1)

(i) Name the **two** types of potential energy involved when a mass–spring system performs vertical simple harmonic oscillations.

[1 mark]

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(ii) Describe the energy changes which take place during one complete oscillation of a vertical mass-spring system, starting when the mass is at its lowest point.

[2 marks]

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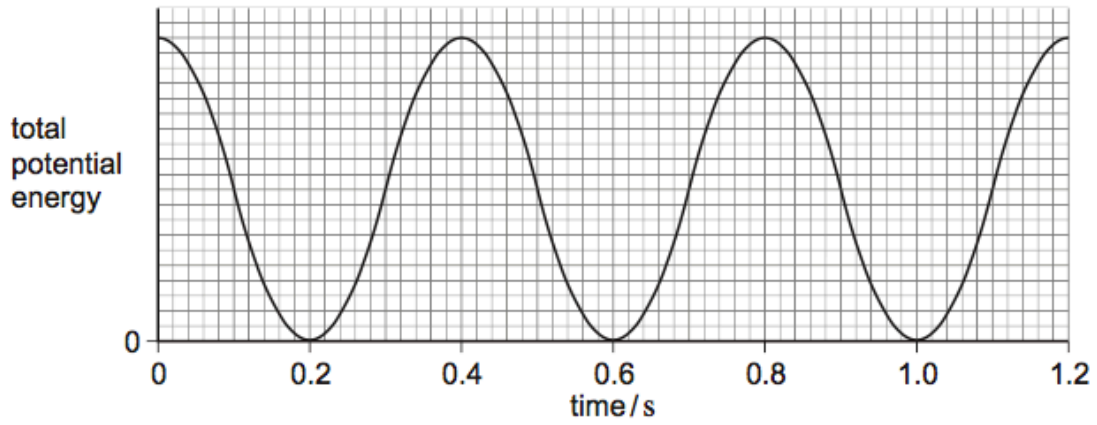
Figure 3 shows how the **total** potential energy due to the simple harmonic motion varies with time when a mass-spring system oscillates vertically.

Figure 3



(i) State the time period of the simple harmonic oscillations that produces the energy–time graph shown in **Figure 3**, explaining how you arrive at your answer.

[2 marks]

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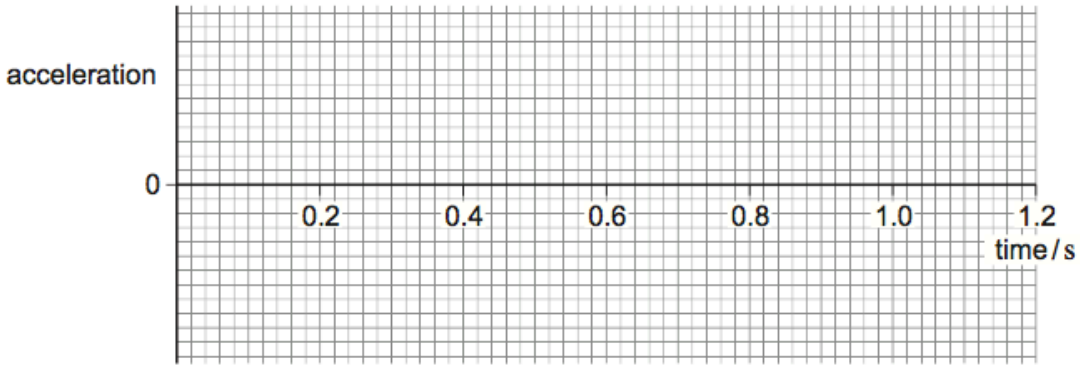
(b) (ii) Sketch a graph on **Figure 4** to show how the acceleration of the mass varies with time over a period of 1.2 s, starting with the mass at the highest point of its oscillations. On your graph, upwards acceleration should be shown as positive and downwards acceleration as negative. Values are not required on the acceleration axis.

[2 marks]

Figure 4



(c) (i) The mass of the object suspended from the spring in part (b) is 0.35 kg. Calculate the spring constant of the spring used to obtain **Figure 3**. State an appropriate unit for your answer.

[3 marks]

spring constant ..... unit .....

(c) (ii) The maximum kinetic energy of the oscillating object is 2.0×10^{-2} J. Show that the amplitude of the oscillations of the object is about 40 mm.

[4 marks]

2)

2)

(a) A simple pendulum is given a small displacement from its equilibrium position and performs *simple harmonic motion*.

State what is meant by simple harmonic motion.

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(2 marks)

(b) (i) Calculate the frequency of the oscillations of a simple pendulum of length 984 mm. Give your answer to an appropriate number of significant figures.

frequency ..... Hz

(3 marks)

(b) (ii) Calculate the acceleration of the bob of the simple pendulum when the displacement from the equilibrium position is 42 mm.

acceleration ..... $m\,s^{-2}$

(2 marks)

(c) A simple pendulum of time period 1.90 s is set up alongside another pendulum of time period 2.00 s. The pendulums are displaced in the same direction and released at the same time.

Calculate the time interval until they next move in phase. Explain how you arrive at your answer.

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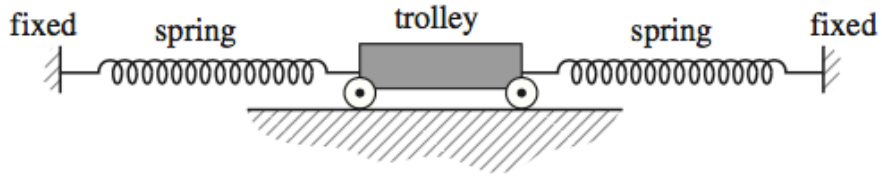
time interval ..... s

(3 marks)

3)

A trolley of mass 0.80 kg rests on a horizontal surface attached to two identical stretched springs, as shown in **Figure 3**. Each spring has a spring constant of 30 N m^{-1}, can be assumed to obey Hooke's law, and to remain in tension as the trolley moves.

Figure 3



(a) (i) The trolley is displaced to the left by 60 mm and then released. Show that the magnitude of the resultant force on it at the moment of release is 3.6 N.

(2 marks)

(a) (ii) Calculate the acceleration of the trolley at the moment of release and state its direction.

answer = ...m s^{-2}

direction .....

(2 marks)

(b) (i) The oscillating trolley performs simple harmonic motion. State the **two** conditions which have to be satisfied to show that a body performs simple harmonic motion.

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(2 marks)

(b) (ii) The frequency f of oscillation of the trolley is given by

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

where m = mass of the trolley
k = spring constant of one spring.

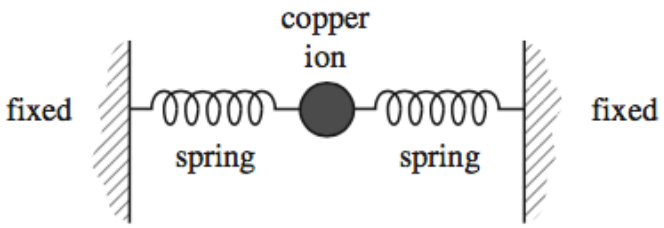
Calculate the period of oscillation of the trolley, stating an appropriate unit.

answer = ...

(3 marks)

(c) Copper ions in a crystal lattice vibrate in a similar way to the trolley, because the inter-atomic forces act in a similar way to the forces exerted by the springs.
Figure 4 shows how this model of a vibrating ion can be represented.

Figure 4



(c) (i) The spring constant of each inter-atomic 'spring' is about $200\,N\,m^{-1}$. The mass of the copper ion is $1.0 \times 10^{-25}\,kg$. Show that the frequency of vibration of the copper ion is about $10^{13}\,Hz$.

(1 mark)

(c) (ii) If the amplitude of vibration of the copper ion is $10^{-11}m$, estimate its maximum speed.

answer = ...$m\,s^{-1}$
(1 mark)

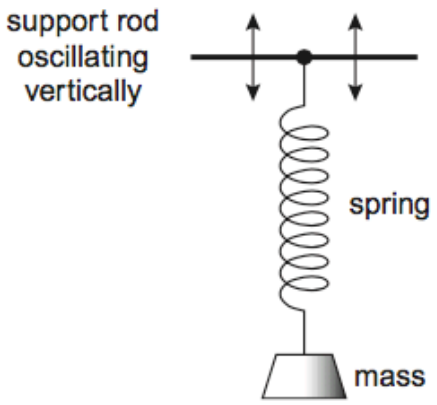
(c) (iii) Estimate the maximum kinetic energy of the copper ion.

answer = ...J
(1 mark)

4)

(a) A mass is attached to one end of a spring and the other end of the spring is suspended from a support rod, as shown in **Figure 1**.

Figure 1



The support rod oscillates vertically, causing the mass to perform forced vibrations. Under certain conditions, the system may demonstrate resonance.

Explain in your answer what is meant by forced vibrations and resonance. You should refer to the frequency, amplitude and phase of the vibrations.

[4 marks]

forced vibrations .....

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resonance .....

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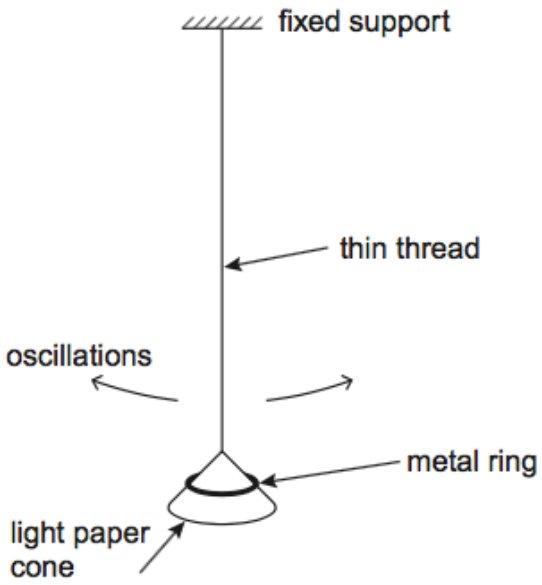
(b) A simple pendulum is set up by suspending a light paper cone (acting as the pendulum bob) on the end of a length of thin thread. A metal ring may be placed over the cone to increase the mass of the bob, as shown in **Figure 2**.

Figure 2



The bob is displaced and released so that it oscillates in a vertical plane. The oscillations are subject to damping.

(b) (i) Are the oscillations of the pendulum more heavily damped when the cone oscillates with the metal ring on it, when it oscillates without the ring, or does the presence of the ring have no effect on the damping of the oscillations? Tick (✓) the correct answer.

[1 mark]

cone oscillates with ring	
cone oscillates without ring	
ring has no effect	

(b) (ii) Explain your answer to part (b)(i).

[3 marks]

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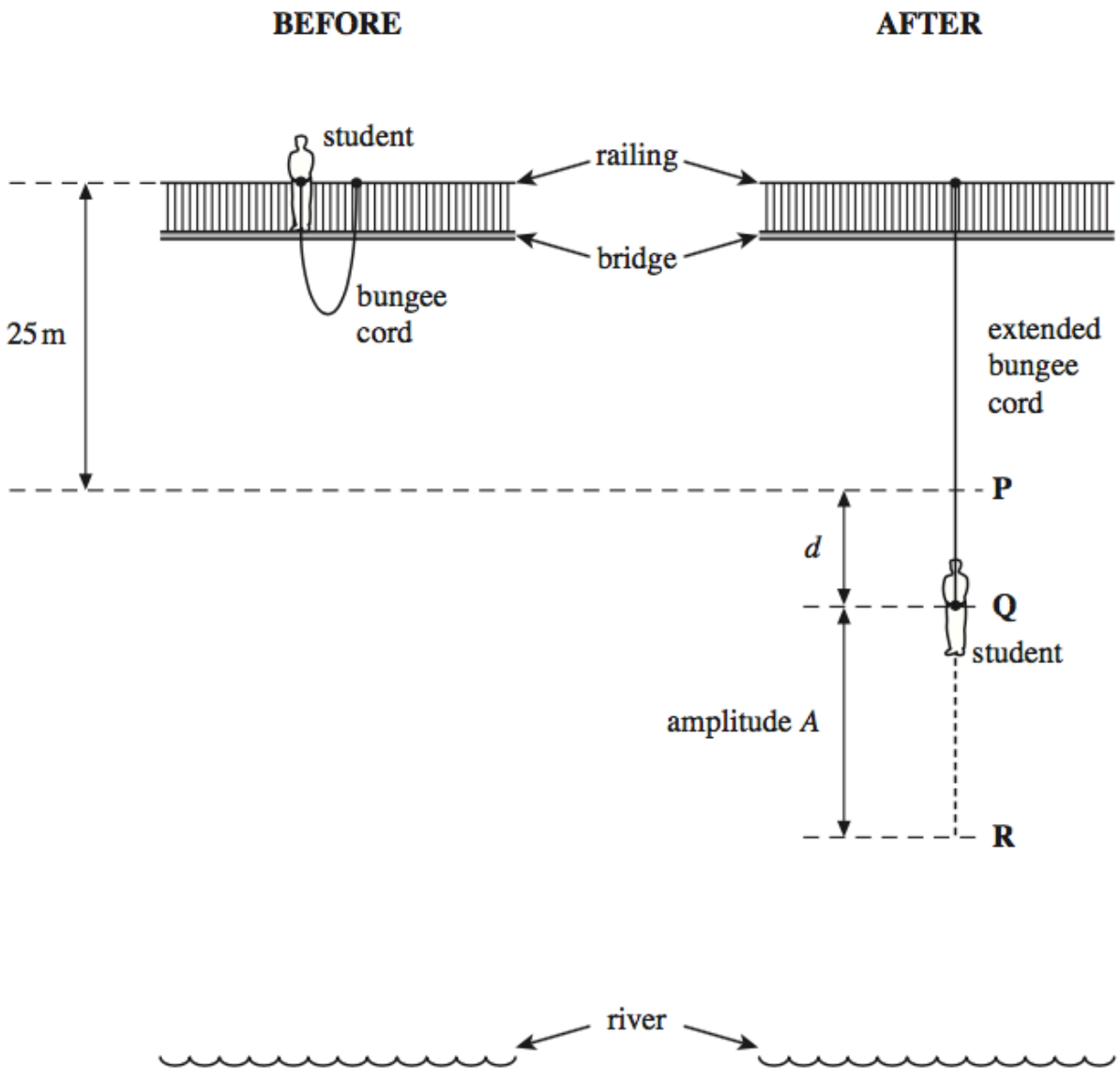
5)

The two diagrams in **Figure 4** 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**.

Figure 4



(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 = ... $m\,s^{-1}$

(2 marks)

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

answer = ... m

(2 marks)

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

(b) (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 marks)

(b) (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 marks)

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

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(2 marks)

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

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(1 mark)

(d) (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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(2 marks)

6)

(a) Describe the energy changes that take place as the bob of a simple pendulum makes one complete oscillation, starting at its maximum displacement.

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(2 marks)

(b)

Figure 1

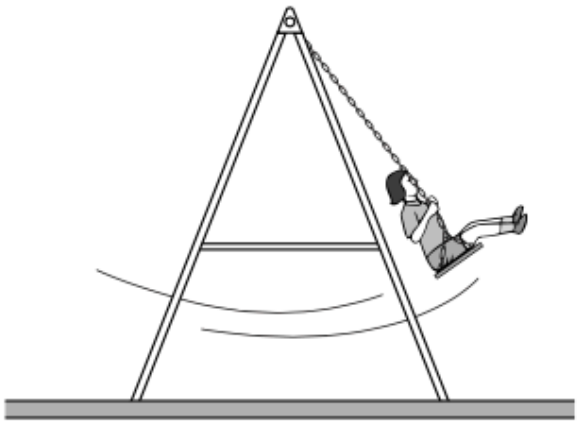


Figure 1 shows a young girl swinging on a garden swing. You may assume that the swing behaves as a simple pendulum. Ignore the mass of chains supporting the seat throughout this question, and assume that the effect of air resistance is negligible.
15 complete oscillations of the swing took 42s.

(b) (i) Calculate the distance from the top of the chains to the centre of mass of the girl and seat. Express your answer to an appropriate number of significant figures.

answer = ... m

(4 marks)

(b) (ii) To set her swinging, the girl and seat were displaced from equilibrium and released from rest. This initial displacement of the girl raised the centre of mass of the girl and seat 250 mm above its lowest position. If the mass of the girl was 18 kg, what was her kinetic energy as she first passed through this lowest point?

answer = ... J

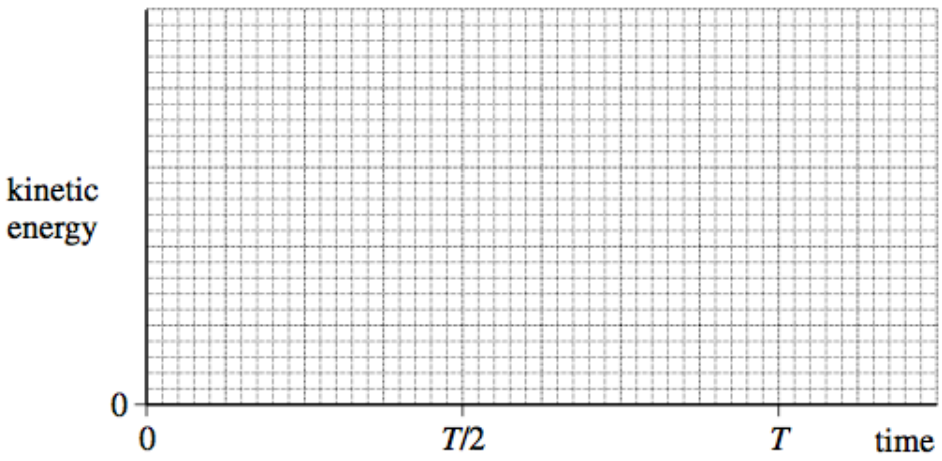
(2 marks)

(b) (iii) Calculate the maximum speed of the girl during the first oscillation.

answer = ... $m\,s^{-1}$

(1 mark)

(c) **Figure 2**



On **Figure 2** draw a graph to show how the kinetic energy of the girl varied with time during the first complete oscillation, starting at the time of her release from maximum displacement. On the horizontal axis of the graph, *T* represents the period of the swing. You do not need to show any values on the vertical axis.

(3 marks)

7)
8)
9)
10)
11)
12)
13)
14)
15)
16)
17)
18)
19)
20)