A Level Mechanics
Practice Test 2: Elasticity and Springs

Instructions:
Answer all questions. Show your working clearly.
Calculators may be used unless stated otherwise.
Draw diagrams where appropriate to illustrate your solutions.
Time allowed: 2 hours

Section A: Hooke's Law Fundamentals [40 marks]

1. **[12 marks]** Define elasticity and explain Hooke's Law:

   (a) Define elastic deformation and give two examples.

   (b) State Hooke's Law in words and write its mathematical expression.

   (c) Define the spring constant and state its SI unit.

   (d) Explain what is meant by the limit of proportionality.

   (e) Sketch a force-extension graph for an elastic spring, labeling the key regions.

   (f) Explain what happens beyond the elastic limit.

2. **[15 marks]** A spring has a natural length of 20 cm. When a 5 N force is applied, it extends to 25 cm.

   (a) Calculate the extension of the spring.

   (b) Find the spring constant.

   (c) What force would be needed to extend the spring to 30 cm?

   (d) Calculate the extension when a 12 N force is applied.

   (e) If the spring obeys Hooke's Law up to a maximum extension of 15 cm, what is the maximum force that can be applied?

3. **[13 marks]** Two springs A and B have spring constants 200 N/m and 300 N/m respectively.

   (a) If both springs are stretched by 8 cm, calculate the force in each spring.

   (b) The springs are connected in series and a 60 N force is applied. Find the extension of each spring.

   (c) Calculate the total extension of the series combination.

   (d) Find the effective spring constant of the series combination.

   (e) The same springs are now connected in parallel. If a 60 N force is applied, find the extension and the effective spring constant.

Section B: Elastic Potential Energy [35 marks]

4. **[12 marks]** Explain elastic potential energy and its applications:
   (a) Define elastic potential energy.
   (b) Derive the formula for elastic potential energy stored in a spring.
   (c) State the relationship between work done and elastic potential energy.
   (d) Explain how elastic potential energy can be converted to kinetic energy.

5. **[15 marks]** A spring with spring constant 400 N/m is compressed by 15 cm from its natural length.
   (a) Calculate the force needed to compress the spring by this amount.
   (b) Find the elastic potential energy stored in the compressed spring.
   (c) The spring is released and pushes a 2 kg mass along a smooth horizontal surface. Calculate the velocity of the mass when the spring returns to its natural length.
   (d) If the surface has friction with coefficient 0.3, find the velocity of the mass when the spring reaches its natural length.
   (e) How far will the mass slide on the rough surface before coming to rest?

6. **[8 marks]** A bungee jumper of mass 70 kg jumps from a height of 50 m. The bungee cord has a spring constant of 100 N/m and natural length 20 m.
   (a) Calculate the extension of the cord at the lowest point of the jump.
   (b) Find the elastic potential energy stored in the cord at this point.
   (c) Calculate the velocity of the jumper when the cord just becomes taut.
   (d) Verify energy conservation throughout the jump.

Section C: Stress, Strain and Young's Modulus [45 marks]

7. **[15 marks]** Define stress, strain and Young's modulus:
   (a) Define stress and state its SI unit.
   (b) Define strain and explain why it has no units.
   (c) Write the equation linking stress and strain.
   (d) Define Young's modulus and state its SI unit.
   (e) Give the equation for Young's modulus in terms of force, area, length and extension.

8. **[20 marks]** A steel wire has length 2.0 m, diameter 1.2 mm and Young's modulus 2.0×10^{11} Pa.
   (a) Calculate the cross-sectional area of the wire.
   (b) When a 150 N force is applied, find the stress in the wire.
   (c) Calculate the strain in the wire.
   (d) Find the extension of the wire.

(e) Calculate the elastic potential energy stored in the wire.

(f) If the diameter of the wire is doubled while keeping all other factors the same, calculate the new extension.

(g) If the length is doubled instead of the diameter, find the new extension.

9. **[10 marks]** The following data was obtained from a test on a rubber band:

Force (N)	Extension (mm)
0	0
2	5
4	10
6	15
8	20
10	25

(a) Plot a graph of force against extension.

(b) Calculate the spring constant of the rubber band.

(c) Determine the elastic potential energy stored when the extension is 20 mm.

(d) If the rubber band has cross-sectional area 4 mm^2 and original length 50 mm, calculate Young's modulus.

Section D: Material Testing and Properties [30 marks]

10. **[12 marks]** Compare the properties of different materials:

(a) Explain why steel is used for construction rather than rubber.

(b) Compare the Young's modulus values for steel (200 GPa) and rubber (0.01 GPa). What does this tell us about their properties?

(c) Explain why copper is used for electrical wires rather than steel.

(d) Give three factors that could affect the Young's modulus of a material.

11. **[18 marks]** A copper wire and an aluminum wire have the same length (3.0 m) and diameter (2.0 mm). Young's modulus for copper is 1.2×10^{11} Pa and for aluminum is 7.0×10^{1} Pa.

(a) Calculate the cross-sectional area of each wire.

(b) If both wires support the same 100 N load, calculate the stress in each wire.

(c) Find the strain in each wire.

(d) Calculate the extension of each wire.

(e) Which wire is stiffer and by what factor?

(f) Calculate the elastic potential energy stored in each wire.

(g) If both wires must not extend by more than 2 mm, what is the maximum load each can support?

Section E: Simple Harmonic Motion with Springs [35 marks]

12. **[15 marks]** A 0.5 kg mass is attached to a spring of spring constant 200 N/m and undergoes simple harmonic motion.

(a) Calculate the period of oscillation.

(b) Find the frequency of oscillation.

(c) If the amplitude is 6 cm, calculate the maximum velocity.

(d) Find the maximum acceleration.

(e) Calculate the total energy of the oscillating system.

13. **[20 marks]** A vertical spring has spring constant 150 N/m. A 2 kg mass is attached and allowed to reach equilibrium.

(a) Calculate the extension of the spring at equilibrium.

(b) The mass is then pulled down a further 8 cm and released. Find the period of oscillation.

(c) Calculate the amplitude of oscillation.

(d) Find the maximum velocity during oscillation.

(e) At what position(s) is the velocity maximum?

(f) Calculate the elastic potential energy when the mass is at its lowest point.

(g) Find the kinetic energy when the mass passes through the equilibrium position.

(h) Verify that total energy is conserved during the motion.

Section F: Combined Applications [25 marks]

14. **[15 marks]** A spring-powered toy car has a spring with constant 800 N/m. The spring is compressed by 10 cm and then released to propel a 0.3 kg car.

(a) Calculate the elastic potential energy stored in the compressed spring.

(b) Find the maximum velocity of the car if there is no friction.

(c) If the car travels on a rough surface with coefficient of friction 0.2, calculate the maximum velocity.

(d) How far will the car travel before coming to rest on the rough surface?

(e) What compression would be needed for the car to travel 5 m on the rough surface?

15. **[10 marks]** A ball of mass 0.2 kg is dropped from a height of 3 m onto a spring of spring constant 2000 N/m.

(a) Calculate the velocity of the ball just before it hits the spring.

(b) Find the maximum compression of the spring.

(c) Calculate the maximum force exerted by the spring.

(d) At what compression does the ball momentarily stop falling and start to rise?

(e) Find the height to which the ball rebounds.

Answer Space

Use this space for your working and answers.

Formulae and Constants

Hooke's Law and Springs:

Force: $F = kx$ where k is spring constant and x is extension

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

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

Elastic Energy:

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

Stress and Strain:

Stress: $\sigma = \frac{F}{A}$ (force per unit area)

Strain: $\epsilon = \frac{x}{L}$ (extension per unit length)

Young's modulus: $E = \frac{\text{stress}}{\text{strain}} = \frac{F/A}{x/L} = \frac{FL}{Ax}$

Simple Harmonic Motion:

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

Frequency: $f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

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

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

Energy and Motion:

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

Gravitational potential energy: $PE = mgh$

Work done against friction: $W = \mu mgd$

Constants:

Acceleration due to gravity: $g = 9.8$ m/s^2

$\pi = 3.14159...$

END OF TEST

Total marks: 210

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