LONDON SCIENCE COLLEGE

Name:

Date:

SIMPLE HARMONIC MOTION
TEST 3

A2-Level

Mark | Grade

PHYSICS

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

Instructions

- Answer all questions
- Answer questions in the space provided
- All working must be shown

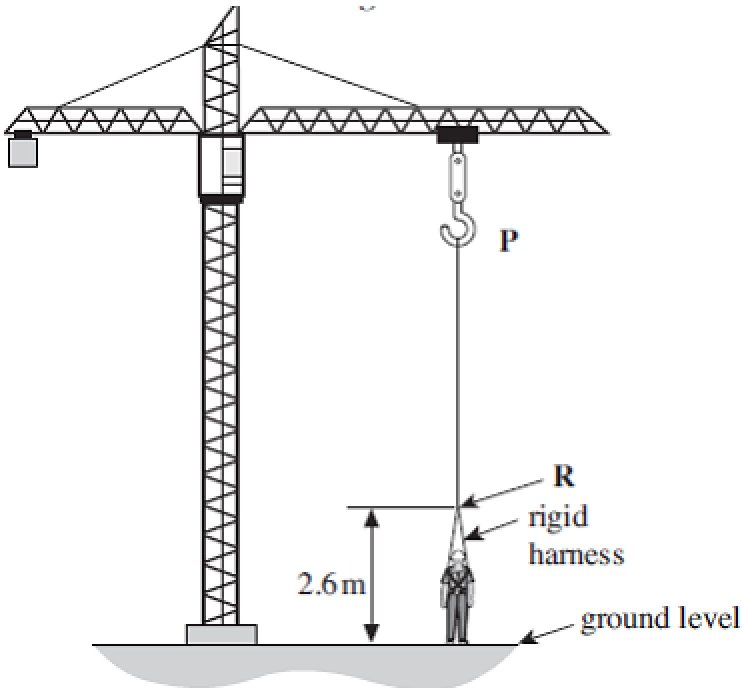
Information

- The marks for the questions are shown in brackets

1 In a reverse bungee experience a 'rider' is catapulted high into the air.
A designer creates a less extreme version for more timid participants, as shown in the figure below.

The rider is strapped into a rigid harness attached to one end of an elastic rope **PR**. The rider and the rope behave in the same way as a mass-spring system.

The rider is initially held at rest at ground level. The top end of the rope, **P**, is raised to stretch the rope. The rider is then released and moves upwards, reaching a maximum height when the rope is at its unstretched (natural) length. The rider then oscillates vertically until eventually coming to rest, suspended above the ground.



The rope has an unstretched length of 20 m. When stretched, the rope obeys Hooke's law and has a stiffness of 92 Nm^{-1}. In the following questions ignore the mass of the rope.

(a) (i) The rider and harness have a total mass of 55 kg.
Calculate the overall length of the rope when the rider comes to rest, suspended above the ground, at the end of the ride.

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overall length ____________________ m

(3)

(ii) At the start of the ride, the lower end of the rope **R** is attached to the rigid harness at a point which is 2.6 m above the ground.

The top end of the rope, **P**, has to be adjusted so that the rope just becomes unstretched when the rider is at the highest point of the ride.
Determine the height of **P** above the ground.
Neglect air resistance in this part of the question.

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height of point **P** ______________________ m

(1)

(b) (i) Show that the frequency of oscillation of the rider on the end of the rope is about 0.2 Hz.

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(3)

(ii) Calculate the maximum speed reached by the rider when the amplitude of the oscillation is 4.2 m.

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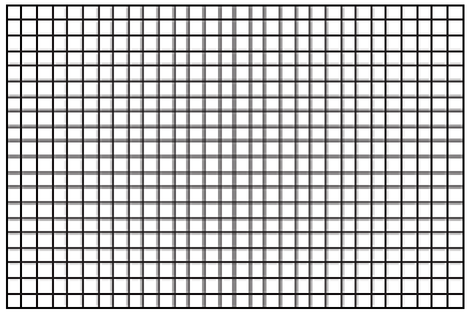
maximum speed ______________________ ms^{-1}

(2)

(iii) In practice, air resistance has an effect. Sketch below, a graph showing how you would expect the velocity to vary with time over the first two complete oscillations, from the instant the rider was released from ground level. Take an upward velocity as being positive.

Label the time axis with a suitable scale. No scale is required on the velocity axis.



(3)

(c) (i) A rider of greater mass now uses the ride. Explain how the height of **P** has to be changed to produce the same initial amplitude of oscillations as that for the previous rider.

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(3)

(ii) A safety officer examines the design of the ride and thinks that, if the end **P** of the rope is raised too high so that the rope is stretched too much at the start, there is a risk that the rider could hit the ground after the first oscillation and suffer an injury. Describe what would happen to the rider during the ride in this case and explain why, even if air resistance is negligible, the safety officer's concerns are unfounded.

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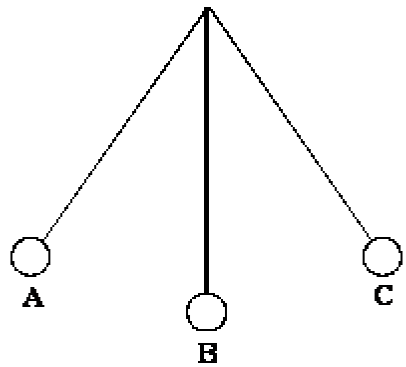
(3)

(Total 18 marks)

2 The diagram below shows a simple pendulum that consists of a large mass at the end of a long string. **A**, **B** and **C** are positions of the pendulum as it oscillates in the air. **A** and **C** are the extreme positions of the motion and **B** is the centre of the motion.



(a) State clearly in terms of the positions shown on the diagram what is meant by the *period of oscillation* of the pendulum.

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(2)

(b) The diagram shows positions of the bob during an oscillation. State at which position the damping is greatest. Explain why the damping is greatest in the position you have quoted.

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(3)

(Total 5 marks)

3 **Figure 1** shows three stages during the oscillations of a loaded spring. The positions shown are when the mass attached to the spring is at the top, equilibrium (middle) position and bottom of its motion.

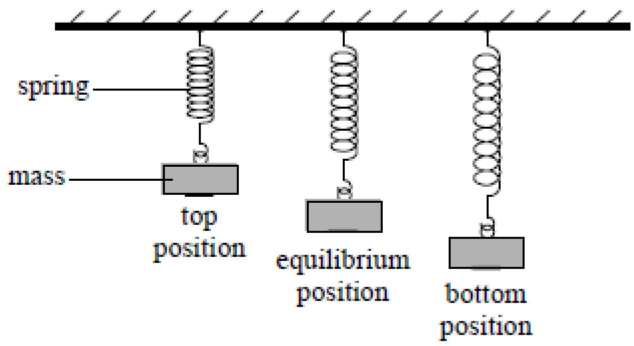

Figure 1

(a) (i) Describe what is meant by the *period* of this oscillation.

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(1)

(ii) Mark and label the *amplitude* of the oscillation on **Figure 1**.

(1)

(b) Explain how you would determine an accurate value for the period of the oscillation.

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(2)

(c) The mass is displaced from its equilibrium position in the air and then released. The graph in **Figure 2** shows the displacement-time graph from the moment of release. The mass-spring system is then submerged in water and set oscillating with the same initial displacement.

Sketch **on the same set of axes** the displacement-time graph for the motion in the water.

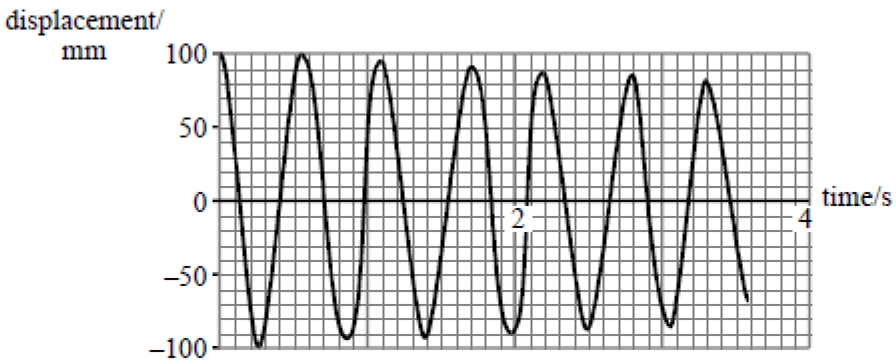
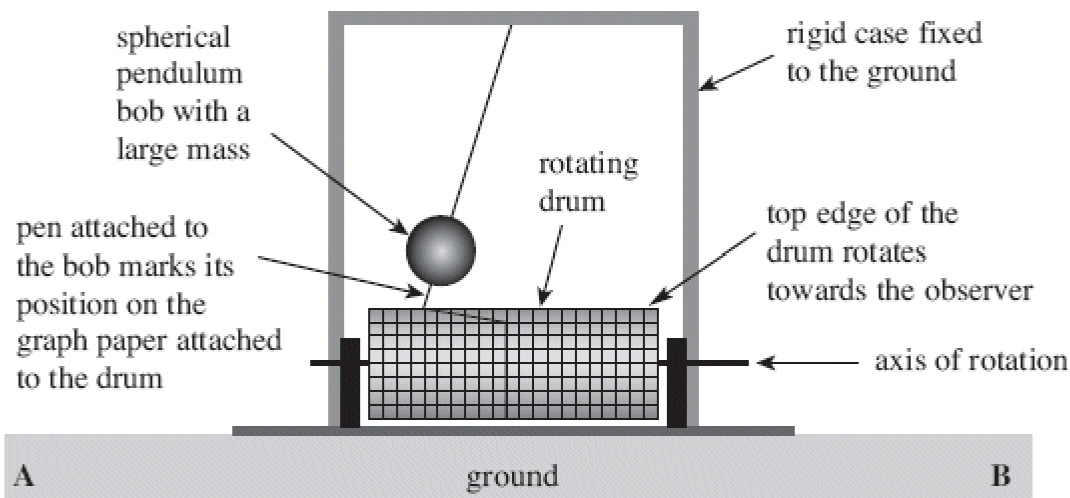


Figure 2

(2)
(Total 6 marks)

4 **Figure 1** shows a seismometer used for detecting the horizontal movement of the ground caused by an earthquake.

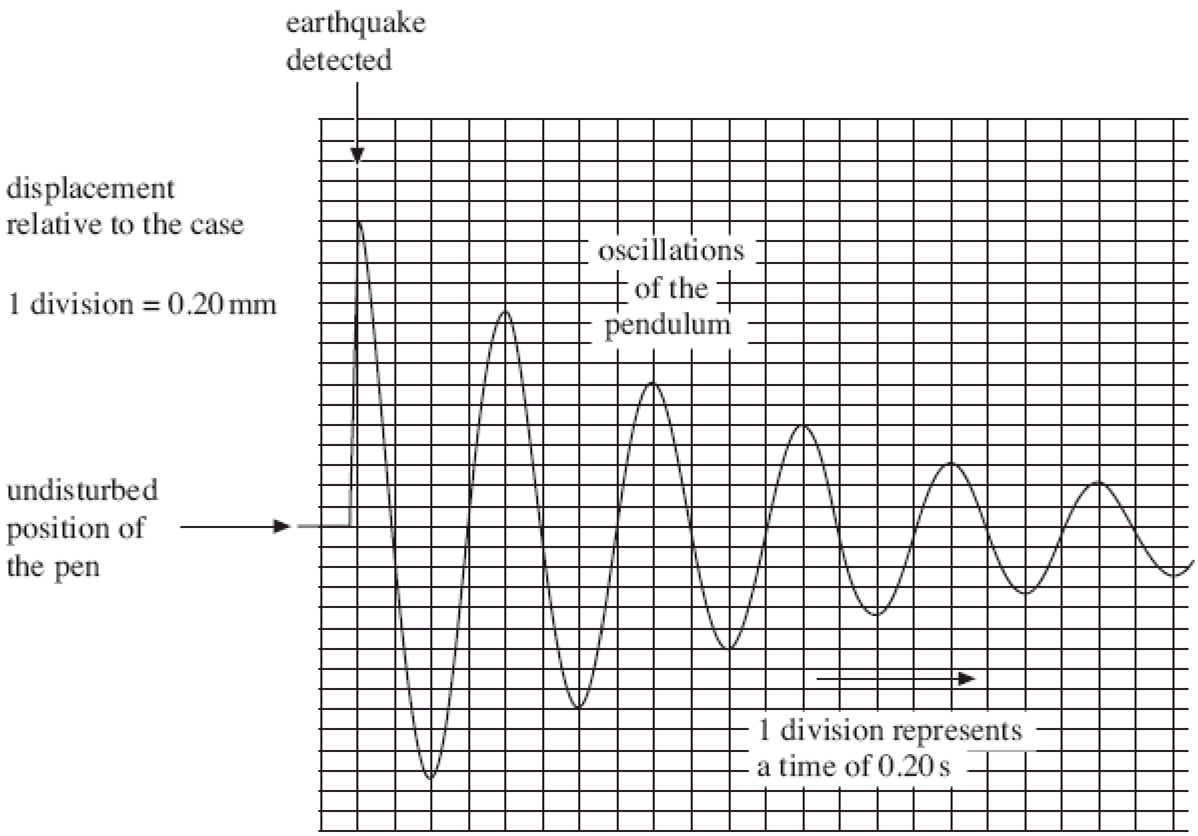
Figure 1



The rigid case is fixed to the ground. When an earthquake occurs, the ground moves horizontally so the rigid case also moves horizontally. Initially, the heavy pendulum bob remains in its original position due to its high inertia. **Figure 1** shows the pendulum immediately after an earthquake is detected.

The rotating drum moves at a steady speed. **Figure 2** shows the trace produced on the graph paper that is attached to the rotating drum following the earthquake.

Figure 2



(a) (i) State whether the ground has moved towards **A** or **B** to produce the situation shown in **Figure 1**.

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(1)

(ii) Determine the magnitude of the initial displacement of the ground that caused the trace in **Figure 2**.

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(1)

(b) (i) Use data from **Figure 2** to calculate the distance between the point of suspension of the pendulum and the centre of mass of the bob. Assume that the arrangement is a simple pendulum.

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distance ______________________ m

(3)

(ii) State and explain the effect of using a bob of the same radius but smaller mass on the initial displacement of the bob,

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the period of oscillation of the bob.

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(4)

(c) (i) Determine whether the amplitude of the oscillations shown in **Figure 2** decreases exponentially.

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(3)

(ii) Explain why the amplitude of the oscillations of the bob decreases following the initial displacement.

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(2)

(iii) State and explain the effect of using a bob with the same radius but smaller mass on the time taken for the bob to come to rest following the initial disturbance.

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(2)

(Total 16 marks)

5 A simple pendulum was made by attaching a small mass to a 1.20 m length of thin string. The pendulum was displaced 10.0 cm sideways and released to swing in a vertical plane. The amplitude of the motion was then observed and recorded after each oscillation. **Figure 1** shows some of the results from the experiment.

Figure 1

Oscillation	0	1	2	3	4	5	6
Amplitude/cm	10.0	8.4	7.1	5.9	5.0	4.2	3.5

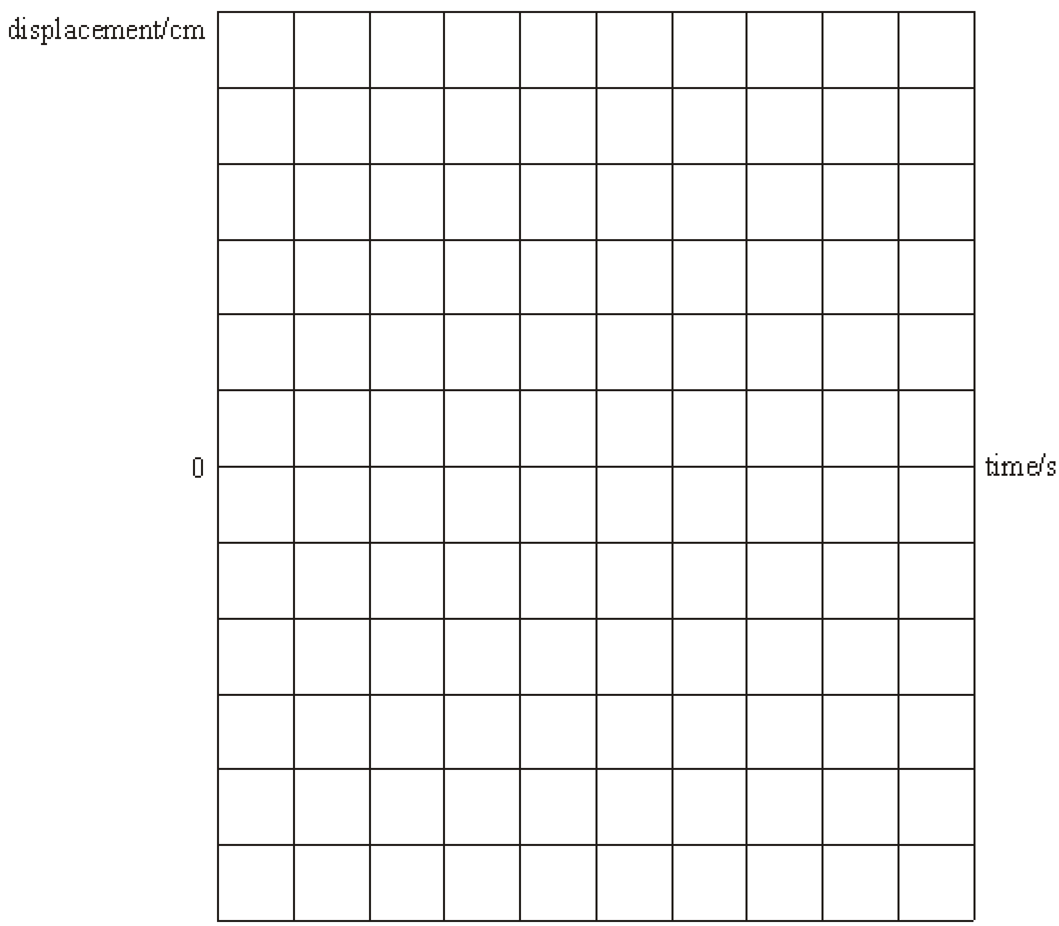
(a) The time for 6 oscillations was 13.2 s. Calculate the periodic time of the oscillations.

periodic time ____________________

(1)

(b) On the axes in **Figure 2**, carefully sketch a graph of displacement against time for the first two oscillations of the pendulum. Mark the scale on each axis.

Figure 2



(4)

(c) State the effect on the motion of the pendulum when

(i) a shorter string is used,

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(ii) a greater mass of the same size is used.

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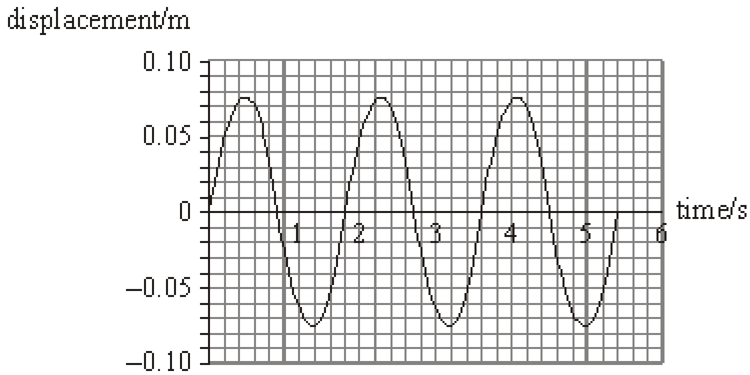
(2)

(Total 7 marks)

6 The figure below shows how the displacement of the bob of a simple pendulum varies with time.



(a) (i) Calculate the frequency of the oscillation.

(2)

(ii) State the magnitude of the amplitude of the oscillation.

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(1)

(iii) State how the frequency and amplitude of a simple pendulum are affected by increased damping.

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(2)

(b) Draw on the figure above the displacement-time graph for a pendulum that has the same period and amplitude but oscillates 90° (π/2 radian) out of phase with the one shown.

(2)

(c) The pendulum bob has a mass of 8.0×10^{-3} kg. Calculate

(i) the maximum acceleration of the bob during the oscillation,

(ii) the total energy of the oscillations.

(5)

(Total 12 marks)

7 A particle of mass 5.0×10^{-3} kg, moving with simple harmonic motion of amplitude 0.15 m, takes 47 s to make 50 oscillations.
What is the maximum kinetic energy of the particle?

A 2.0×10^{-3} J

B 2.5×10^{-3} J

C 3.9×10^{-3} J

D 5.0×10^{-3} J

(Total 1 mark)

8 Which line, **A** to **D**, in the table gives the amplitude and frequency of a body performing simple harmonic motion whose displacement x at time t is given by the equation $x = P \cos Qt$?

	Amplitude	**Frequency**
A	$\frac{P}{2}$	$\frac{Q}{2\pi}$
B	P	$2\pi Q$
C	P	$\frac{Q}{2\pi}$
D	$2P$	$\frac{Q}{2\pi}$

(Total 1 mark)

9 A particle of mass m oscillates in a straight line with simple harmonic motion of constant amplitude. The total energy of the particle is E. What is the total energy of another particle of mass $2m$, oscillating with simple harmonic motion of the same amplitude but double the frequency?

A E

B $2E$

C $4E$

D $8E$

(Total 1 mark)

10 A particle of mass 0.20 kg moves with simple harmonic motion of amplitude 2.0×10^{-2} m. If the total energy of the particle is 4.0×10^{-5}J, what is the time period of the motion?

A $\frac{\pi}{4}$ seconds

B $\frac{\pi}{2}$ seconds

C π seconds

D 2π seconds

(Total 1 mark)