4.1 Oscillations

Question Paper

Course	DP IB Physics
Section	4. Waves
Topic	4.1 Oscillations
Difficulty	Hard

Time allowed: 50

Score: /35

Percentage: /100

Question 1a

A mass-spring system has been set up horizontally on the lab bench, so that the mass can oscillate.

The time period of the mass is given by the equation:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

(a)

(i)

Calculate the spring constant of a spring attached to a mass of 0.7 kg and time period 1.4 s.

[1]

(ii) Outline the condition under which the equation can be applied.

[1]

[2 marks]

Question 1b

(b)

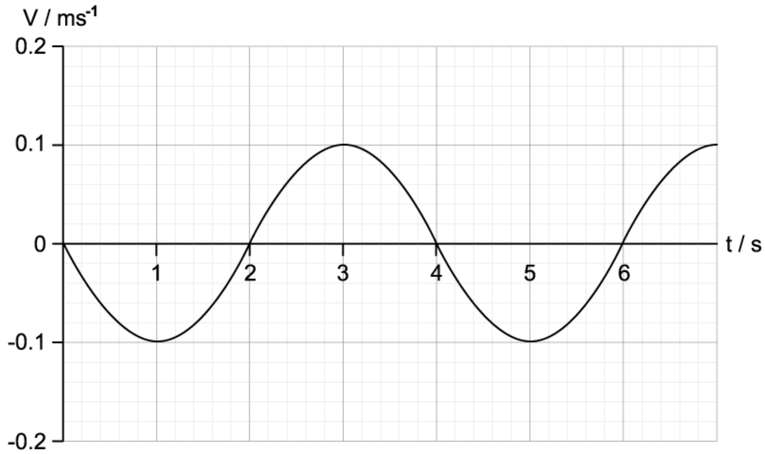
Sketch a velocity-displacement graph of the motion of the block as it undergoes simple harmonic motion.

[2 marks]

Question 1c

A new mass of m = 50 g replaces the 0.7 kg mass and is now attached to the mass-spring system.

The graph shows the variation with time of the velocity of the block.



(c)
Determine the total energy of the system with this new mass.

[2]

[2 marks]

Question 1d

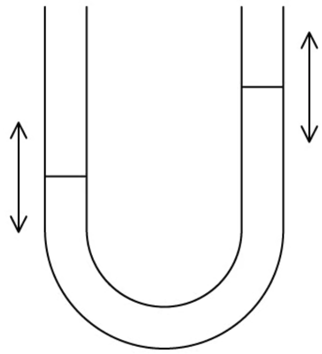
(d)
Determine the potential energy of the system when 6 seconds have passed.

[1]

[1 mark]

Question 2a

A volume of water in a U-shaped tube performs simple harmonic motion.



(a)
State and explain the phase difference between the displacement and the acceleration of the upper surface of the water.

[2 marks]

Question 2b

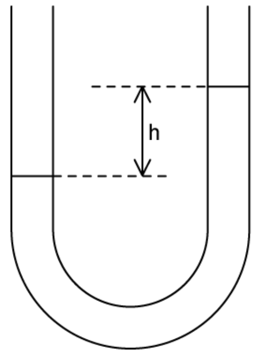
The U-tube is tipped and then set upright, to start the water oscillating. Over a period of a few minutes, a motion sensor attached to a data logger records the change in velocity from the moment the U-tube is tipped. Assume there is no friction in the tube.

(b)
Sketch the graph the data logger would produce.

[2 marks]

Question 2c

The height difference between the two arms of the tube h, and the density of the water ρ.



(c)
Construct an equation to find the restoring force, F, for the motion.

[3 marks]

Question 2d

The time period of the oscillating water is given by $T = 2\pi\sqrt{\frac{L}{g}}$ where L is the height of the water column at equilibrium and *g* is the acceleration due to gravity.

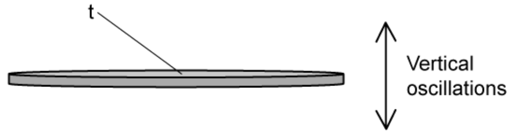
(d)
If L is 15 cm, determine the frequency of the oscillations.

[1]

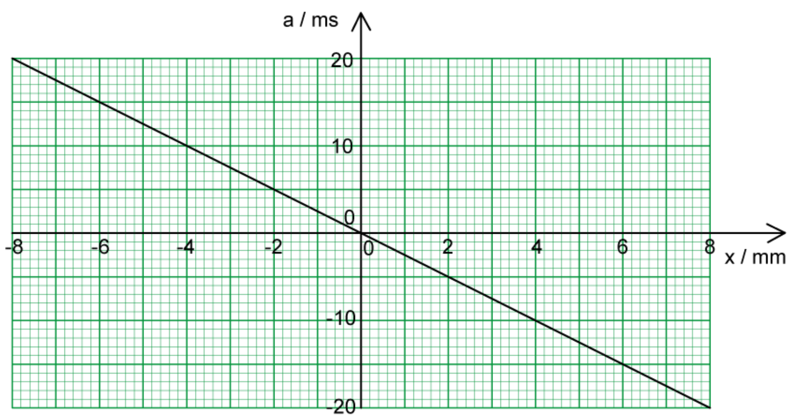
[1 mark]

Question 3a

The diagram shows a flat metal disk placed horizontally, that oscillates in the vertical plane.



The graph shows how the disk's acceleration, *a*, varies with displacement, *x*.



(a)
Show that the oscillations of the disk are an example of simple harmonic motion.

[3]

[3 marks]

Question 3b

Some grains of salt are placed onto the disk.

The amplitude of the oscillation is increased gradually from zero.

(b)
At amplitude A_Z, the grains of salt are seen to lose contact with the metal disk.

(i)
Determine and explain the acceleration of the disk when the grains of salt first lose contact with it.

[3]

(ii)
Deduce the value of amplitude A_Z.

[1]

[4 marks]

Question 3c

(c)
For the amplitude at which the grain of salt loses contact with the disk:

(i)
Deduce the maximum velocity of the oscillating disk.

[2]

(ii)
Calculate the period of the oscillation.

[1]

[3 marks]

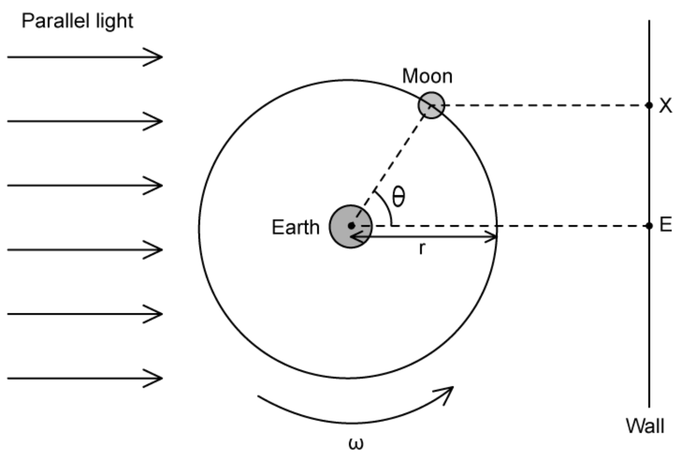
Question 4a

For a homework project, some students constructed a model of the Moon orbiting the Earth to show the phases of the Moon.

The model was built upon a turntable with radius *r*, that rotates uniformly with an angular speed ω.

The students positioned LED lights to provide parallel incident light that represented light from the Sun.

The diagram shows the model as viewed from above.



The students noticed that the shadow of the model Moon could be seen on the wall.

At time t = 0, θ = 0 and the shadow of the model Moon could not be seen at position E as it passed through the shadow of the model Earth.

Some time later, the shadow of the model Moon could be seen at position X

(a)
For this model Moon and Earth

(i)
Construct an expression for θ in terms of ω and *t*

[1]

(ii)
Derive an expression for the distance EX in terms of r, ω and *t*

[1]

(iii)
Describe the motion of the shadow of the Moon on the wall

[1]

[3 marks]

Question 4b

The diameter, *d*, of the turntable is 50 cm and it rotates with an angular speed, ω, of 2.3 rad s^{-1}.

(b)
For the motion of the shadow of the model Moon, calculate:

(i)
The amplitude, *A*.

[1]

(ii)
The period, *T*.

[1]

(iii)
The speed as the shadow passes through position E.

[2]

[4 marks]

Question 4c

The defining equation of SHM links acceleration, a, angular speed, ω, and displacement, x.

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

(c)
For the shadow of the model Moon:

(i)
Determine the magnitude of the acceleration when the shadow is instantaneously at rest.

[2]

(ii)
Without the use of a calculator, predict the change in the maximum acceleration if the angular speed was reduced by a factor of 4 and the diameter of the turntable was half of its original length.

[1]

[3 marks]