

## PISA Style Scientific Literacy Question

# Bungee

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Read the text about Bungee jumping.



Bungee jumping is thought to have originated on Pentecost Island in the South Pacific. It has become the tradition there for the men of the island to tie long vines or lianas to their ankles and jump from a tall wooden tower they have built in their village.

Modern day bungee jumping began on 1<sup>st</sup> April 1979 when four members of the Oxford University Dangerous Sports Club jumped from the 80 metre high Clifton Suspension Bridge in Bristol, England, using an elastic cord.

A bungee jump involves two phases:

- The first phase is free falling. This happens in the initial phase of the jump when the cord has not extended to its full length.
- The second phase of the jump involves the elastic cord extending like a spring.

The English scientist, Robert Hooke described the extension of a spring in 1670. He said in Latin 'Ut tensio, sic vis' or translated into English 'As the extension, so the force'. This is now referred to as the Law of Elasticity, or most commonly, Hooke's Law.

Hooke's Law tells us that the elastic bungee cord will stretch by a known amount for each person depending on their weight. Elastic objects stretch by the same amount each time we add the same amount of weight or force until it reaches its elastic limit. During the jump there is an exchange of energy between the person jumping and the bungee cord, in line with the principle of conservation of energy.

### Question 1 : BUNGEE

In the text, Robert Hooke is quoted as saying '*As the extension, so the force*'. Which of the statements below best fits in with Hooke's Law of Elasticity.

- A The extension of the bungee cord is directly proportional to the weight of the person attached to it.
- B The extension of the bungee cord is inversely proportional to the weight of the person attached to it.
- C The extension of the bungee cord is not proportional to the weight of the person attached to it.
- D The extension of the bungee cord is indirectly proportional to the weight of the person attached to it.

### Question 2 : BUNGEE

On a graph, the relationship between extension and force described by Hooke's Law would be displayed as:

- A a bell shaped curve
- B a straight line showing a positive correlation
- C a straight line showing a negative correlation
- D a straight line travelling horizontally

### Question 3 : BUNGEE

The extension of a spring according to Hooke's Law can be worked out using a mathematical formula  $F = k \times e$

In this equation **k** stands for :

- A the spring constant of the elastic object
- B the gravitational force being applied to the elastic object
- C the extension of the elastic object
- D the weight of whatever is attached to the elastic object

### Question 4 : BUNGEE

Using Hooke's Law can help the organiser to carry out the bungee jump safely. To do this, the organiser will need to have some important information.

Circle 'yes' or 'no' for each statement.

The organiser will need to know this to use Hooke's Law to ensure a safe jump	Yes or No ?
The mass or weight of the person who is jumping	Yes / No
The spring constant of the elastic cord	Yes / No
The distance between the platform they will jump off and the ground	Yes / No
Whether the person jumping is a man or a woman	Yes / No

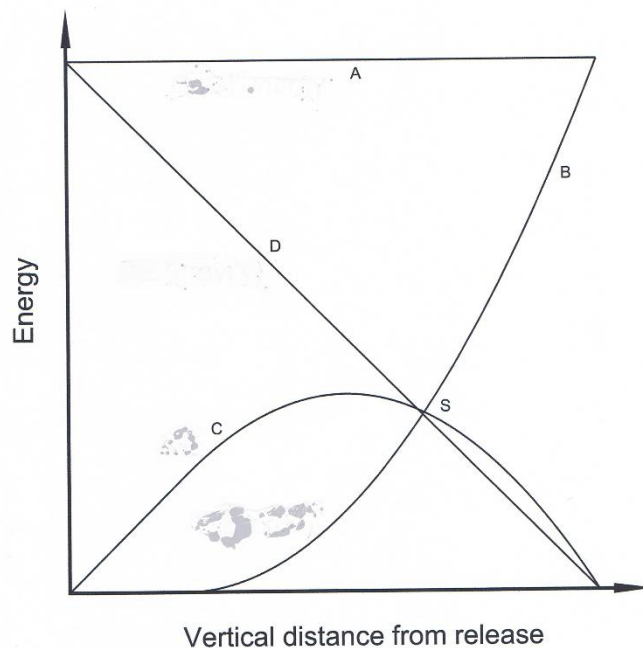
### Question 5 : BUNGEE

A person who weighs 100kg (1000 N) is going to do a bungee jump. The spring constant of the bungee cord is 50 N/m (newtons per metre). Using the formula  $e = F / k$ , what will be the extension of the bungee cord when the person jumping reaches the end of the jump and the cord is in equilibrium?

- A 50 metres
- B 40 metres
- C 30 metres
- D 20 metres

### Question 6 : BUNGEE

The graph shows the energy exchange that takes place between the person jumping and the cord until the cord is tight and at maximum stretch.



Which graph from the lines labelled A-D:	A - D
Shows the change of potential energy of the jumper as he falls	
Shows the change of kinetic energy of the jumper as he falls	
Shows the change in potential energy of the cord during the fall	
Shows the total energy during the fall	

**Question 7: BUNGEE**

Explain how the graphs at point S can be used to explain that energy is conserved during the fall.

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**Question 8: BUNGEE**

Tom and Sarah are discussing how to calculate a safe height to carry out a bungee jump. Tom says that it is possible to calculate the safe height from which to jump knowing the weight of the person jumping, the length of the cord and by calculating the extension of the cord using the spring constant. Sarah says you cannot just use Hooke's Law for the calculation. Explain what Sarah means.

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## SCORING : BUNGEE

### Question 1

#### **Full credit**

A The extension of the bungee cord is directly proportional to the weight of the person attached to it

#### **No credit**

Other responses

Missing

#### **Narrative :**

Directly proportional means that the weight of the person increases **at the same rate** (e.g. doubles) as the extension of the spring. In this case, when weight and extension are plotted on a graph it would produce a straight line through the origin. Inversely proportional means that as the weight increases the extension decreases so it is incorrect. Indirectly proportional is not commonly used but means the same as inversely proportional. In this case when weight and extension are plotted on a graph it would **NOT** produce a straight line through the origin

Framework Categories	2015 Framework
Knowledge type	Knowledge of the content of science
Competency	Explain phenomena scientifically
Context	Frontiers of science and technology
Cognitive demand	Low

### Question 2

#### **Full credit**

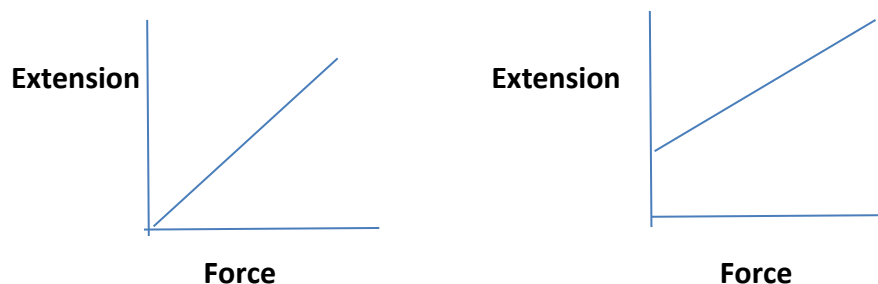
B A straight line going upwards

#### **No credit**

Other responses

Missing

**Narrative :**



The graph on the left hand side – shows that the extension is directly proportional to the force e.g. if the force was doubled then the extension would be doubled etc  
The graph on the right hand side – shows that the extension is proportional to the force applied. Both show positive correlation

Framework Categories	2015 Framework
Knowledge type	Procedural
Competency	Interpret data and evidence scientifically
Context	Frontiers of science and technology
Cognitive demand	Medium

### **Question 3**

***Full credit***

A The spring constant of the elastic object

***No credit***

Other responses

Missing

**Narrative :**

In the equation  $e = \frac{F}{k}$  the extension, the amount the spring stretches when a force is applied.  $F$  = the gravitational force or weight which causes the spring to extend.

Framework Categories	2015 Framework
Knowledge type	Knowledge of the content of science
Competency	Explain phenomena scientifically
Context	Frontiers of science and technology
Cognitive demand	Low

#### **Question 4**

##### ***Full credit***

Yes, Yes, Yes, No, in that order

##### ***No credit***

Other responses

Missing

##### **Narrative :**

Using the equation  $F=k \times e$  then to work this out  $F = \text{weight of the person}$ ,  $k$  is the spring constant and this will enable you to work out the extension produced using  $e = F/k$ , you will also need the distance from the platform to the ground to ensure that there is sufficient drop to cover the length of spring and the extension produced. Since weight is used it does not matter whether it is a man or woman that is jumping.

Framework Categories	2015 Framework
Knowledge type	Knowledge of the content of science
Competency	Evaluate and design scientific enquiry
Context	Frontiers of science and technology
Cognitive demand	Medium

### **Question 5**

**Full credit**

D 20 metres

**No credit**

Other responses

Missing

**Narrative :**

Substituting into the equation  $e=F/k = 1000/50 = 20\text{m}$

Since the weight = force, using the mass of 100kg is incorrect in the equation.

<b>Framework Categories</b>	<b>2015 Framework</b>
<b>Knowledge type</b>	Knowledge of the content of science
<b>Competency</b>	Explain phenomena scientifically
<b>Context</b>	Frontiers of science and technology
<b>Cognitive demand</b>	Medium

### **Question 6**

**Full credit**

**D; C; B; A in that order**

**No Credit**

Other responses

Missing

**Narrative :**

The potential energy ( $PE = mgh$ ) is dependent on  $h$  the height as this decreases so does the PE of the person jumping, so the answer is D. As the PE of the person



jumping decreases, the KE increases as they fall ( $KE = \frac{1}{2} mv^2$ ) but this is not linear since KE is proportional to  $v^2$  so it is a curve, the answer being C. Initially the energy of the cord would be zero until it began to stretch in which case it would gain PE, so the answer is B.

The total energy in the system remains constant throughout (law of conservation of energy) so the answer is A.

Framework Categories	2015 Framework
Knowledge type	Knowledge of the content of science
Competency	Explain phenomena scientifically
Context	Frontiers of science and technology
Cognitive demand	Medium

### **Question 7**

#### ***Full credit***

When the height of the three graphs, from the horizontal axis to point S, are added together they equal the height of graph A (from the horizontal axis to the horizontal graph A)

**OR**

sum of energies at S = total energy in the system

#### ***No credit***

Other responses

Missing

#### **Narrative :**

The vertical distance from the horizontal axis to the point S of the curves C, B and D when measured and added together would be equal the vertical distance from the horizontal axis to the line A. This shows that the total energy in the system remains the same.

Framework Categories	2015 Framework
Knowledge type	Knowledge of the content of science
Competency	Explain phenomena scientifically
Context	Frontiers of science and technology
Cognitive demand	High

### **Question 8 : BUNGEE**

#### ***Full credit***

When the cord is fully stretched the weight of the person jumping takes it, initially at least, beyond the equilibrium point which is calculated using Hooke's law and the spring constant.

**OR**

There is a limit to the proportionality of the extension of the cord (according to Hooke's law). If the elastic limit of the cord was reached it could extend further than predicted/not proportionally as predicted by Hooke's law. OR The cord could even reach the yield point and beyond, so the cord could snap.

#### ***No credit***

Other responses

Missing

#### **Narrative :**

Hooke's law only predicts the length of a spring / elastic at equilibrium. Before the spring / elastic settles at its equilibrium length it will extend and go back several times. This is what makes the person doing the bungee jump bounce up and down. During this phase of the jump the elastic / spring will extend further than the equilibrium predicted by Hooke's law. If the bungee jump organisers only used Hooke's law to predict the drop needed then there is the possibility of an accident where the person jumping may hit the ground, because the elastic stretches further than the equilibrium point during this phase of the jump. There is also a possibility that the cord will reach its elastic limit during the point where it stretches beyond equilibrium and this could cause the cord to snap. This could also be very dangerous for the person jumping.

<b>Framework Categories</b>	<b>2015 Framework</b>
<b>Knowledge type</b>	Knowledge of the content of science
<b>Competency</b>	Explain phenomena scientifically
<b>Context</b>	Frontiers of science and technology
<b>Cognitive demand</b>	High