Q1. A baby bouncer consisting of a harness and elastic ropes is suspended from a doorway. When a baby of mass 10 kg is placed in the harness, the ropes stretch by 0.25 m. When the baby bounces, she starts to move with vertical simple harmonic motion. What is the time period of her motion?

A 1.0 s

B 2.1 s

C 2.3 s

D 3.1 s

(Total 1 mark)

Q2. Which one of the following statements is true when an object performs simple harmonic motion about a central point O?

A The acceleration is always directed away from O.

B The acceleration and velocity are always in opposite directions.

C The acceleration and the displacement from O are always in the same direction.

D The graph of acceleration against displacement is a straight line.

(Total 1 mark)

Q3. A body moves with simple harmonic motion of amplitude 0.50 m and period 4π seconds. What is the speed of the body when the displacement of the body from the equilibrium position is 0.30 m?

A 0.10 m s^{-1}

B 0.15 m s^{-1}

C 0.20 m s^{-1}

D 0.40 m s^{-1}

(Total 1 mark)

Q4. The time period of oscillation of a simple pendulum of length l is the same as the time period of oscillation of a mass M attached to a vertical spring. The length and mass are then changed. Which row, **A** to **D**, in the table would give a simple pendulum with a time period twice that of the spring oscillations?

	new pendulum length	**new mass on spring**
A	$2l$	$2M$
B	$2l$	$\frac{M}{2}$
C	$\frac{l}{2}$	$2M$
D	$\frac{l}{2}$	$\frac{M}{2}$

(Total 1 mark)

Q5. A body moves with simple harmonic motion of amplitude 0.90 m and period 8.9 s. What is the speed of the body when its displacement is 0.70 m?

A 0.11 m s^{-1}

B 0.22 m s^{-1}

C 0.40 m s^{-1}

D 0.80 m s^{-1}

(Total 1 mark)

Q6. A mechanical system is oscillating at resonance with a constant amplitude. Which one of the following statements is **not** correct?

A The applied force prevents the amplitude from becoming too large.

B The frequency of the applied force is the same as the natural frequency of oscillation of the system.

C The total energy of the y tem i con tant

D The amplitude of oscillations depends on the amount of damping.

(Total 1 mark)

Q7. The period of vertical oscillation of a mass-spring system is T when the spring carries a mass of 1.00 kg. What mass should be added to the 1.00 kg if the period is to be increased to 1.50 T?

A 0.25 kg

B 1.00 kg

C 1.25 kg

D 2.00 kg

(Total 1 mark)

Q8. A body moves with simple harmonic motion of amplitude A and frequency $\frac{b}{2\pi}$.
What is the magnitude of the acceleration when the body is at maximum displacement?

A zero

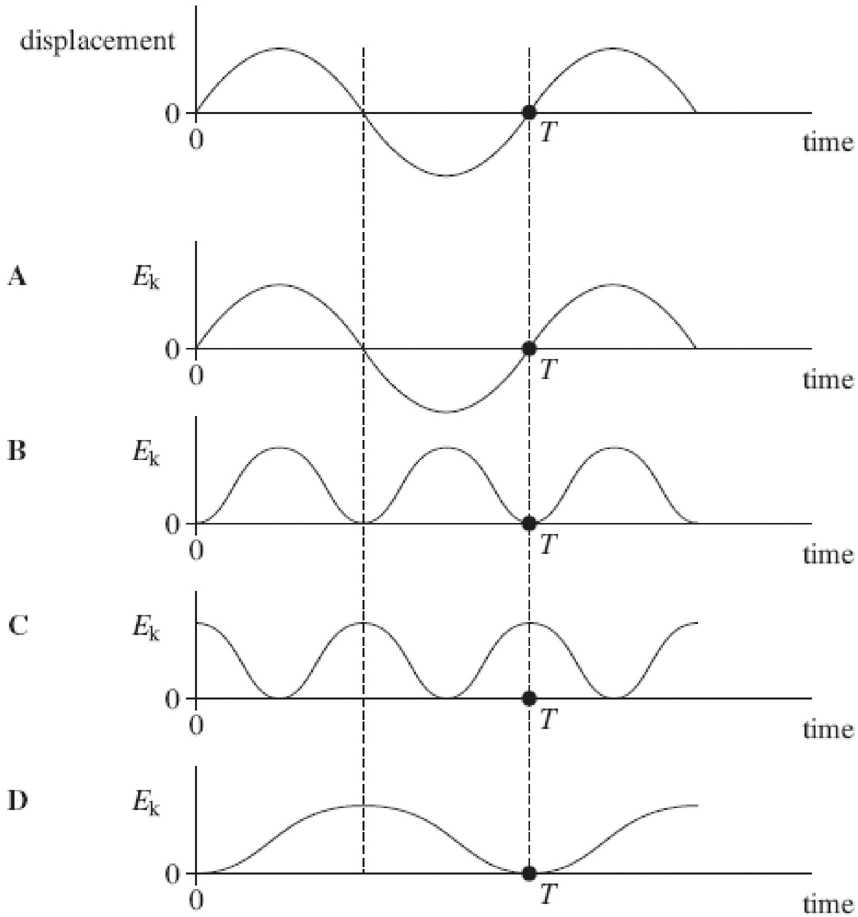
B $4\pi^2Ab^2$

C Ab^2

D $\frac{4\pi^2 A}{b^2}$

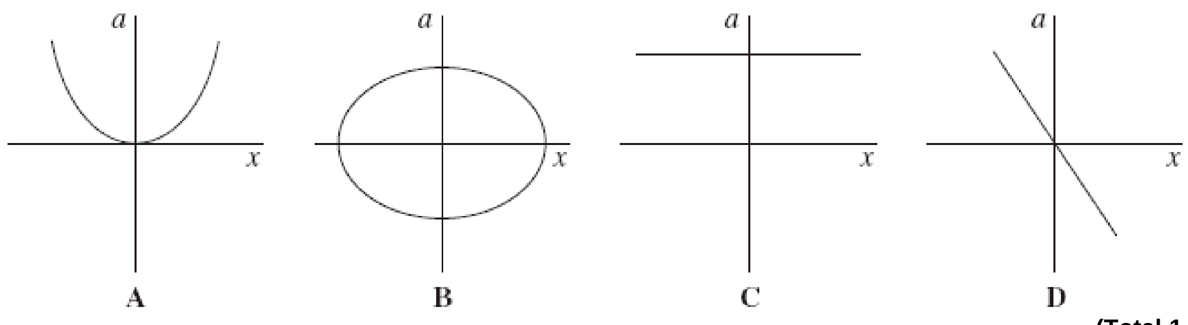
(Total 1 mark)

Q9. An object oscillating in simple harmonic motion has a time period T. The first graph shows how its displacement varies with time. Which of the subsequent graphs, **A** to **D**, show how the kinetic energy, E_k, of the object varies with time?



(Total 1 mark)

Q10. Which one of the following graphs shows how the acceleration, *a*, of a body moving with simple harmonic motion varies with its displacement, *x*?



(Total 1 mark)

Q11. The time period of a pendulum on Earth is 1.0 s. What would be the period of a pendulum of the same length on a planet with half the density but twice the radius of Earth?

A 0.5 s

B 1.0 s

C 1.4 s

D 2.0 s

(Total 1 mark)

Q12. Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is in the same direction as the acceleration.

B It is in the same direction as the displacement.

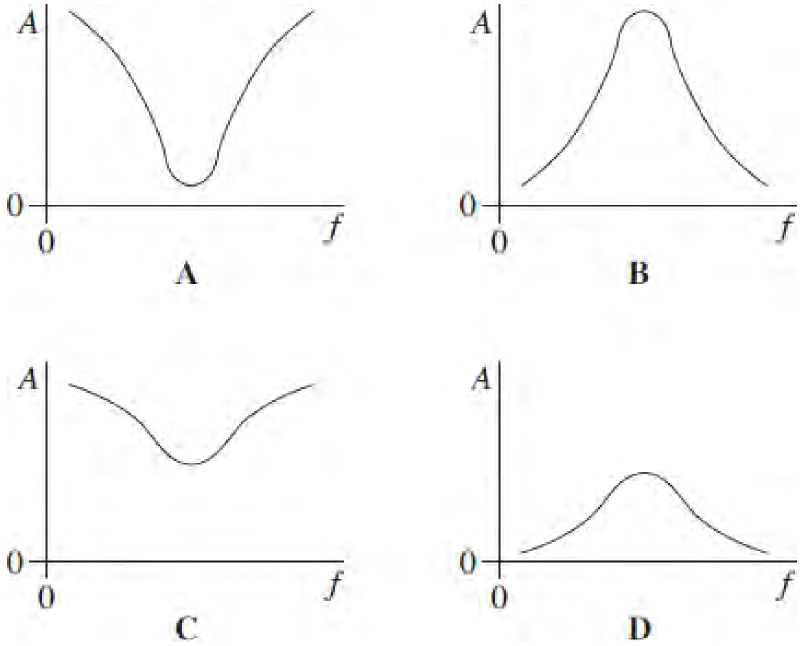
C It is in the opposite direction to the velocity.

D It is proportional to the displacement.

(Total 1 mark)

Q13. An oscillatory system, subject to damping, is set into vibration by a periodic driving force of frequency *f*. The graphs, **A** to **D**, which are to the same scale, show how the amplitude of vibration *A* of the system might vary with *f*, for various degrees of damping.

Which graph best shows the lightest damping?



(Total 1 mark)

Q14. A simple pendulum and a mass-spring system both have the same time period *T* at the surface of the Earth. If taken to another planet where the acceleration due to gravity is twice that on Earth, which line, **A** to **D**, in the table gives the correct new time periods?

	simple pendulum	**mass-spring**
A	$T\sqrt{2}$	$\frac{T}{\sqrt{2}}$
B	$T\sqrt{2}$	T
C	$\frac{T}{\sqrt{2}}$	T
D	$\frac{T}{\sqrt{2}}$	$T\sqrt{2}$

(Total 1 mark)

Q15. The frequency of a body moving with simple harmonic motion is doubled. If the amplitude remains the same, which one of the following is also doubled?

A the time period

B the total energy

C the maximum velocity

D the maximum acceleration

(Total 1 mark)

Q16. A mass on the end of a spring undergoes vertical simple harmonic motion. At which point (s) is the magnitude of the resultant force on the mass a minimum?

A at the centre of the oscillation

B only at the top of the oscillation

C only at the bottom of the oscillation

D at both the top and bottom of the oscillation

(Total 1 mark)

Q17. (a) A spring, which hangs from a fixed support, extends by 40 mm when a mass of 0.25 kg is suspended from it.

(i) Calculate the spring constant of the spring.

....

....

(ii) An additional mass of 0.44 kg is then placed on the spring and the system is set into vertical oscillation. Show that the oscillation frequency is 1.5 Hz.

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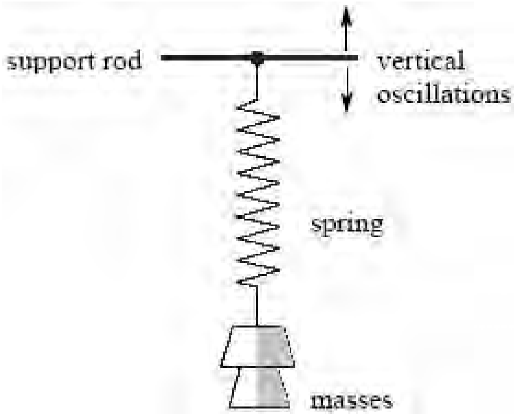
....

....

(4)

(b) With both masses still in place, the spring is now suspended from a horizontal support rod that can be made to oscillate vertically, as shown in the diagram below, with amplitude 30 mm at several different frequencies.



The response of the masses suspended from the spring to the vertical oscillations of the support rod varies with frequency. Describe and explain, as fully as you can, the motion of the masses when the support rod oscillates at a frequency of (i) 0.2 Hz, (ii) 1.5 Hz and (iii) 10 Hz.

The quality of your written answer will be assessed in this question.

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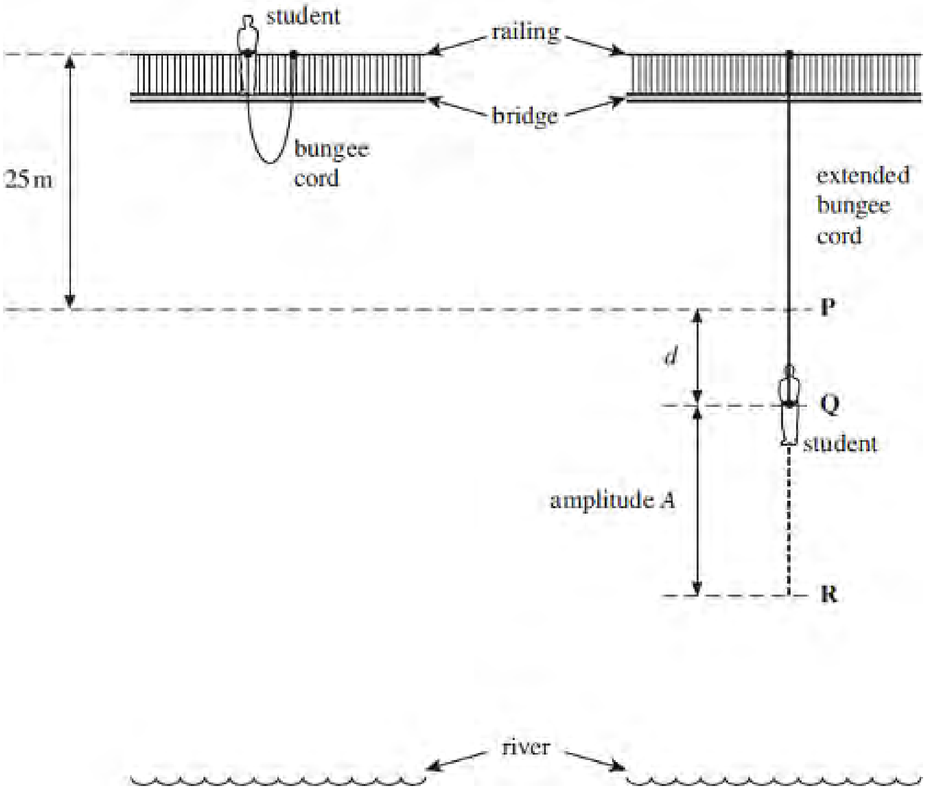
(6)
(Total 10 marks)

Q18. The two diagrams in the figure below show a student before and after she makes a bungee jump from a high bridge above a river. One end of the bungee cord, which is of unstretched length 25 m, is fixed to the top of a railing on the bridge. The other end of the cord is attached to the waist of the student, whose mass is 58 kg. After she jumps, the bungee cord goes into tension at point **P**. She comes to rest momentarily at point **R** and then oscillates about point **Q**, which is a distance *d* below **P**.

BEFORE **AFTER**



(a) (i) Assuming that the centre of mass of the student has fallen through a vertical distance of 25 m when she reaches point **P**, calculate her speed at **P**.
You may assume that air resistance is negligible.

answer = ... ms^{-1}

(2)

(ii) The bungee cord behaves like a spring of spring constant 54 Nm^{-1}.
Calculate the distance *d*, from **P** to **Q**, assuming the cord obeys Hooke's law.

answer = ... m

(2)

(b) As the student moves below **P**, she begins to move with simple harmonic motion for part of an oscillation.

(i) If the arrangement can be assumed to act as a mass-spring system, calculate the time taken for one half of an oscillation.

answer = ... s

(2)

(ii) Use your answers from parts (a) and (b)(i) to show that the amplitude *A*, which is the distance from **Q** to **R**, is about 25 m.

(3)

(c) Explain why, when the student rises above point **P**, her motion is no longer simple harmonic.

....

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(2)

(d) (i) Where is the student when the stress in the bungee cord is a maximum?

....

....

(1)

(ii) The bungee cord has a significant mass. Whereabouts along the bungee cord is the stress a maximum? Explain your answer.

....

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....

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(2)
(Total 14 marks)

M1. A

[1]

M2. D

[1]

M3. C

[1]

M4. B

[1]

M5 C

[1]

M6. A

[1]

M7. C

[1]

M8. C

[1]

M9. C

[1]

M10. D

[1]

M11. B

[1]

M12. C

[1]

M13. B

[1]

M14. C

[1]

M15. C

[1]

M16. A

[1]

M17. (a) (i) $mg = ke$ **(1)**

$k =$ [redacted] $= 61(.3)\ \text{N m}^{-1}$ **(1)**

(ii) $T = \left(= 2\pi\sqrt{\frac{m}{k}}\right) = 2\pi\sqrt{\frac{0.69}{61.3}}$ **(1)** (= 0.667 s)

$f\left(= \frac{1}{T}\right) = \frac{1}{0.667}$ **(1)** (= 1.5(0) Hz)

4

(b) The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question.

Level	**Descriptor** an answer will be expected to meet most of the criteria in the level descriptor	**Mark range**
Good **3**	– answer supported by appropriate range of relevant points – good use of information or ideas about physics, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of spelling, punctuation and grammar	**5-6**
Modest **2**	– answer partially supported by relevant points – good use of information or ideas about physics given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of spelling, punctuation and grammar	**3-4**
Limited **1**	– valid points but not clearly linked to an argument structure – limited use of information or ideas about physics – unstructured – errors in spelling, punctuation and grammar or lack of fluency	**1-2**
0	– incorrect, inappropriate or no response	**0**

examples of the sort of information or idea that might be used to support an argument

- forced vibrations (at 0.2 Hz) **(1)**
- amplitude fairly large (≈ 30 mm) **(1)**
- in phase with driver **(1)**
- resonance (at 1.5 Hz) **(1)**
- amplitude very large (> 30 mm) **(1)**
- oscillations may appear violent **(1)**
- phase difference at 90º **(1)**
- forced vibrations (at 10 Hz) **(1)**
- small amplitude **(1)**
- out of phase with driver or phase lag of π on driver **(1)**

[10]

M18. (a) (i) speed at P, v (= $\sqrt{2gh}$) = $\sqrt{2 \times 9.81 \times 25}$ ✓

= 22(.1) (m s^{-1}) ✓

2

(ii) use of $F = k\Delta L$ gives $d\left(= \frac{F}{K}\right) = \frac{58 \times 9.81}{54}$ ✓

= 11 (10.5) (m) ✓

2

(b) (i) period $T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{58}{54}}$ ✓ (= 6.51 s)

time for one half oscillation = 3.3 (3.26) (s) ✓

2

(ii) frequency $f\left(=\frac{1}{T}\right)=\frac{1}{6.51}$ ✓ (= 0.154 (Hz))

use of $v = \pm 2\pi f\sqrt{A^2 - x^2}$ when x = 10.5 m and v = 22.1 m s^{-1} gives 22.1^2

$= 4\pi^2 \times > 0.154^2 (A^2 - 10.5^2)$ ✓

from which A = 25.1 (m) ✓

[alternatively, using energy approach gives $\frac{1}{2} mv_P^2 + mg\Delta L = \frac{1}{2} k(\Delta L)^2$ ✓

$\therefore (29 \times 22.1^2) + (58 \times 9.81 \times \Delta L) = 27 (\Delta L)^2$

solution of this quadratic equation gives ΔL = 35.7 (m) ✓

from which A = 25.2 (m) ✓]

3

(c) bungee cord becomes slack ✓

student's motion is under gravity (until she returns to **P**) ✓

has constant downwards acceleration **or** acceleration is not ∝ displacement ✓

2

(d) (i) when student is at **R** or at bottom of oscillation ✓

1

(ii) at uppermost point **or** where it is attached to the railing ✓

because stress = *F/A* and force at this point includes weight of whole cord ✓

[accept alternative answers referring to mid-point of cord because cord will show thinning there as it stretches **or** near knots at top or bottom of cord where A will be smaller with a reference to stress = *F/A*]

2

[14]