A Level Mechanics
Practice Test 4: Elasticity and Springs

Instructions:
Answer all questions. Show your working clearly.
Calculators may be used unless stated otherwise.
Draw clear, labelled diagrams where appropriate.
Time allowed: 2 hours 15 minutes

Section A: Hooke's Law and Elastic Behavior [50 marks]

Question 1 [15 marks] A spring has a natural length of 30.0 cm. The table below shows how the total length varies with applied force:

Force (N)	Total Length (cm)
0	30.0
2	32.5
4	35.0
6	37.5
8	40.0
10	42.5
12	45.0

(a) Calculate the extension for each applied force and complete a force-extension table. [**3 marks**]

(b) Plot a graph of force against extension. [**4 marks**]

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

(d) Write the equation relating force and extension for this spring. [**2 marks**]

(e) Calculate the force needed to extend the spring to a total length of 48.0 cm. [**3 marks**]

Question 2 [20 marks] A physics teacher demonstrates elastic behavior using two springs, P and Q, with spring constants 80 N/m and 120 N/m respectively.

(a) Define the term "spring constant" and state its SI unit. [**3 marks**]

(b) The springs are connected in series and a force of 24 N is applied. Calculate:

- (i) The extension of spring P. [**3 marks**]
- (ii) The extension of spring Q. [**3 marks**]
- (iii) The total extension of the series combination. [**2 marks**]
- (iv) The effective spring constant of the series combination. [**3 marks**]

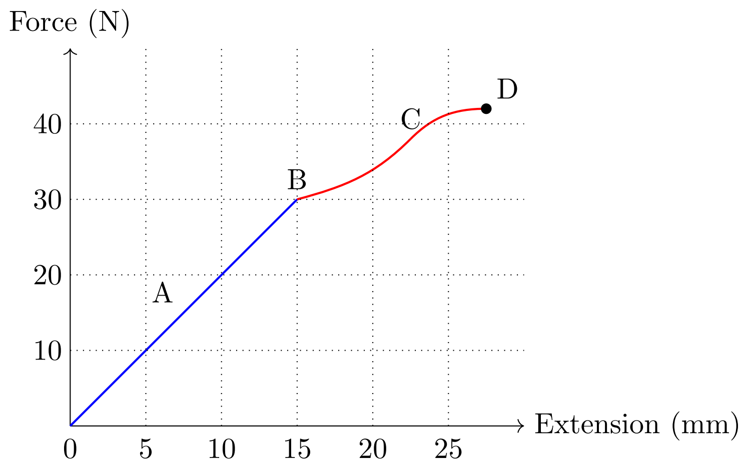
(c) The same springs are now connected in parallel. When the same 24 N force is applied:

(i) Calculate the force in each spring. **[2 marks]**

(ii) Find the extension of the parallel combination. **[2 marks]**

(iii) Calculate the effective spring constant of the parallel combination. **[2 marks]**

Question 3 [**15 marks**] The force-extension graph below shows the behavior of an elastic material up to its breaking point:



(a) Describe what is happening to the material in each region: AB, BC, CD. [**6 marks**]

(b) Calculate the spring constant in the elastic region. [**3 marks**]

(c) At which point does the material cease to obey Hooke's Law? [**2 marks**]

(d) Calculate the elastic potential energy stored at point B. [**4 marks**]

Section B: Elastic Potential Energy and Applications [55 marks]

Question 4 [**18 marks**]

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

(b) Starting from the definition of work done, derive the expression for elastic potential energy stored in a spring: $E_p = \frac{1}{2}kx^2$. [**6 marks**]

(c) Explain what is meant by elastic potential energy in terms of:

(i) The work done on the spring. [**2 marks**]

(ii) The energy that can be recovered from the spring. [**2 marks**]

(d) A spring with spring constant 200 N/m is compressed by 8.0 cm. Calculate the elastic potential energy stored. [**3 marks**]

(e) If this energy is completely converted to kinetic energy of a 0.5 kg mass, calculate the velocity of the mass. [**3 marks**]

Question 5 [**22 marks**] A catapult consists of a spring with spring constant 500 N/m. The spring is compressed by 15 cm and used to launch a 50 g projectile.

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

(b) Assuming 90% energy efficiency, calculate:

(i) The kinetic energy of the projectile as it leaves the catapult. [**2 marks**]

(ii) The launch velocity of the projectile. [**3 marks**]

(iii) The energy lost due to friction and other factors. [**2 marks**]

(c) The projectile is launched horizontally from a height of 2.0 m above the ground. Calculate:

(i) The time of flight. [**3 marks**]

(ii) The horizontal distance traveled. [**3 marks**]

(iii) The velocity components just before impact with the ground. [**4 marks**]

(iv) The total kinetic energy just before impact. [**2 marks**]

Question 6 [**15 marks**] A trampolinist of mass 65 kg lands on a trampoline and compresses the springs by 0.80 m before bouncing back up.

(a) If the trampoline can be modeled as a single spring, calculate the effective spring constant. [**4 marks**]

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

(c) Assuming 85% of this energy is returned to the trampolinist, calculate:

(i) The kinetic energy of the trampolinist as they leave the trampoline. [**2 marks**]

(ii) Their velocity as they leave the trampoline surface. [**3 marks**]

(iii) The maximum height they reach above the trampoline surface. [**3 marks**]

Section C: Stress, Strain and Material Properties [60 marks]

Question 7 [**20 marks**]

(a) Define the following terms:

(i) Tensile stress, including its SI unit. [**3 marks**]

(ii) Tensile strain, explaining why it has no units. [**3 marks**]

(iii) Young's modulus, including its SI unit. [**3 marks**]

(b) Write the equation that defines Young's modulus in terms of:

(i) Stress and strain. [**2 marks**]

(ii) Force, area, length and extension. [**3 marks**]

(c) Explain what a large value of Young's modulus tells us about the mechanical properties of a material. [**3 marks**]

(d) State two factors that might affect the Young's modulus of a material. [**3 marks**]

Question 8 [**25 marks**] A crane uses a steel cable with the following specifications:

- Length: 60.0 m
- Cross-sectional area: $2.5 \times 10\ m^2$
- Young's modulus for steel: 2.1×10^{11} Pa
- Density of steel: 7800 kg/m^3

(a) Calculate the mass of the cable itself. [**3 marks**]

(b) When the cable supports a load of 15,000 N (in addition to its own weight), calculate:

(i) The total force in the cable at the top. [**3 marks**]

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

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

(iv) The extension of the cable. [**4 marks**]

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

(d) If the cable diameter were doubled while keeping the length constant, calculate the new extension under the same load. [**5 marks**]

Question 9 [**15 marks**] A student investigates the Young's modulus of different materials by testing wire samples. For a copper wire of length 1.80 m and diameter 0.80 mm, the following stress-strain data is obtained:

Stress ($\times 10$ Pa)	Strain ($\times 10^3$)
0	0
25	0.20
50	0.40
75	0.60
100	0.80
125	1.00

(a) Plot a graph of stress against strain. [**4 marks**]

(b) Use your graph to determine Young's modulus for copper. [**4 marks**]

(c) Calculate the extension of the wire when the stress is 100×10 Pa. [**3 marks**]

(d) If the accepted value for Young's modulus of copper is 1.3×10^{11} Pa, calculate the percentage error in the student's result. [**2 marks**]

(e) Suggest one improvement to the experimental method to reduce uncertainty. [**2 marks**]

Section D: Simple Harmonic Motion and Springs [45 marks]

Question 10 [**25 marks**] A mass of 1.2 kg is attached to a horizontal spring with spring constant 480 N/m and undergoes simple harmonic motion.

(a) Explain why the motion is simple harmonic. [**3 marks**]

(b) The mass is displaced 6.0 cm from equilibrium and released. Calculate:

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

(ii) The frequency of oscillation. [**2 marks**]

(iii) The angular frequency. [**2 marks**]

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

(c) Calculate:

(i) The maximum velocity during the motion. [**3 marks**]

(ii) The maximum acceleration during the motion. [**3 marks**]

(iii) The velocity when the displacement is 3.0 cm from equilibrium. [**4 marks**]

(d) Find the total mechanical energy of the oscillating system and show that energy is conserved at any point during the motion. [**4 marks**]

Question 11 [20 marks] A vertical spring-mass system consists of a spring with spring constant 240 N/m supporting a mass of 2.0 kg.

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

(b) The mass is pulled down an additional 8.0 cm from its equilibrium position and released. For the resulting simple harmonic motion, calculate:

- (i) The amplitude of oscillation. **[1 mark]**
- (ii) The period of oscillation. **[3 marks]**
- (iii) The maximum speed during oscillation. **[3 marks]**
- (iv) The maximum acceleration during oscillation. **[3 marks]**

(c) Calculate the elastic potential energy stored in the spring when the mass is:

- (i) At its lowest point during oscillation. **[3 marks]**
- (ii) At its highest point during oscillation. **[4 marks]**

Physics Data Sheet

Elasticity and Springs:

Hooke's Law: $F = kx$

Series springs: $\frac{1}{k_{eff}} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3} + ...$

Parallel springs: $k_{eff} = k_1 + k_2 + k_3 + ...$

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

Material Properties:

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

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

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

Energy:

Kinetic energy: $E_k = \frac{1}{2}mv^2$

Gravitational potential energy: $E_p = mgh$

Work done: $W = Fs\cos\theta$

Simple Harmonic Motion:

Restoring force: $F = -kx$

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

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

Angular frequency: $\omega = 2\pi f = \sqrt{\frac{k}{m}}$

Maximum velocity: $v_{max} = \omega A$

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

Velocity: $v = \omega\sqrt{A^2 - x^2}$

Kinematics:

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{u+v}{2}t$

Constants:

Acceleration due to gravity: $g = 9.81 \text{ m s}^{-2}$

$\pi = 3.14159...$

END OF TEST

Total marks: 210

Grade boundaries: A* 189, A 168, B 147, C 126, D 105, E 84

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stepupmaths.co.uk