

Elastic Potential Energy

Mark Scheme



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1. When you pull back a rubber band or squash a spring, the work you do is stored as elastic potential energy.

- a) Which of the following scenarios best describes an object possessing elastic potential energy?

C – is the only correct answer.	1 mark
	Total: 1 mark

- b) A student carries out an experiment to investigate how a steel spring stretches when different weights are attached to it. Which value is missing from the table?

B – is the only correct answer.	1 mark
	Total: 1 mark

- c) The diagram below shows an unstretched spring and the same spring with a weight attached to it. Calculate the elastic potential energy stored in the spring.

A – is the only correct answer.	1 mark
	Total: 1 mark

- d) The formula for elastic potential energy is $E_e = \frac{1}{2} k \times e^2$
If the distance a spring is compressed (x) is doubled, what happens to the elastic potential energy?

C – is the only correct answer.	1 mark
	Total: 1 mark

- e) A spring with a spring constant $k = 200 \text{ N/m}$ is stretched by 0.5 m from its starting position. How much elastic potential energy is stored in the spring?

A – is the only correct answer.	1 mark
	Total: 1 mark

- f) A toy spring stores 2.0 J of energy when it is compressed by 10 cm . What is the spring constant (k) of this spring?

A – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 6 marks)

2. Calculate the elastic potential energy for each of the following questions.

a) A spring has a spring constant of 20 N/m. It is extended by 2.0 m.

Calculate the elastic potential energy stored.

$E = 0.5 \times 20 \times 2.0^2$	1 mark
$E = 0.1 \times 20 \times 4.0$	
$E = 40 \text{ J}$	1 mark
	Total: 2 marks

b) A shock absorber has a spring constant of 100 N/m. It is compressed by 0.5 m.

Calculate the elastic potential energy stored.

$E = 0.5 \times 100 \times 0.5^2$	1 mark
$E = 0.5 \times 100 \times 0.25$	
$E = 12.5 \text{ J}$	1 mark
	Total: 2 marks

c) A bungee cord has a spring constant of 60 N/m. It is stretched by 3.0 m.

Calculate the elastic potential energy stored.

$E = 0.5 \times 60 \times 3.0^2$	1 mark
$E = 0.5 \times 60 \times 9$	
$E = 270 \text{ J}$	1 mark
	Total: 2 marks

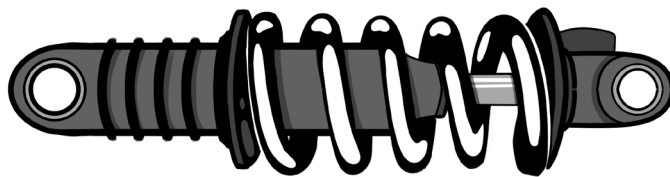
d) A toy spring has a spring constant of 50 N/m. It is extended by 10 cm.

Calculate the elastic potential energy stored.

$E = 0.5 \times 50 \times 0.1^2$	1 mark
$E = 0.5 \times 50 \times 0.01$	
$E = 0.25 \text{ J}$	1 mark
	Total: 2 marks

(Total for Question 2 is 8 marks)

3. A mountain bike has a suspension spring fitted to the rear wheel to absorb bumps.
The spring has a spring constant of 40 000 N/m.



- a) Write down the equation that links elastic potential energy (E_e), spring constant (k) and extension (e).

Elastic potential energy = $0.5 \times \text{spring constant} \times \text{extension}^2$	1 mark
Accept any correct version of the equation above.	
	Total: 1 mark

- b) The rider sits on the bike and the spring compresses by 5 cm.
Calculate the elastic potential energy stored in the spring.

0.05 m	1 mark
$E = 0.5 \times 40\,000 \times 0.05^2$	1 mark
$E = 50 \text{ J}$	1 mark
	Total: 3 marks

- c) Later in the ride, the cyclist hits a large bump and the spring compresses by 10 cm (double the original compression).

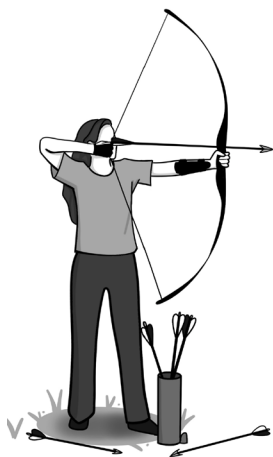
Without a full calculation, suggest how the energy stored in the spring now compares to your answer in part (b).

Explain your answer.

An explanation to include the following:	1 mark
It will be four times greater or 4x as much.	1 mark
Allow: it will be 200 (J).	
Because energy is proportional to the (extension) squared.	1 mark
Allow: because $2^2 = 4$ Allow: because the formula uses e^2 (so doubling e quadruples energy)	
	Total: 2 marks

(Total for Question 3 is 6 marks)

4. An archer uses a bow to shoot an arrow.
When the archer pulls the string back, the bow stores elastic potential energy.
The figure below shows an archer drawing their bow.



- a) State the unit used for the spring constant (k).

N/m or newtons per metre.	1 mark
	Total: 1 mark

- b) The bow has a spring constant of 800 N/m. The archer pulls the string back by 40 cm.
Calculate the elastic potential energy stored in the bow.

40 cm = 0.4 m	1 mark
$E = 0.5 \times 800 \times 0.4^2$	1 mark
$E = 64 \text{ J}$	1 mark
	Total: 3 marks

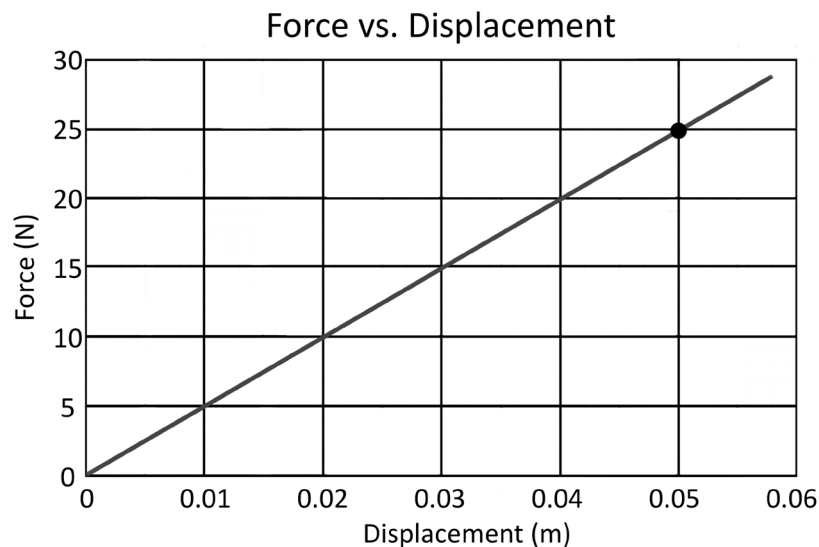
- c) The archer swaps to a different, stiffer bow.
When this new bow is stretched by 0.50 m, it stores 150 J of energy.
Calculate the spring constant (k) of this new bow.

$150 = 0.5 \times k \times 0.50^2$	1 mark
$k = 1200$	1 mark
	Total: 2 marks

(Total for Question 4 is 6 marks)

5. A student is investigating the properties of a spring inside a pinball machine launcher. The figure below shows the spring that's used inside a pinball machine to launch a ball.

The results are plotted in the figure below.



- a) Calculate the spring constant (k) of the spring.

$K = \text{gradient}$	
$K = (F \div e)$	
$K = (25 \div 0.05)$	1 mark
$K = 500$	1 mark
	Total: 2 marks

- b) To launch the pinball, the player pulls the plunger back, compressing the spring by 8.0 cm. Calculate the elastic potential energy stored in the spring at this compression.

$8 \text{ cm} = 0.08 \text{ m}$	1 mark
$E_e = 0.5 \times 500 \times 0.08^2$	1 mark
$E_e = 1.6$	1 mark
	Total: 3 marks

- c) The pinball has a mass of 50 g. When the spring is released, the ball is fired vertically up a ramp. Assuming there is no friction or air resistance, calculate the maximum vertical height the ball could reach. (Gravitational field strength, $g = 9.8 \text{ N/kg}$)

$1.6 = 0.05 \times 9.8 \times h$	1 mark
$h = 1.6 \div 0.49$	1 mark
$h = 3.27$	1 mark
m or metres	1 mark
	Total: 4 marks

- d) In reality, the ball only reaches a height of 2.8 m.

Calculate the percentage efficiency of the energy transfer from the spring to the gravitational potential store of the ball.

$\text{Useful } E_p = 0.05 \times 9.8 \times 2.8 = 1.372 \text{ (J)}$	1 mark
$\text{Efficiency} = (1.372 \div 1.6) \times 100 = 85.75 \%$	1 mark
	Total: 2 marks

(Total for Question 5 is 12 marks)

6. A safety engineer is testing a new spring-loaded "buffer stop" for a miniature railway line.
The purpose of the buffer is to stop the train if the brakes fail.

- a) Calculate the kinetic energy of the train just before impact.

$E_k = 0.5 \times 120 \times 4.0^2$	1 mark
$E_k = 960 \text{ J}$	1 mark
	Total: 2 marks

- b) The buffer contains a stiff spring.

Upon impact, the train compresses the spring by 25 cm before coming to a complete stop.

Assuming that 100% of the train's kinetic energy is transferred to the spring's elastic potential store, calculate the spring constant (k) of the spring.

$25 \text{ cm} = 0.25 \text{ m}$	1 mark
$960 = 0.5 \times k \times 0.25^2$	1 mark
$30\,720 \text{ J}$	2 marks
	Total: 4 marks

- c) Calculate the maximum force exerted on the train by the spring at the moment of maximum compression (25 cm).

$F = k \times e = 30720 \times 0.25$	1 mark
$E_e = 0.5 \times F \times e$	1 mark
$60 = 0.5 \times F \times 0.25$	
$F = 7680 \text{ N}$	1 mark
	Total: 3 marks

- d) In a second test, the engineer greases the wheels of the train to reduce friction.
Calculate how much energy was lost to friction in the first test (part b).

$E_e = 0.5 \times 30720 \times 0.20^2$	1 mark
Actual $E_e = 614.4 \text{ J}$	1 mark
$\text{Energy lost} = 960 - 614.4 = 345.6 \text{ J}$	1 mark
	Total: 3 marks

(Total for Question 6 is 12 marks)