LONDON SCIENCE COLLEGE

Name:

Date:

# SIMPLE HARMONIC MOTION
# TEST 2

# 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

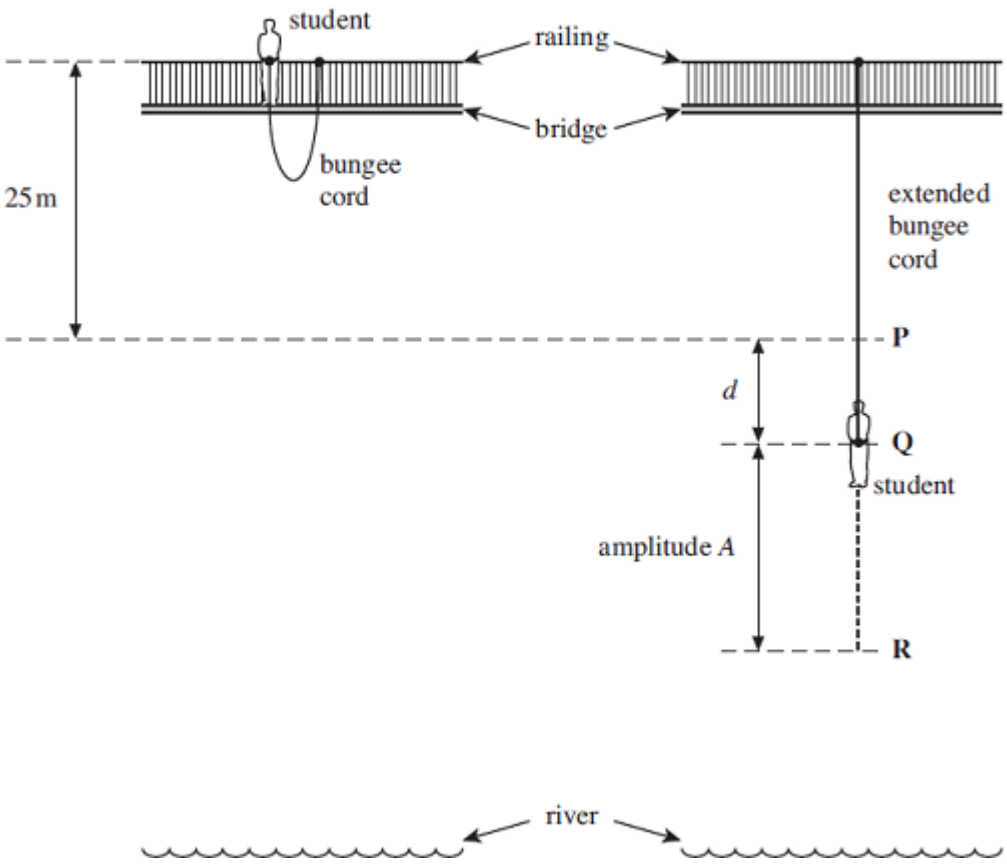
- Answer all questions
- Answer questions in the space provided
- All working must be shown

## Information

- The marks for the questions are shown in brackets

**1** 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.

_____

_____

_____

_____

_____

_____

_____

**(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.

_____

_____

_____

_____

**(2)**

**(Total 14 marks)**

**2** (a) A body is moving with simple harmonic motion. State **two** conditions that must be satisfied concerning the *acceleration* of the body.

condition 1 _____

_____

condition 2 _____

_____

**(2)**

(b) A mass is suspended from a vertical spring and the system is allowed to come to rest. When the mass is now pulled down a distance of 76 mm and released, the time taken for 25 oscillations is 23 s.

Calculate

(i) the frequency of the oscillations,

_____

_____

(ii) the maximum acceleration of the mass,

_____

_____

(iii) the displacement of the mass from its rest position 0.60 s after being released. State the direction of this displacement.

_____

_____

_____

_____

**(6)**

(c)

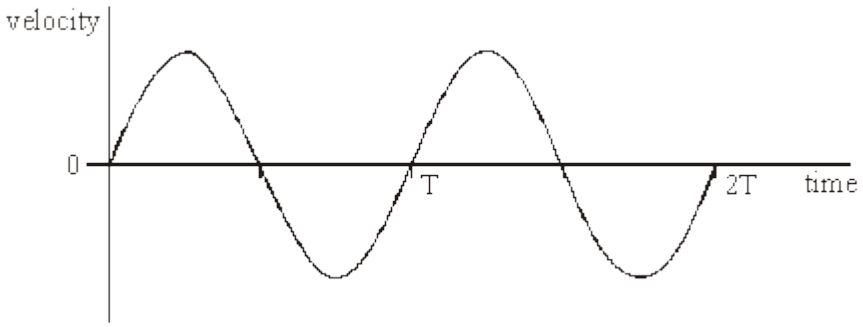



**Figure 1**

**Figure 1** shows qualitatively how the velocity of the mass varies with time over the first two cycles after release.

(i) Using the axes in **Figure 2**, sketch a graph to show qualitatively how the displacement of the mass varies with time during the same time interval.

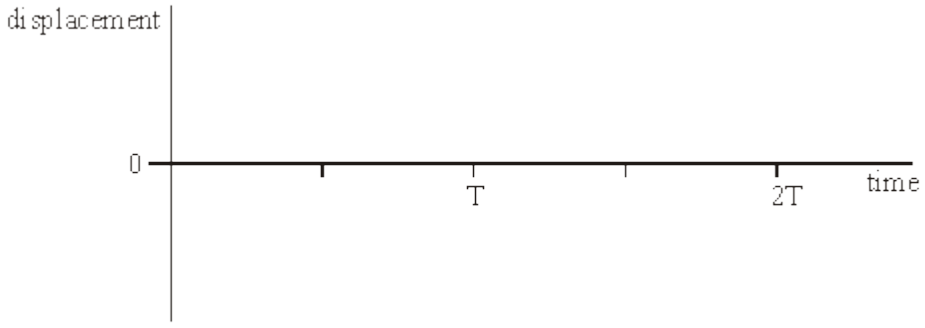



**Figure 2**

(ii) Using the axes in **Figure 3**, sketch a graph to show qualitatively how the potential energy of the mass-spring system varies with time during the same time interval.

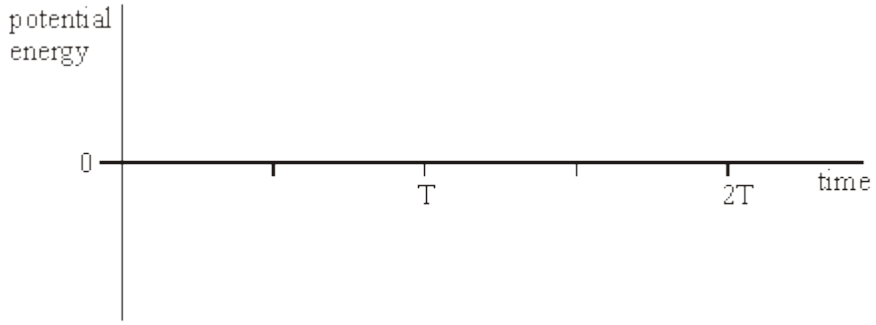



**Figure 3**

**(4)**

**(Total 12 marks)**

**3** (a) Simple harmonic motion may be represented by the equation

$$a = -(2\pi f)^2 x$$

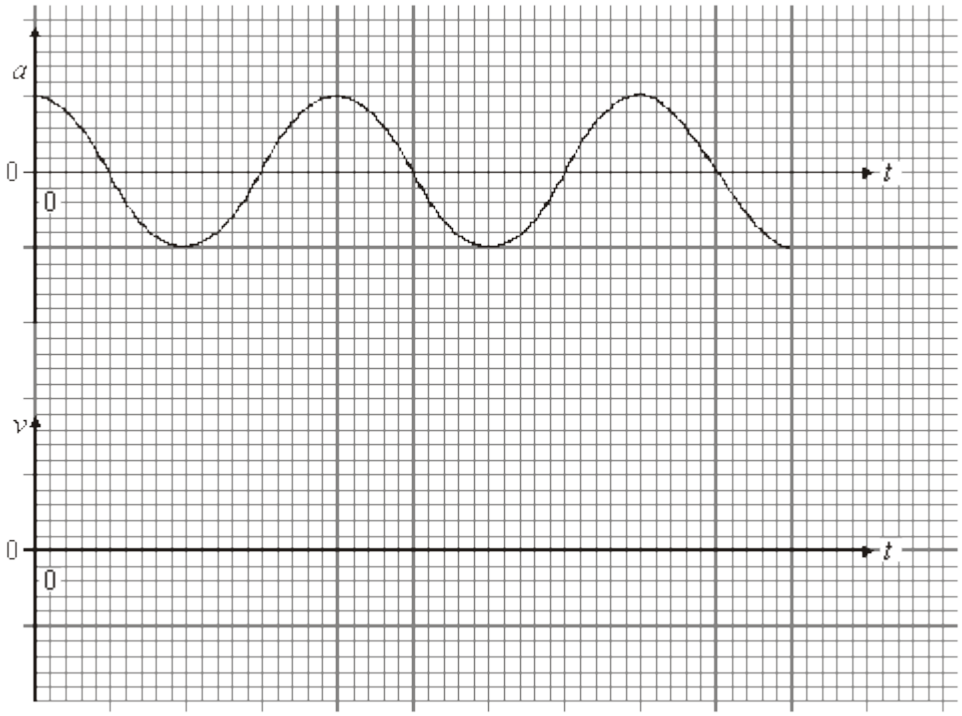
(i) Explain the significance of the minus sign in this equation.

_____

_____

**(1)**

(ii) In **Figure 1** sketch the corresponding *v*-*t* graph to show how the **phase** of velocity *v* relates to that of the acceleration *a*.

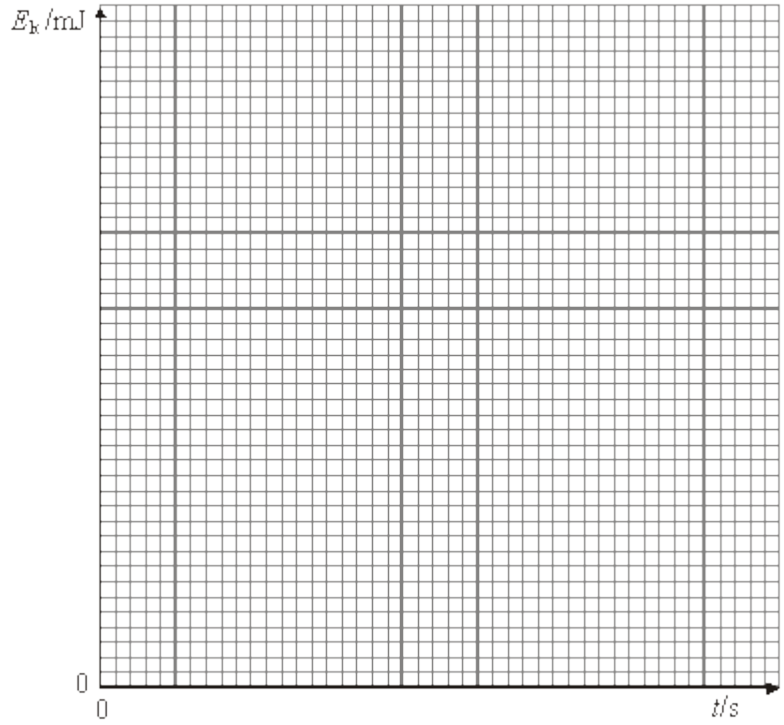



**(1)**

(b) (i) A mass of 24 kg is attached to the end of a spring of spring constant 60 N $m^{-1}$. The mass is displaced 0.035 m vertically from its equilibrium position and released. Show that the maximum kinetic energy of the mass is about 40 mJ.

**(5)**

(ii) When the mass on the spring is quite heavily damped its amplitude halves by the end of each complete cycle. On the grid of **Figure 2** sketch a graph to show how the kinetic energy, $E_k$, of the mass on the spring varies with time over a single period. Start at time, $t = 0$, with your maximum kinetic energy. You should include suitable values on each of your scales.




**(3)**

**(Total 10 marks)**

**4** (a) State the conditions necessary for a mass to undergo simple harmonic motion.

_____

_____

**(2)**

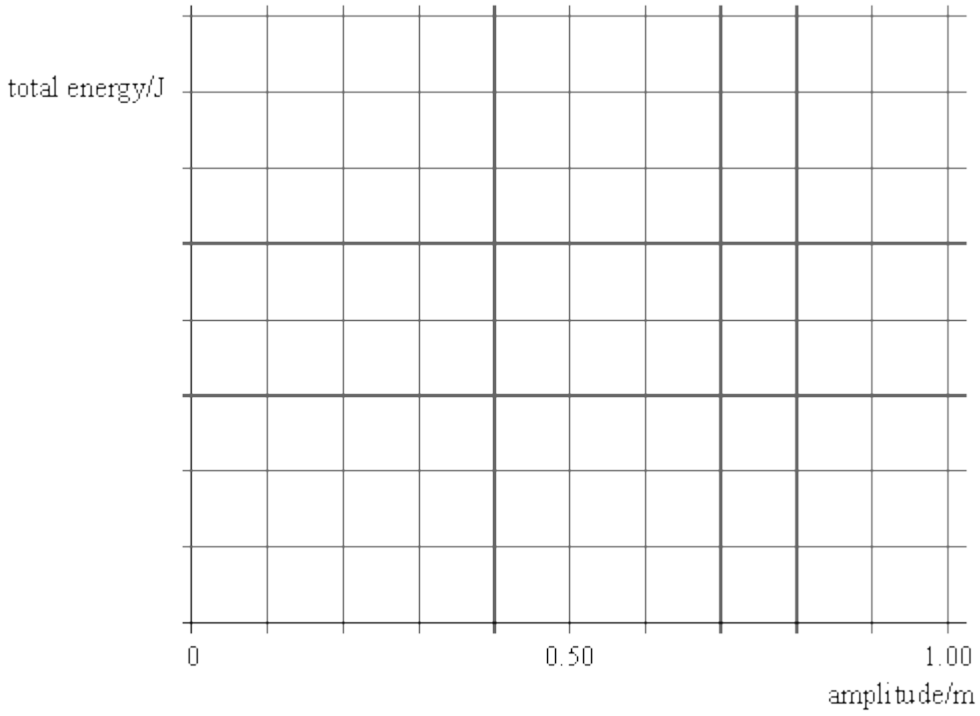
(b) A child on a swing oscillates with simple harmonic motion of period 3.2 s.

acceleration of free fall = 9.8 m $s^{-2}$

(i) Calculate the distance between the point of support and the centre of mass of the system.

**(2)**

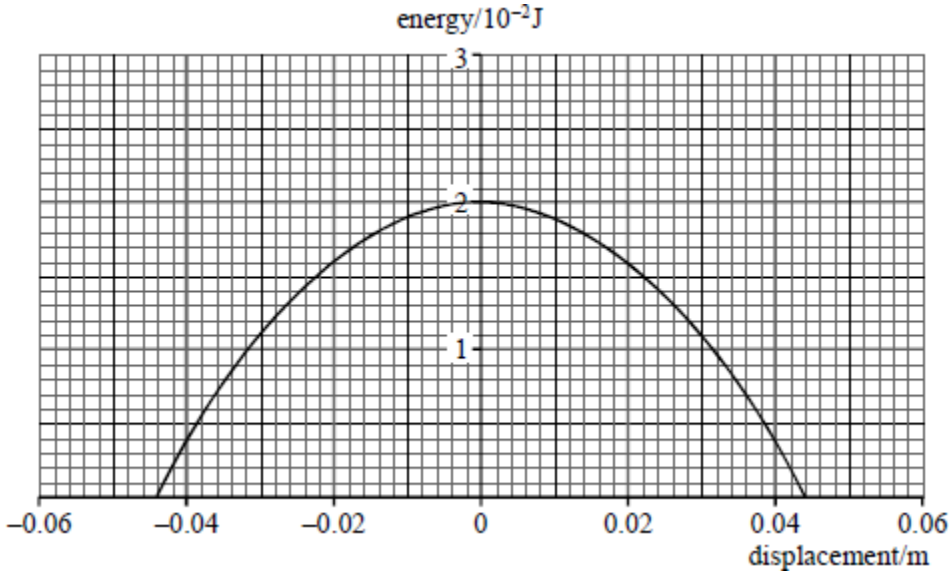
(ii) The total energy of the oscillations is 40 J when the amplitude of the oscillations is 0.50 m. Sketch a graph showing how the total energy of the child varies with the amplitude of the oscillations for amplitudes between 0 and 1.00 m. Include a suitable scale on the total energy axis.




**(2)**

**(Total 6 marks)**

**5** The diagram below shows how the kinetic energy of a simple pendulum varies with displacement.




(a) Sketch on the diagram above a graph to show how the potential energy of the pendulum varies with displacement.

**(2)**

(b) (i) State the amplitude of the oscillation.

_____

**(1)**

(ii) The frequency of vibration of the pendulum is 3.5 Hz. Write down the equation that models the variation of position with time for the simple harmonic motion of **this** pendulum.

_____

**(1)**

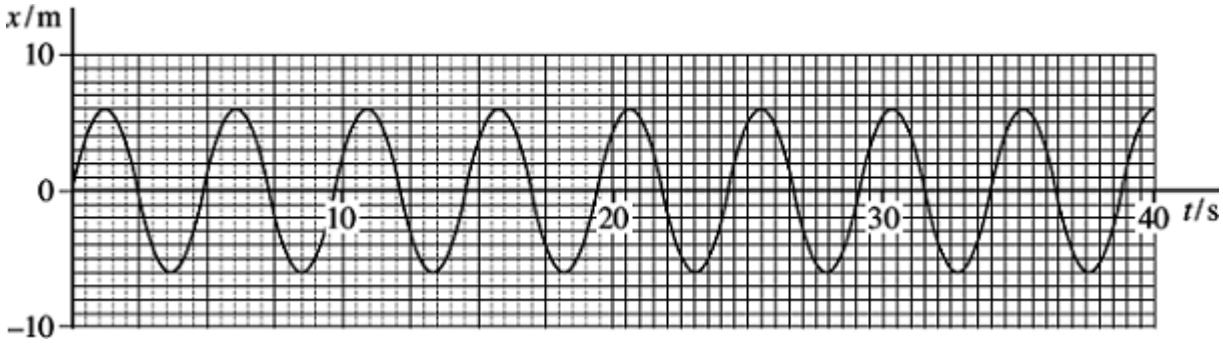
(iii) Calculate the maximum acceleration of the simple pendulum.

**(2)**

**(Total 6 marks)**

**6** A pirate ship is a type of amusement park pendulum ride in which a gondola carrying passengers is made to oscillate. The ride can be modelled using a simple pendulum consisting of a mass on a string.

The figure below shows how the displacement x of the mass varies with time *t*.




(a) (i) Define amplitude.

_____

_____

**(1)**

(ii) Determine the amplitude of the oscillations of the mass.

amplitude _____ m

**(1)**

(iii) Calculate the period of the pendulum.

period _____ s

**(2)**

(b) Another model was constructed using a pendulum of frequency 0.25 Hz with the mass having an initial amplitude of 4.5 m.

(i) Calculate the maximum velocity of the mass.

maximum velocity _____ $ms^{-1}$

**(2)**

(ii) Calculate the maximum acceleration of the mass.

maximum acceleration _____ $ms^{-2}$

**(2)**

(iii) Calculate the length of the simple pendulum that has a frequency of 0.25 Hz.

length _____ m

**(2)**

(c) To simplify the driving mechanism of the actual ride it is suggested that the gondola should be pushed each time it reaches the centre moving in one direction.
Explain why this would lead to large amplitude oscillations.

**(2)**

(d) When the force is no longer applied the gondola will naturally come to rest. The time for this to happen will usually be too long to satisfy the ride operators. External dampers are used to reduce the time taken to stop the gondola.
Explain why the gondola would come to rest naturally and what feature of an energy efficient ride design would make this a lengthy process.

**(3)**

**(Total 15 marks)**

**7** A particle oscillates with undamped simple harmonic motion.

The acceleration of the particle

**A** is always in the opposite direction to its velocity. ⬭

**B** decreases as the potential energy increases. ⬭

**C** is proportional to the frequency. ⬭

**D** is least when the speed is greatest. ⬭

**(Total 1 mark)**

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

**A** The acceleration is always directed away from the central point.
**B** The acceleration and velocity are always 180° out of phase.
**C** The velocity and displacement are always in the same direction.
**D** Acceleration and displacement are always 180° out of phase.

**(Total 1 mark)**

**9** For a body performing simple harmonic motion, which one of the following statements is correct?

**A** The maximum kinetic energy is directly proportional to the frequency.

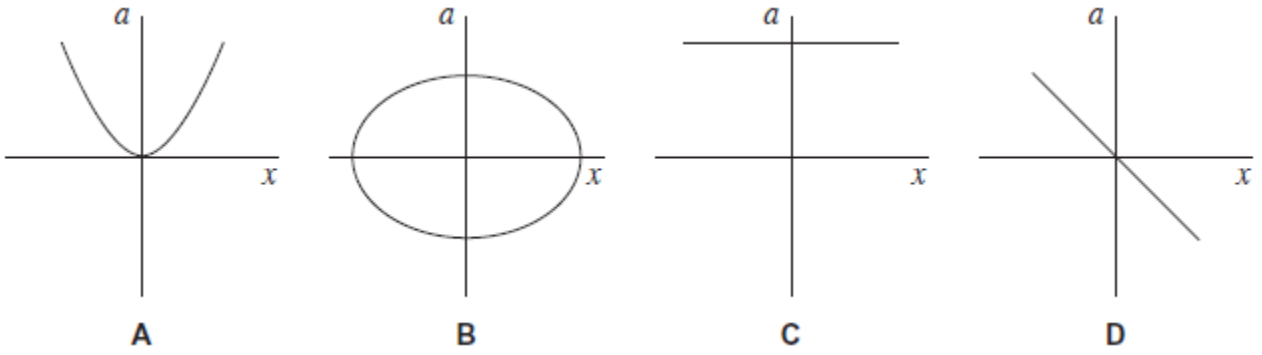
**B** The time for one oscillation is directly proportional to the frequency.

**C** The speed at any instant is directly proportional to the displacement.

**D** The maximum acceleration is directly proportional to the amplitude.

**(Total 1 mark)**

**10** 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)**