# 9.1 Simple Harmonic Motion

## Question Paper

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|---|---|
| Course | DP IB Physics |
| Section | 9. Wave Phenomena (HL only) |
| Topic | 9.1 Simple Harmonic Motion |
| Difficulty | Medium |

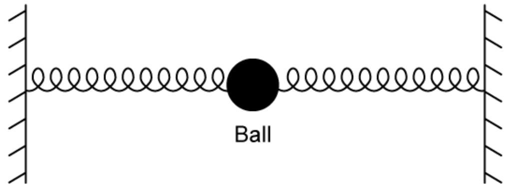
**Time allowed:** 70

**Score:** /55

**Percentage:** /100

## Question 1a

A ball within a ball-spring system oscillates about an equilibrium point.



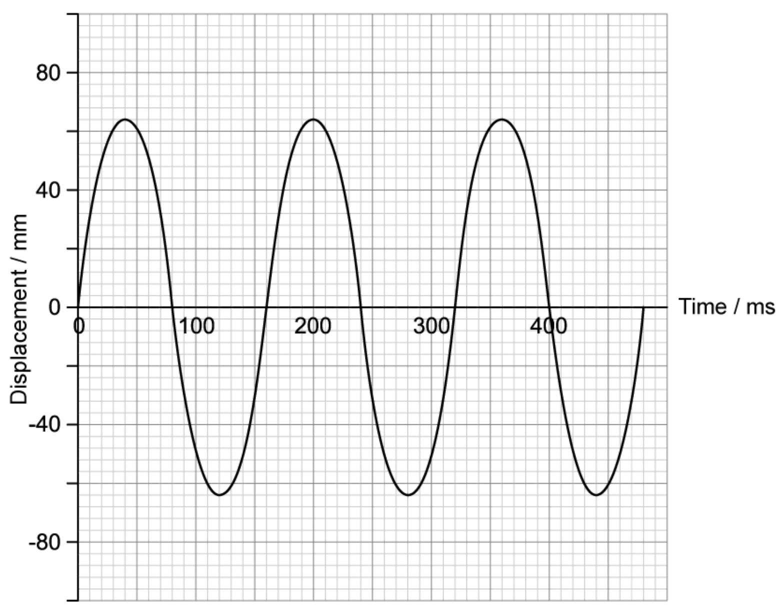

(a)
Outline how the ball-spring system demonstrates simple harmonic motion.

[2]

**[2 marks]**

## Question 1b

The ball is oscillating in simple harmonic motion. The graph shows the displacement of the ball over time.




(b)
Determine the maximum velocity of the ball.

[2]

**[2 marks]**

## Question 1c

(c)
For the motion of the ball

(i)
Show that the acceleration of the ball at 90 ms is 43 m $s^{-2}$.

[2]

(ii)
On the graph, mark an X at a point where the resultant force acting on the ball is zero.

[1]

**[3 marks]**

## Question 1d

(d)

On the axes provided, taking the oscillation as beginning at the positive amplitude when $t = 0$, sketch for the ball's motion:

(i)

The variation of displacement with time, label this graph *x*

[1]

(ii)

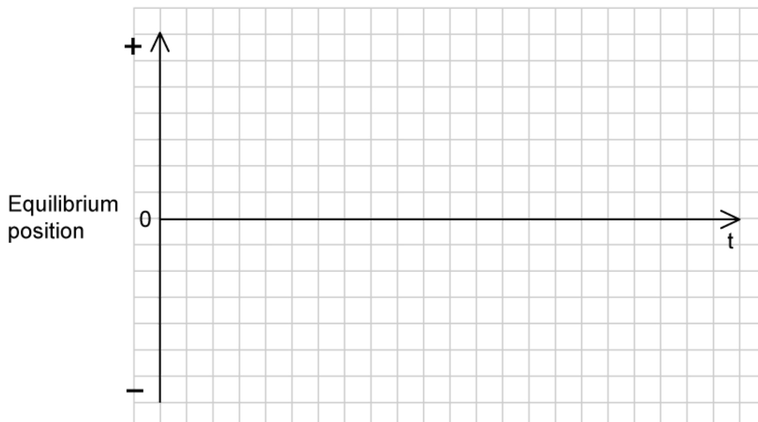
The variation of velocity with time, label this graph *v*

[1]

(iii)

The variation of acceleration with time, label this graph *a*

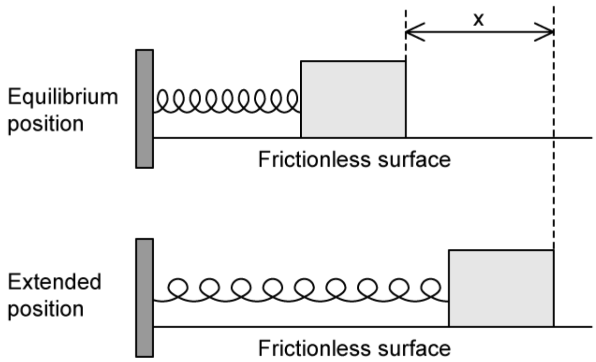
[1]




**[3 marks]**

## Question 2a

A mass of 45 g on a spring undergoes simple harmonic motion with a period of 0.84 s.
A wooden block attached to the same spring undergoes simple harmonic motion with a period of 0.64 s. The wooden block is displaced horizontally by 3.6 cm from the equilibrium position on a frictionless surface.




(a)
Determine the total energy in the oscillation of the wooden block.

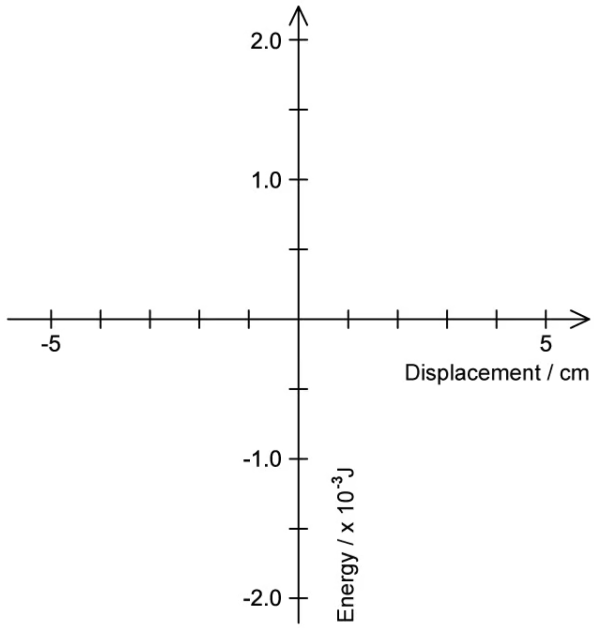
[4]

**[4 marks]**

## Question 2b

(b)

Using the information from part (a), sketch on the axes the kinetic, potential, and total energies of the oscillating wooden block as they vary with displacement.

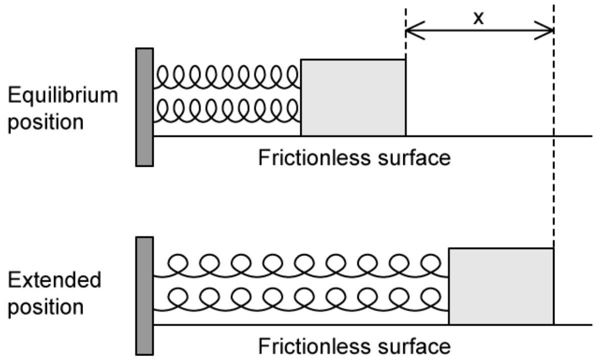



[3]

**[3 marks]**

## Question 2c

The investigation from part (a) is repeated. The same wooden block and spring are used, but a second identical spring is added in parallel.




(c)

Suggest how this change will affect the fractional uncertainty in the mass of the wooden block.

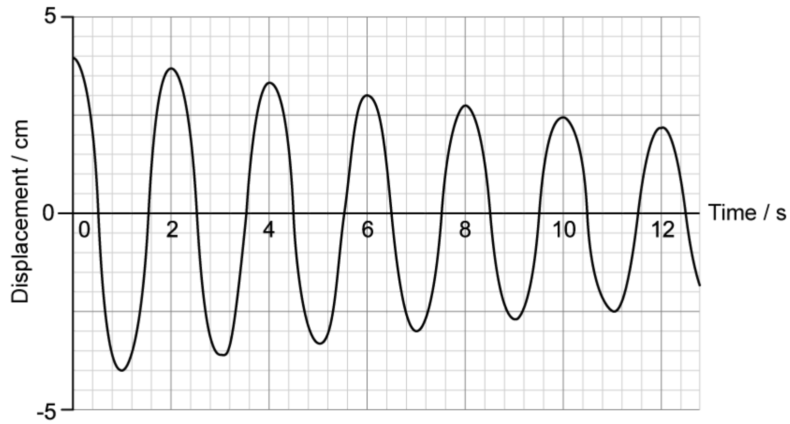
[3]

**[3 marks]**

## Question 2d

The spring from part (a) is attached to the mass in part (a), and oscillates freely in simple harmonic motion.

The graph shows the variation of displacement with time *t* of the mass on the spring.




(d)
For the new mass-spring system

(i)
Describe the motion of the mass on the spring.

[1]

(ii)
Determine the initial energy of the mass-spring system.

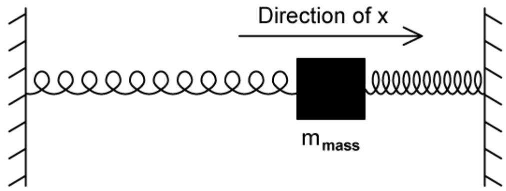
[2]

**[3 marks]**

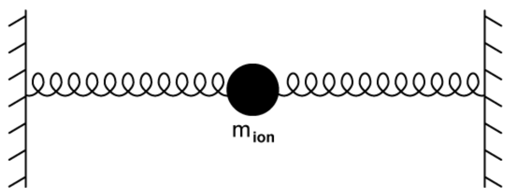
## Question 3a

A mass of 75 g is connected between two identical springs. The mass-spring system rests on a frictionless surface. A force of 0.025 N is needed to compress or extend the spring by 1.0 mm.

The mass is pulled from its equilibrium position to the right by 0.055 m and then released. The mass oscillates about the equilibrium position in simple harmonic motion.




The mass-spring system can be used to model the motion of an ion in a crystal lattice structure.




The frequency of the oscillation of the ion is $8 \times 10^{12}$ Hz and the mass of the ion is $6 \times 10^{-26}$ kg. The amplitude of the vibration of the ion is $2 \times 10^{-11}$ m.

(a)
For the oscillations

(i) Calculate the acceleration of the mass at the moment of release.

[1]

(ii) Estimate the maximum kinetic energy of the ion.

[1]

**[2 marks]**

## Question 3b

(b)
For the mass-spring system

(i)
Calculate the total energy of the system.

[1]

(ii)
Use the axes to sketch a graph showing the variation over time of the kinetic energy of the mass and the potential energy of the springs.

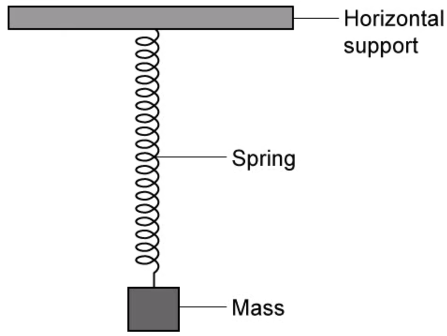
You should include appropriate values, and show the oscillation over one full period.

[2]

**[3 marks]**

## Question 3c

The same mass and a single spring from part (a) are attached to a rigid horizontal support.




The length of the spring with the mass attached is 64 mm. The mass is pulled downwards until the length of the spring is 76 mm. The mass is released, and the vertical mass-spring system performs simple harmonic motion.

(c)
For the new mass-spring system
(i)
Determine the velocity of the mass 2 seconds after its release.

[1]

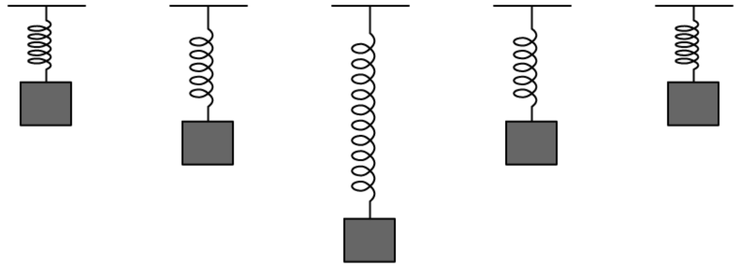
(ii)
Determine the kinetic energy of the mass at this point.

[2]

**[3 marks]**

## Question 3d

The diagram shows the vertical spring-mass system as it moves through one period.



(d)
Annotate the diagram to show when:

$E_p$ = max

$E_k$ = max

$v$ = 0

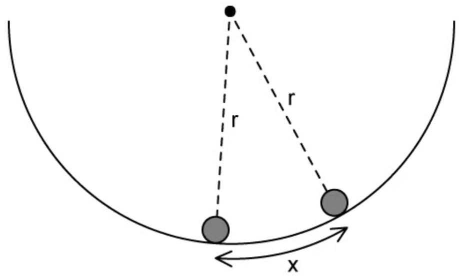
$v$ = max

[2]

**[2 marks]**

## Question 4a

A ball is displaced through a small distance *x* from the bottom of a bowl and then released.




The frequency of the resulting oscillation is 1.5 Hz and the maximum velocity reaches 0.36 m $s^{-1}$. *r* is the radius of the bowl.

(a)
For the oscillating ball:

(i)
Show that the radius of the bowl in which it oscillates is approximately 11 cm.

[1]

(ii)
Calculate the amplitude of oscillation.

[1]

**[2 marks]**

## Question 4b

(b)
For the ball

(i)
Calculate the time taken for the displacement to fall to 0.01 m after it is released.

[2]

(ii)
Determine the acceleration at 0.2 s after it is released.

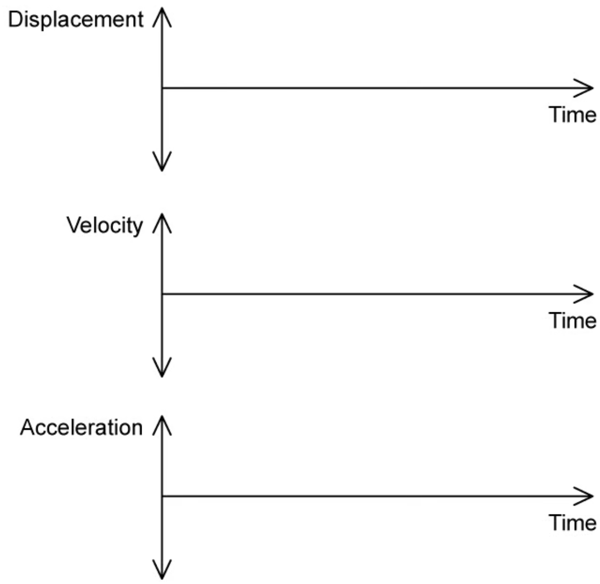
[1]

**[3 marks]**

## Question 4c

(c)

Sketch the graphs showing how the displacement, velocity and acceleration of the ball vary with time. You should include any relevant values.




[4]

**[4 marks]**

## Question 4d

The ball was replaced by a ball of the same size, but with a greater mass.

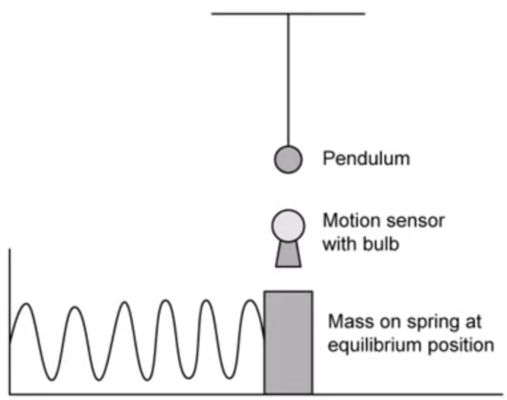
(d)
Outline what effect this would have on the period of the oscillation.

[2]

**[2 marks]**

## Question 5a

An experiment is carried out on Planet Z using a simple pendulum and a mass-spring system. The block moves horizontally on a frictionless surface. A motion sensor is placed above the equilibrium position of the block which lights up every time the block passes it.




The pendulum and the block are displaced from their equilibrium positions and oscillate with simple harmonic motion. The pendulum bob completes 150 full oscillations in seven minutes and the bulb lights up once every 0.70 seconds. The block has a mass of 349 g.

(a)
Show that the value of the spring constant *k* is approximately 7 N m$^{-1}$.

[2]

**[2 marks]**

## Question 5b

The volume of Planet Z is the same as the volume of Earth, but Planet Z is twice as dense.

(b)
For the experiment on Planet Z
(i)
Show that the length of the pendulum, $l = \dfrac{4mg}{k}$

[2]

(ii)
Calculate the value of $l$.

[2]

**[4 marks]**

## Question 5c

The angle that the pendulum string makes with the horizontal is 81.4 ° when the acceleration of the pendulum bob is at a maximum.

(c)
Determine the maximum speed reached my the pendulum bob.

[3]

**[3 marks]**

## Question 5d

(d)
Compare and contrast how performing the experiment on Planet Z, rather than on Earth, affects the period of the oscillations of the pendulum and the mass-spring system.

[2]

**[2 marks]**