9.1 Simple Harmonic Motion

Question Paper

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

Time allowed: 80

Score: /65

Percentage: /100

Question 1a

(a)
State what is meant by the time period of an oscillation.

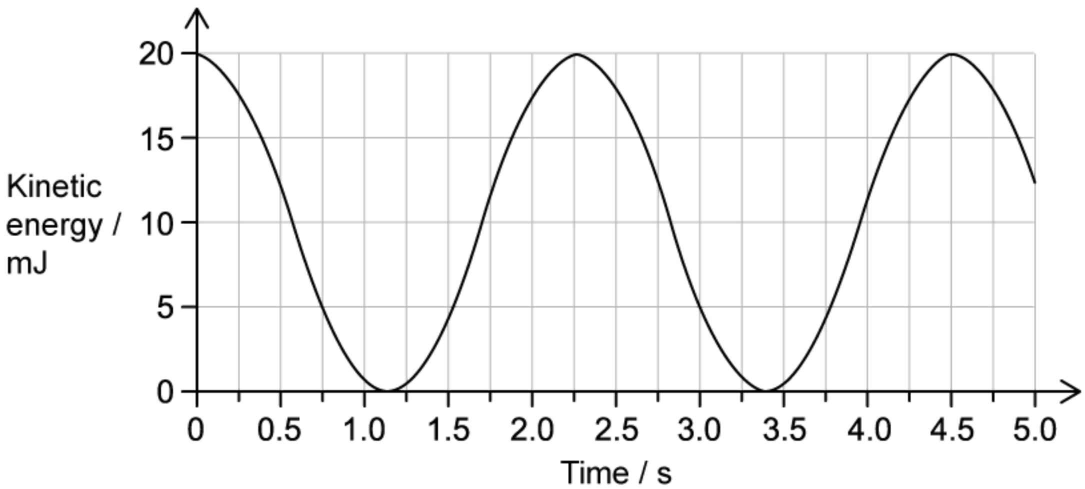
[1]

[1 mark]

Question 1b

A small metal pendulum bob is suspended from a fixed point by a thread with negligible mass. Air resistance is also negligible.

The pendulum begins to oscillate from rest. Assume that the motion of the system is simple harmonic, and in one vertical plane. The graph shows the variation of kinetic energy of the pendulum bob with time.



(b)
Determine the time period of the pendulum.

[1]

[1 mark]

Question 1c

(c)
Label a point X on the graph where the pendulum is in equilibrium.

[1]

[1 mark]

Question 1d

The mass of the pendulum bob is 60×10^{-3} kg.

(d)

(i)

Determine the maximum kinetic energy of the pendulum bob.

[1]

(ii)

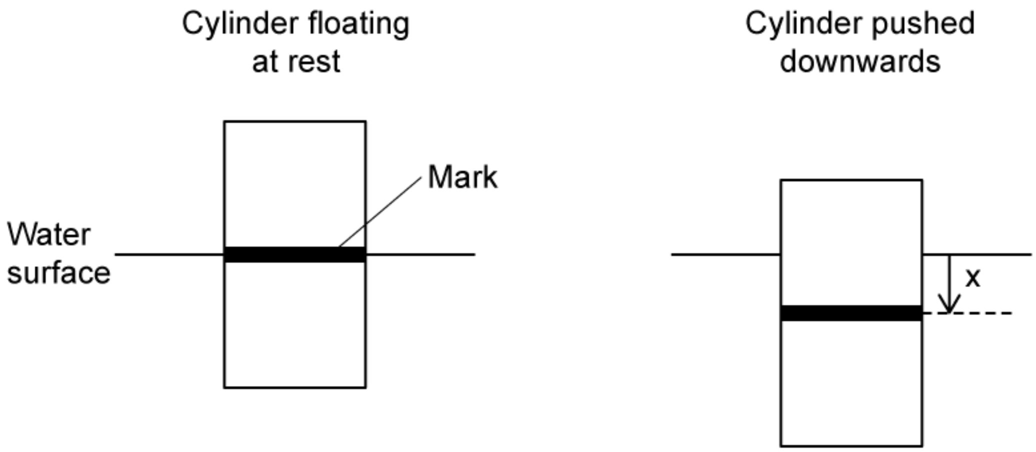
Hence or otherwise, show that the maximum speed of the bob is about 0.82 m s^{-1}.

[3]

[4 marks]

Question 2a

A solid vertical cylinder of uniform cross-sectional area A floats in water. The cylinder is partially submerged. When the cylinder floats at rest, a mark is aligned with the water surface. The cylinder is pushed vertically downwards so that the mark is a distance *x* below the water surface.



The cylinder is released at time $t = 0$. The resultant force on the cylinder is related to the displacement x by:

$$F = kx$$

(a)

(i)
Define simple harmonic motion.

[2]

(ii)
Outline why the cylinder performs simple harmonic motion when released.

[2]

[4 marks]

Question 2b

The mass, m, of the cylinder is 100 kg and the value of k is 3000 kg s^{-2}.

(b)

(i)
Define angular frequency.

[1]

(ii)
Show that the equation from part (a) can be related to an expression for angular frequency to give $-\omega^2 m = k$.

[3]

(iii)
Hence, show that the angular frequency, ω of oscillation of the cylinder is 5.5 rad s^{-1}.

[2]

[6 marks]

Question 2c

The cylinder was initially pushed down by a displacement $x = 0.15$ m.

(c)

(i)
Determine the force applied to the cylinder.

[1]

(ii)
Determine the maximum kinetic energy E_{kmax} of the cylinder.

[3]

[4 marks]

Question 2d

(d)
Draw, on the axes below, the graph to show how the kinetic energy of the cylinder varies with time during one period of oscillation *T*.

[2 marks]

Question 3a

A vibrating guitar string is an example of an object oscillating with simple harmonic motion.

(a)
Give three other real-world examples of objects that oscillate with simple harmonic motion.

[3]

[3 marks]

Question 3b

The guitar string vibrates with simple harmonic oscillations at a frequency of 225 Hz.

(b)
Determine the time it takes to perform 15 complete oscillations.

[3]

[3 marks]

Question 3c

The amplitude of the oscillation is 0.4 mm.

(c)
Determine the maximum acceleration of the guitar string.

[4]

[4 marks]

Question 3d

(d)
Calculate the total energy in the string during this oscillation, given that the mass of the string is 3.3 g.

[3]

[3 marks]

Question 4a

(a)
The defining equation of simple harmonic motion is:

$$a = -\omega^2 x$$

(i)
Define each variable and give an appropriate unit for each.

[3]

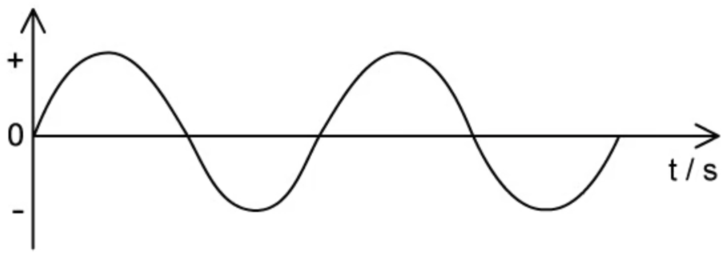
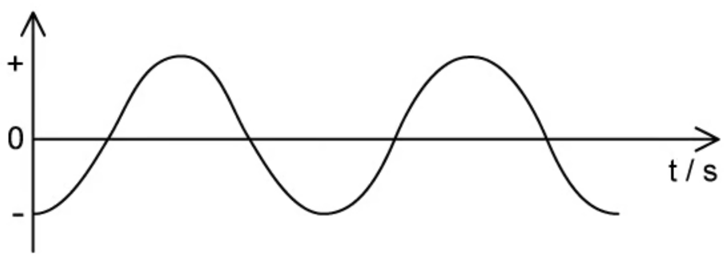
(ii)
State the significance of the minus sign.

[1]

[4 marks]

Question 4b

A mass on a spring begins oscillating from its equilibrium position. Time, t = 0 s is measured from where the mass begins moving in the negative direction. The motion of the oscillation is shown in the graphs below.

<table>
<tr><th>Graph</th><th>Variable on y-axis</th></tr>
<tr><td>
</td><td>Acceleration</td></tr>
<tr><td>
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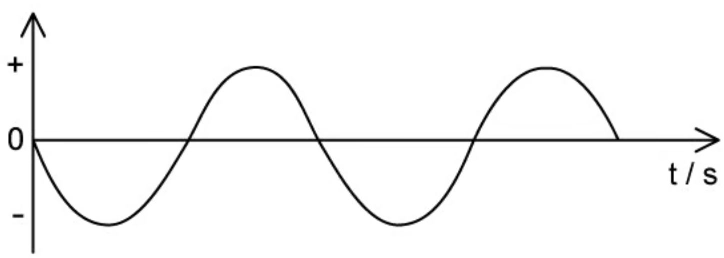
<tr><td>
</td><td></td></tr>
</table>

(b)
Complete the table to show the correct variable on the *y*-axis of each graph.

[2]

[2 marks]

Question 4c

The period of the oscillation T = 1.84 s and the mass is 55 g. The mass-spring system oscillates with an amplitude of 5.2 cm.

(c)
Calculate the spring constant of the spring.

[3]

[3 marks]

Question 4d

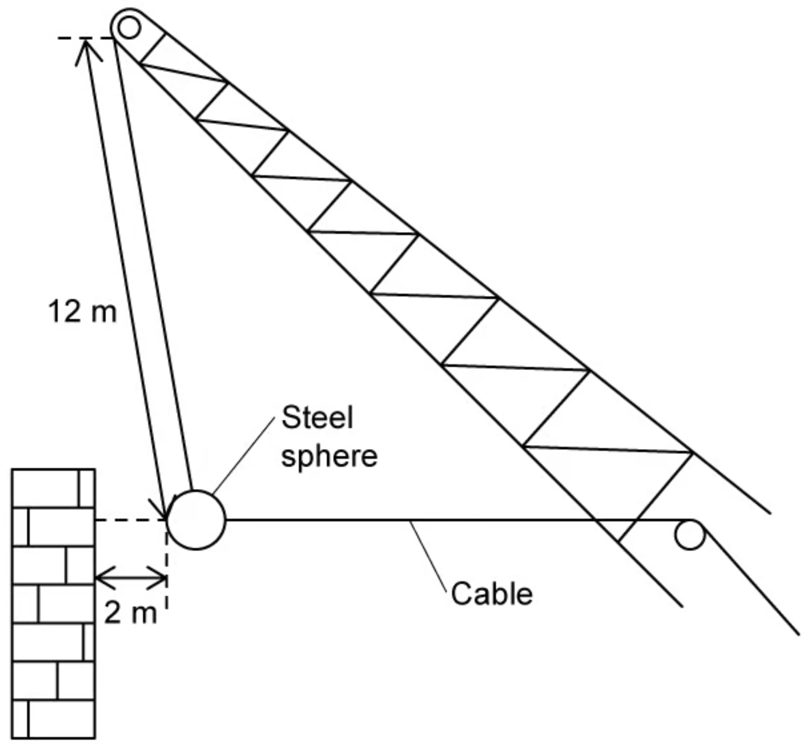
(d)
Determine the magnitude of the displacement of the mass at t = 1.2 s.

[3]

[3 marks]

Question 5a

The diagram below shows a system used for demolishing buildings.



A 2750 kg steel sphere is suspended by a steel cable of length 12 m. The steel sphere is pulled 2 m to the side by another cable and then released.

When the wall is not in the way, the system performs simple harmonic motion.

(a)
Calculate the frequency of the oscillation.

[4]

[4 marks]

Question 5b

When the steel sphere hits the wall, the suspension cable is vertical.

(b)
Calculate the speed of the steel sphere when it hits the wall.

[4]

[4 marks]

Question 5c

(c)
Calculate the kinetic energy of the steel sphere as it hits the wall. Give your answer to an appropriate amount of significant figures.

[5]

[5 marks]

Question 5d

(d)
Complete the following sentences using appropriate words to describe the effect on the kinetic energy of the sphere when doubling its mass and displacement.

Doubling the mass of the steel sphere would cause the kinetic energy to __________ by a factor of ________. This is because kinetic energy is proportional to _________________.

Doubling the displacement of the steel sphere would cause the kinetic energy to __________ by a factor of ________. This is because the kinetic energy is proportional to ___________________.

[4]

[4 marks]