energy as it applies to elastic systems. **[2 marks]**

Question 5 [15 marks] A spring with spring constant 320 N/m is compressed by 12.0 cm from its natural length.

(a) Calculate the force required to compress the spring by this amount. **[2 marks]**

(b) Find the elastic potential energy stored in the compressed spring. **[3 marks]**

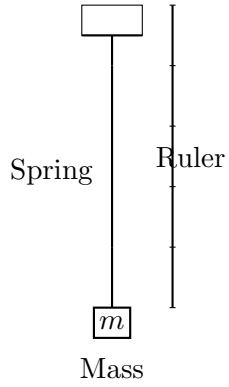
(c) The spring is released and pushes a block of mass 1.5 kg along a smooth horizontal surface. Calculate the maximum velocity reached by the block. **[4 marks]**

(d) If the horizontal surface has a coefficient of friction of 0.25, calculate:

(i) The maximum velocity reached by the block. **[3 marks]**

(ii) The distance the block travels before coming to rest. **[3 marks]**

Question 6 [15 marks] A student investigates elastic potential energy using the apparatus shown below:



The student obtains the following results:

Mass added (g)	Extension (cm)
0	0.0
100	2.4
200	4.8
300	7.2
400	9.6
500	12.0

(a) Plot a graph of force (N) against extension (m) for this data. **[4 marks]**

(b) Use your graph to determine the spring constant. **[3 marks]**

(c) Calculate the elastic potential energy stored when a 300 g mass is attached. **[3 marks]**

(d) The 300 g mass is lifted and then released. Calculate the maximum speed it reaches during its oscillation. **[3 marks]**

(e) State two sources of uncertainty in this experiment. **[2 marks]**

Section C: Stress, Strain and Material Properties [45 marks]

Question 7 [12 marks]

(a) Define stress and state its SI unit. **[2 marks]**

(b) Define strain and explain why it has no units. **[3 marks]**

(c) Define Young's modulus and state its SI unit. **[3 marks]**

(d) Write an equation linking Young's modulus to stress and strain. **[2 marks]**

(e) State what Young's modulus tells us about the properties of a material. **[2 marks]**

Question 8 [18 marks] A steel cable has a length of 50.0 m and a diameter of 8.0 mm. The Young's modulus for steel is 2.1×10^{11} Pa.

(a) Calculate the cross-sectional area of the cable. **[2 marks]**

(b) When the cable supports a load of 8000 N, calculate:

(i) The tensile stress in the cable. **[2 marks]**

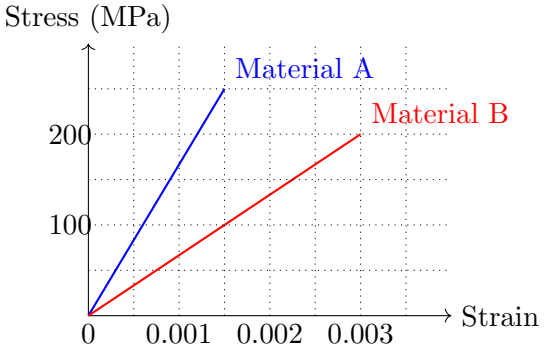
(ii) The tensile strain in the cable. **[3 marks]**

(iii) The extension of the cable. **[3 marks]**

(c) Calculate the elastic potential energy stored in the stretched cable. **[4 marks]**

(d) If the diameter of the cable were doubled while keeping all other factors constant, calculate the new extension. **[4 marks]**

Question 9 [15 marks] A materials scientist tests samples of two different materials, A and B, both with the same dimensions. The results are shown in the stress-strain graphs below:



(a) Calculate Young's modulus for material A. **[4 marks]**

(b) Calculate Young's modulus for material B. **[4 marks]**

(c) Which material is stiffer? Justify your answer. **[2 marks]**

(d) If both materials are subjected to the same stress of 150 MPa, which will have the greater strain? **[3 marks]**

(e) Suggest what types of materials A and B might be, giving reasons for your answers. **[2 marks]**

Section D: Simple Harmonic Motion with Springs [30 marks]

Question 10 [**15 marks**] A mass of 0.8 kg is attached to a horizontal spring with spring constant 200 N/m. The mass undergoes simple harmonic motion with amplitude 5.0 cm.

(a) Calculate the period of oscillation. [**3 marks**]

(b) Find the frequency of oscillation. [**2 marks**]

(c) Calculate the maximum velocity of the mass. [**3 marks**]

(d) Find the maximum acceleration of the mass. [**3 marks**]

(e) Calculate the total mechanical energy of the oscillating system. [**2 marks**]

(f) At what displacement from the equilibrium position is the kinetic energy equal to the potential energy? [**2 marks**]

Question 11 [**15 marks**] A vertical spring-mass system consists of a spring with spring constant 180 N/m and a mass of 1.2 kg.

(a) Calculate the extension of the spring when the mass is in equilibrium. [**3 marks**]

(b) The mass is pulled down an additional 6.0 cm from its equilibrium position and released. Calculate:

(i) The period of the resulting oscillation. [**3 marks**]

(ii) The amplitude of oscillation. [**1 mark**]

(iii) The maximum speed during the oscillation. [**3 marks**]

(c) Find the elastic potential energy in the spring when the mass is at its lowest point. [**3 marks**]

(d) Calculate the kinetic energy of the mass as it passes through the equilibrium position during oscillation. [**2 marks**]

Formulae Sheet

Springs and Elasticity:

Hooke's Law: $F = kx$

Springs in series: $\frac{1}{k_{total}} = \frac{1}{k_1} + \frac{1}{k_2} + ...$

Springs in parallel: $k_{total} = k_1 + k_2 + ...$

Elastic potential energy: $E_p = \frac{1}{2}kx^2$

Stress and Strain:

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

Strain: $\epsilon = \frac{\Delta L}{L}$

Young's modulus: $E = \frac{\sigma}{\epsilon} = \frac{FL}{A\Delta L}$

Simple Harmonic Motion:

Period: $T = 2\pi\sqrt{\frac{m}{k}}$

Frequency: $f = \frac{1}{T}$

Maximum velocity: $v_{max} = \omega A = A\sqrt{\frac{k}{m}}$

Maximum acceleration: $a_{max} = \omega^2 A$

Energy:

Kinetic energy: $KE = \frac{1}{2}mv^2$
Gravitational potential energy: $PE = mgh$
Work done against friction: $W = \mu Ns$

Constants:
$g = 9.81$ m s^{-2}
$\pi = 3.14$

END OF TEST

Total marks: 150
Grade boundaries: A* 135, A 120, B 105, C 90, D 75, E 60

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