IB · DP · Physics

2 hours 14 questions

Structured Questions

4.1 Oscillations

4.1.1 Properties of Oscillations / 4.1.2 Simple Harmonic Oscillations / 4.1.3 SHM Graphs / 4.1.4 Energy in SHM

Easy (5 questions)	/46
Medium (5 questions)	/61
Hard (4 questions)	/35
Total Marks	**/142**

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Easy Questions

1 (a) Complete the table by adding the correct key terms to the definitions.

Definition	Key Term
The time interval for one complete oscillation	
The distance of a point on a wave from its equilibrium position	
The number of oscillations per second	
The repetitive variation with time of the displacement of an object about its equilibrium position	
The maximum value of displacement from the equilibrium position	
The oscillations of an object have a constant period	

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(3 marks)

(b) The graph shows the displacement of an object with time.

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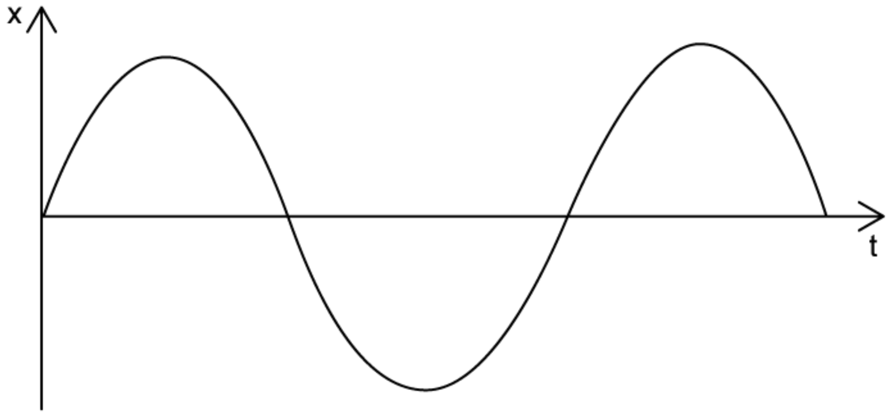


On the graph, label the following:

(i) the time period T

[1]

(ii) the amplitude x_0

[1]

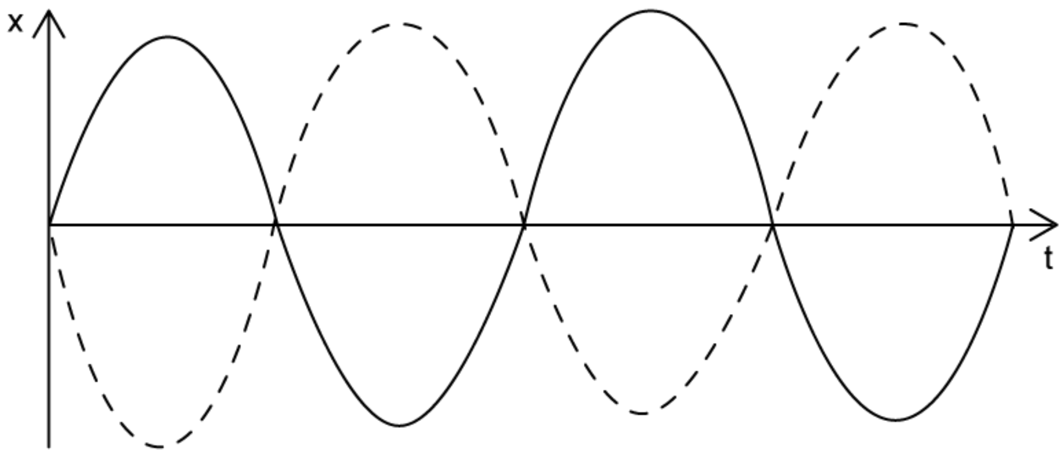
(2 marks)

(c) An object oscillates isochronously with a frequency of 0.4 Hz.

Calculate the period of the oscillation.

(1 mark)

(d) The graph shows the oscillations of two different waves.



For the two oscillations, state:

(i) The phase difference in terms of wavelength λ, degrees and radians.

[3]

(ii) Whether the oscillations are in phase or in anti-phase.

[1]

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(4 marks)

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2 (a) Fill in the blank spaces with a suitable word.

Objects in simple harmonic motion ___________ about an equilibrium point. The restoring force and __________ always act toward the equilibrium, and are ___________ to ___________, but act in the opposite direction.

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(3 marks)

(b) Hooke's law can be used to describe a mass-spring system performing simple harmonic oscillations. Hooke's Law states that;

$$F = -kx$$

State the definition of the following variables and an appropriate unit for each:

(i) F

[1]

(ii) k

[1]

(iii) x

[1]

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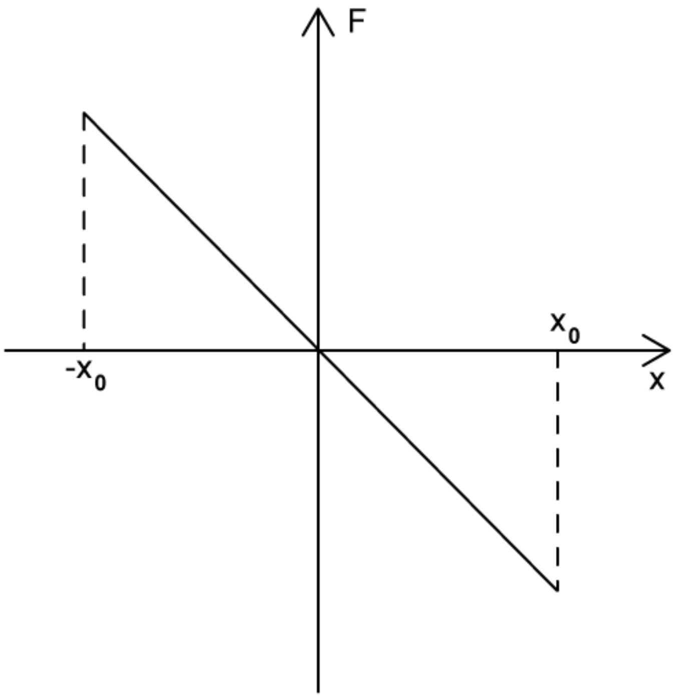
(3 marks)

(c) The graph shows the restoring force on a bungee cord.



Identify the quantity given by the gradient, where $F = -kx$

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(1 mark)

(d) For an object in simple harmonic motion:

(i) State the direction of the restoring force in relation to its displacement

[1]

(ii) State the relationship between force and displacement

[1]

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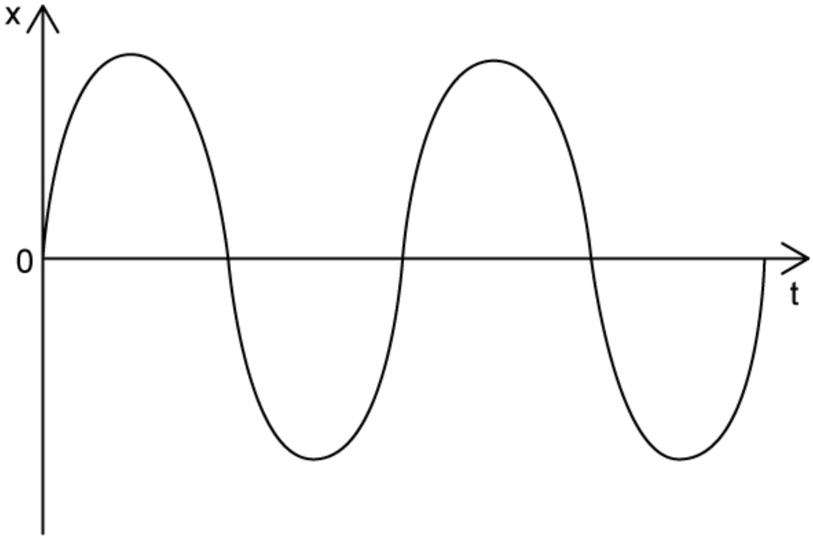
(2 marks)

3 (a) An object oscillates in simple harmonic motion. The graph shows the variation of displacement with time. The object starts from the equilibrium position when time t = 0.



For this object:

(i) Describe the shape of the displacement-time graph

[1]

(ii) Outline how the shape of the graph would change if the oscillation was measured from amplitude x_0

[2]

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(3 marks)

(b) Identify the correct *v-t* graph for the oscillation of the object in the *x-t* graph from part (a)

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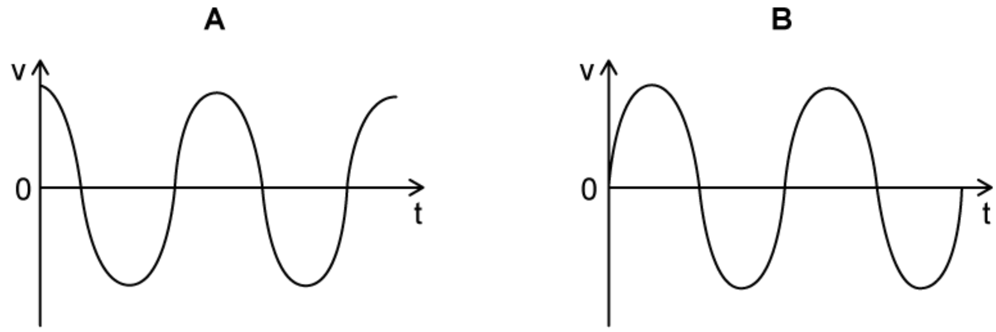

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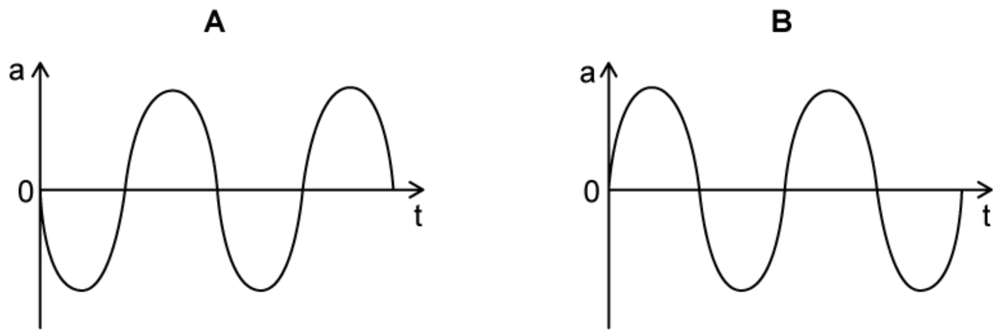
(1 mark)

(c) Identify the correct a-*t* graph for the oscillation of the object in the *x*-*t* graph from part (a)



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(1 mark)

(d) State the phase difference in radians between the displacement-time graph from part (a) and the correct velocity-time graph from part (b)

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(2 marks)

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4 (a) Define the term 'total energy' for a system oscillating in simple harmonic motion.

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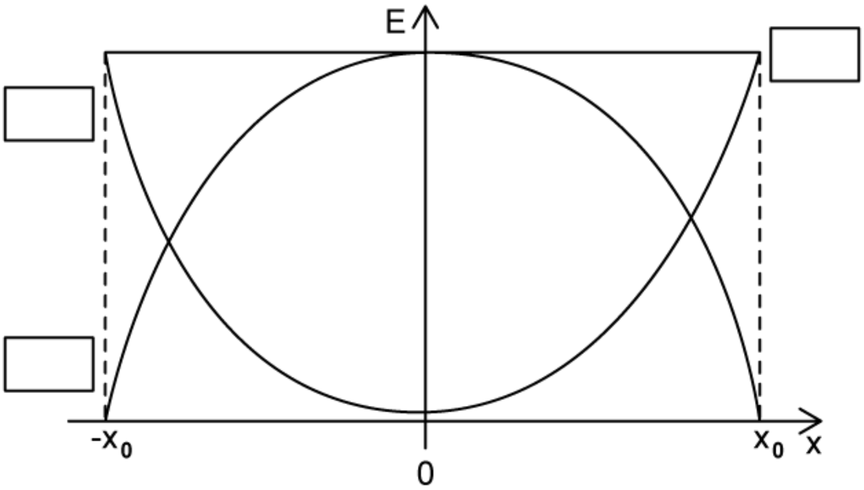
(1 mark)

(b) The graph shows the potential energy E_P, kinetic energy E_K and total energy E_T of a system in simple harmonic motion.



Add the following labels to the correct boxes on the graph:

- E_T
- E_P
- E_K

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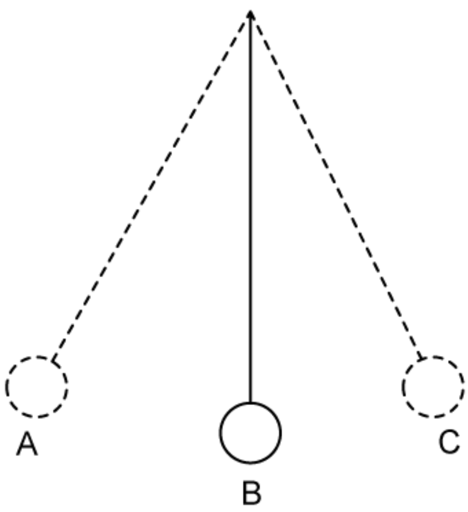
(3 marks)

(c) The diagram indicates the positions of a simple pendulum in simple harmonic motion.



Identify the position of the pendulum when:

(i) Kinetic energy is zero

[1]

(ii) Potential energy is at a maximum

[1]

(iii) Kinetic energy is at a maximum

[1]

(iv) Potential energy is zero

[1]

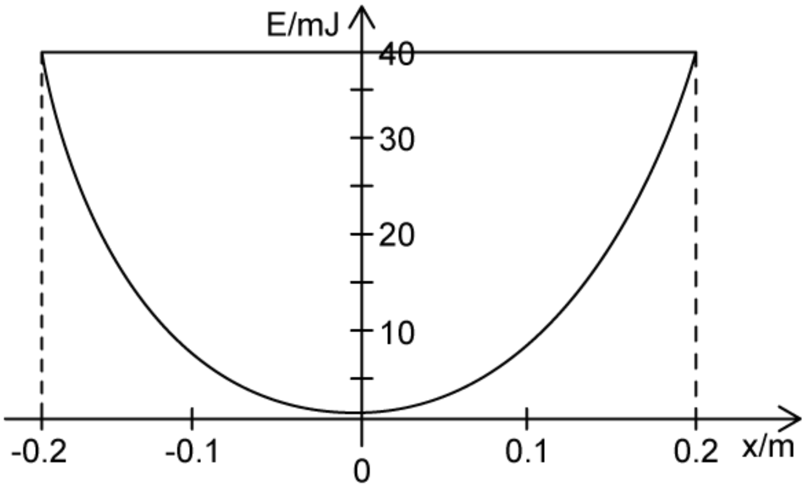
(4 marks)

(d) The period of the oscillation shown in part (c) is 2.2 s.

Calculate the frequency of the oscillation.

(2 marks)

5 (a) A mass-spring system oscillates with simple harmonic motion. The graph shows how the potential energy of the spring changes with displacement.



For the mass-spring system, determine:

(i) The maximum potential energy

[1]

(ii) The total energy

[1]

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(2 marks)

(b) Using the graph in part (a), determine:

(i) The amplitude x_0 of the oscillation

[1]

(ii) The potential energy in the spring when the displacement x = 0.1 m

[1]

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(2 marks)

(c) The block used in the same mass-spring system has a mass *m* of 25 g. The maximum kinetic energy of the block is 40 mJ.

Calculate the maximum velocity of the oscillating block

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(4 marks)

(d) The spring constant *k* of the spring used is 1.8 N m^{-1}

Calculate the restoring force acting on the mass-spring system at amplitude x_0

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(2 marks)

Medium Questions

1 (a) A pendulum undergoes small-angle oscillations.

Outline the equation that defines simple harmonic motion.

(3 marks)

(b) Sketch a graph to represent the change in amplitude, x_0 against time for one swing of the pendulum. Start the time at zero seconds.

(2 marks)

(c) The time period of 10 oscillations is found to be 12.0 s.

Determine the frequency when the bob is 1.0 cm from its equilibrium position.

(2 marks)

(d) The student wants to double the frequency of the pendulum swing. The time period, *T* of a simple pendulum is given by the equation:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where *L* is the length of the string and *g* is the acceleration due to gravity

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Deduce the change which would achieve this.

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(4 marks)

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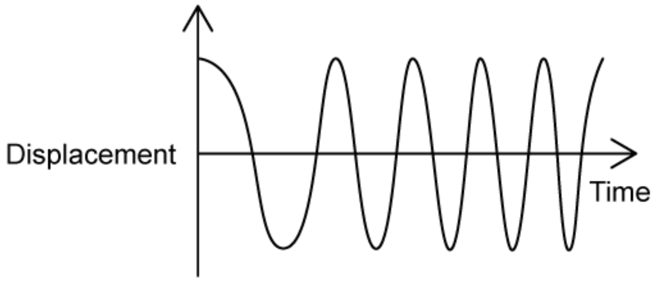
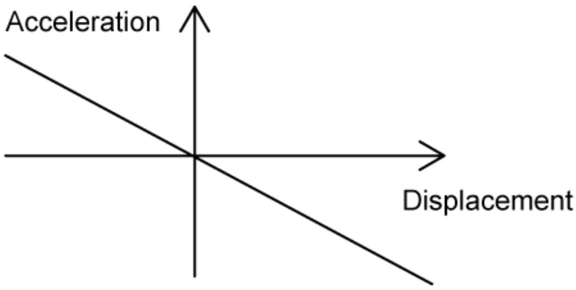
2 (a) State and explain whether the motion of the objects in graphs I, II and III are simple harmonic oscillations

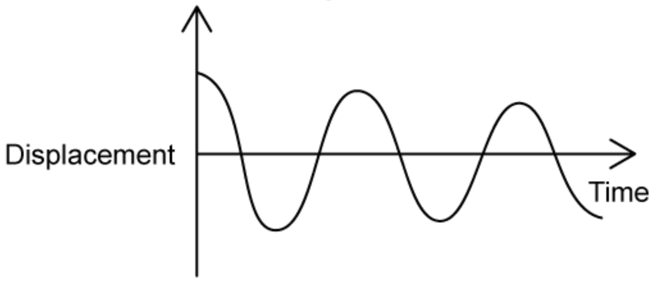
Graph 1



Graph 2



Graph 3

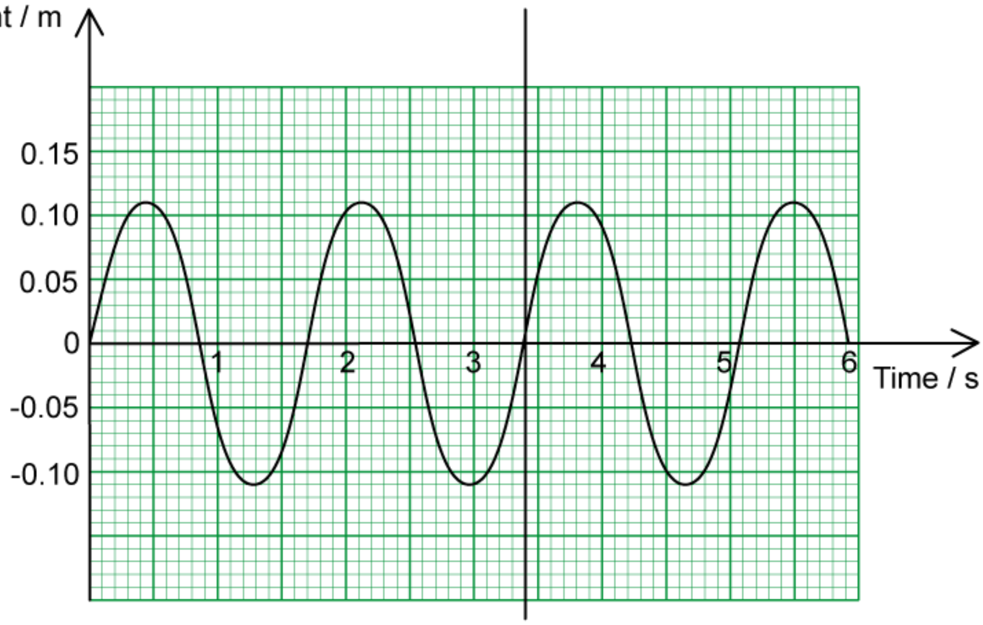


(6 marks)

(b) Explain why, in practice, a freely oscillating pendulum cannot maintain a constant amplitude.

(2 marks)

(c) The motion of an object undergoing SHM is shown in the graph below.



For this oscillator, determine:

(i) The amplitude, *A.*

[1]

(ii) The period, *T.*

[1]

(iii) The frequency, *f.*

[1]

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(3 marks)

(d) Using the graph from part (c), state a time in seconds when the object performing SHM has:

(i) Maximum positive velocity.

[1]

(ii) Maximum negative acceleration.

[1]

(iii) Maximum potential energy.

[1]

(3 marks)

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3 (a) A ball of mass 44 g on a 25 cm string oscillating in simple harmonic motion obeys the following equation:

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

Demonstrate mathematically that the graph of this equation is a downward sloping straight line that goes through the origin.

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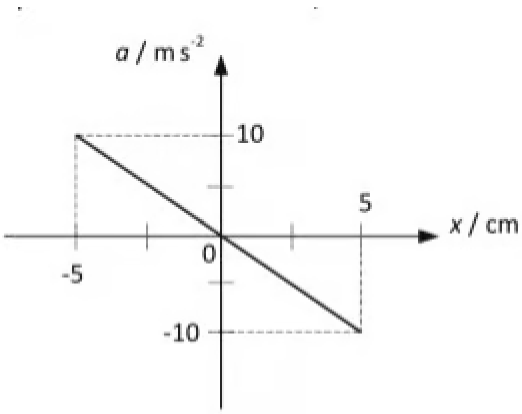
(3 marks)

(b) The graph below shows the acceleration, *a*, as a function of displacement, *x*, of the ball on the string.



The angular speed, ω, in rad s^{-1}, is related to the frequency, *f*, of the oscillation by the following equation:

$$\omega = 2\pi f$$

For the ball on the string, determine the period, *T*, of the oscillation.

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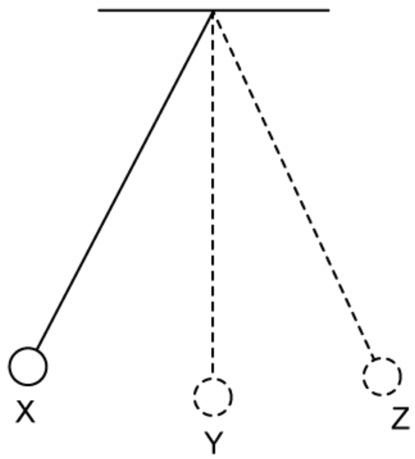
(3 marks)

(c) The ball is held in position X and then let go. The ball oscillates in simple harmonic motion.

Explain the change in acceleration as the ball on the string moves through half an oscillation from position X.

You can assume the ball is moving at position X.



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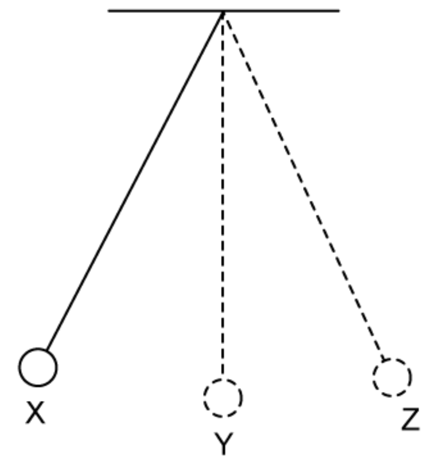
(4 marks)

(d) Describe the energy transfers occurring as the ball on the string completes half an oscillation from position X.



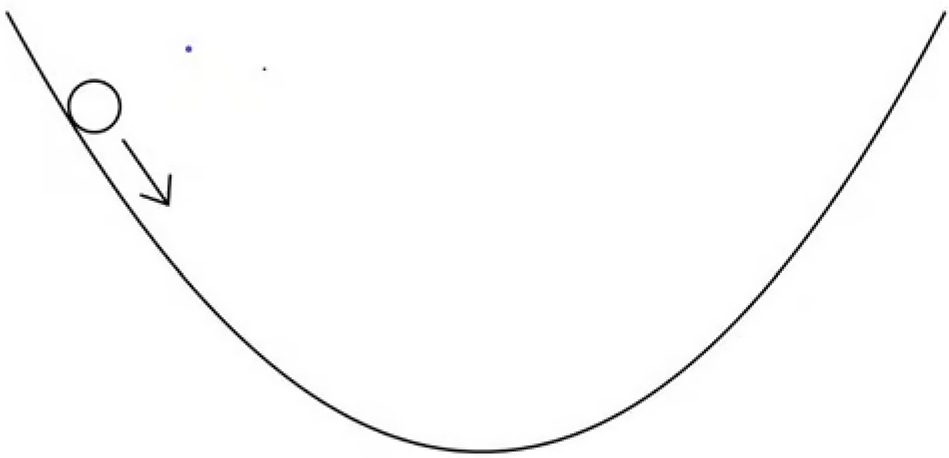
(3 marks)

4 (a) A smooth glass marble is held at the edge of a bowl and released. The marble rolls up and down the sides of the bowl with simple harmonic motion.

The magnitude of the restoring force which returns the marble to equilibrium is given by:

$$F = \frac{mgx}{R}$$

Where x is the displacement at a given time, and is the radius of the bowl.



Outline why the oscillations can be described as simple harmonic motion.

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(3 marks)

(b) Describe the energy changes during the simple harmonic motion of the marble.

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(3 marks)

(c) As the marble is released it has potential energy of 15 μJ. The mass of the marble is 3 g.

Calculate the velocity of the marble at the equilibrium position.

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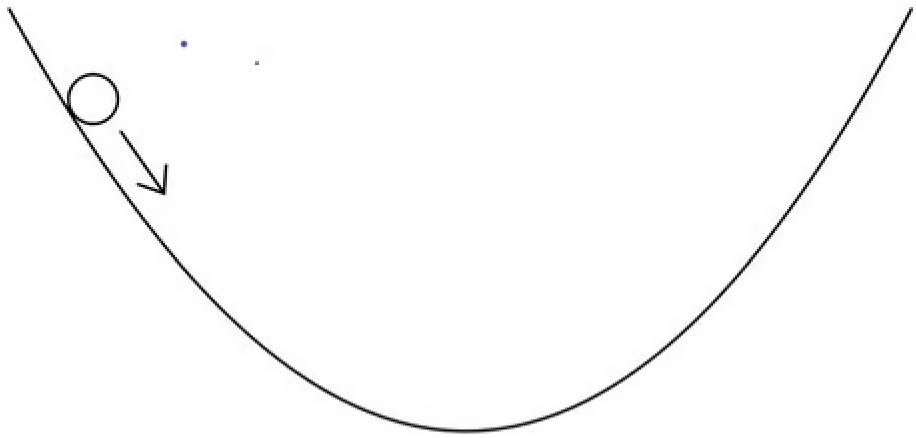
(2 marks)

(d) Sketch a graph to represent the kinetic, potential and total energy of the motion of the marble, assuming no energy is dissipated as heat. Clearly label any important values on the graph.



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(3 marks)

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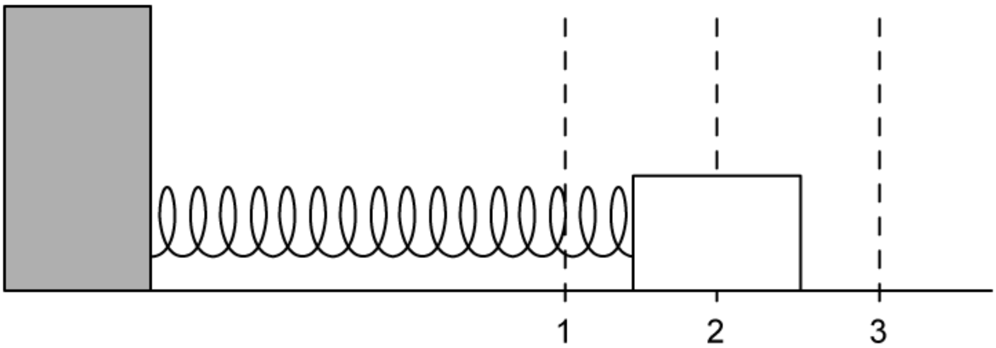
5 (a) An object is attached to a light spring and set on a frictionless surface. It is allowed to oscillate horizontally. Position 2 shows the equilibrium point.



(i) Sketch a graph of acceleration against displacement for this motion.

[2]

(ii) On your graph, mark positions 1, 2 and 3 according to the diagram.

[1]

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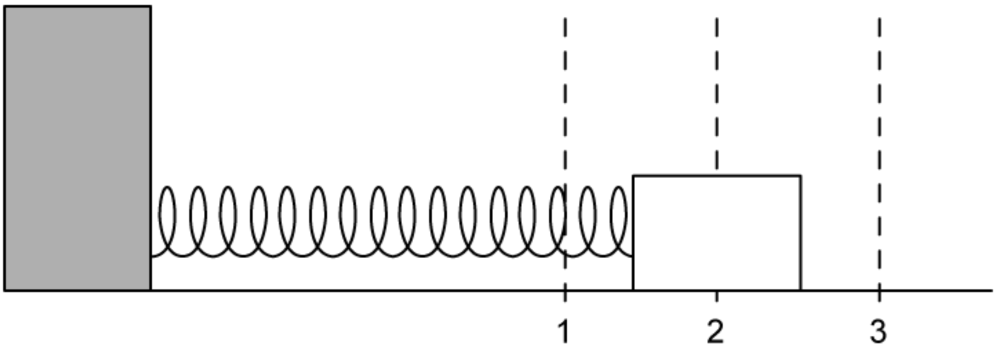
(3 marks)

(b) The mass begins its motion from position 1 and completes a full oscillation.



(i) Sketch a graph of velocity against time to show this.

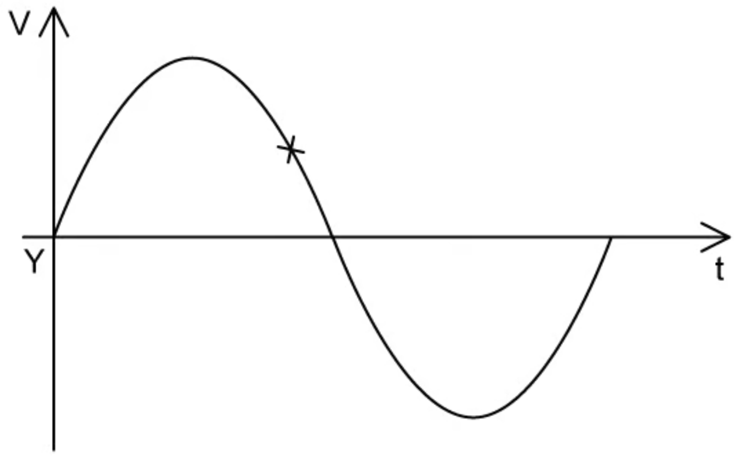
[2]

(ii) On your graph, add labels to show points 1, 2 and 3

[2]

(4 marks)

(c) At the point marked **Y** on the graph, the potential energy of the block is E_P. The block has mass *m*, and the maximum velocity it achieves is v_{max}.

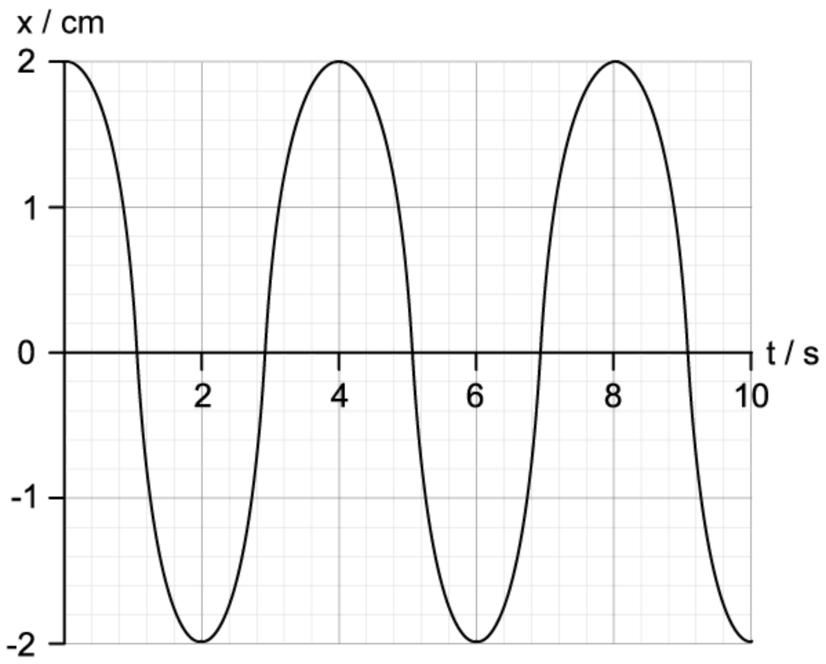


Determine an equation for the potential energy at the point marked X.

Give your answer in terms of v_{max} , V_x and *m*.

(3 marks)

(d) The graph shows how the displacement *x* of the mass varies with time *t.*



Determine the frequency of the oscillations.

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(2 marks)

Hard Questions

1 (a) 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:

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

(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)

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

(2 marks)

(c) 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.

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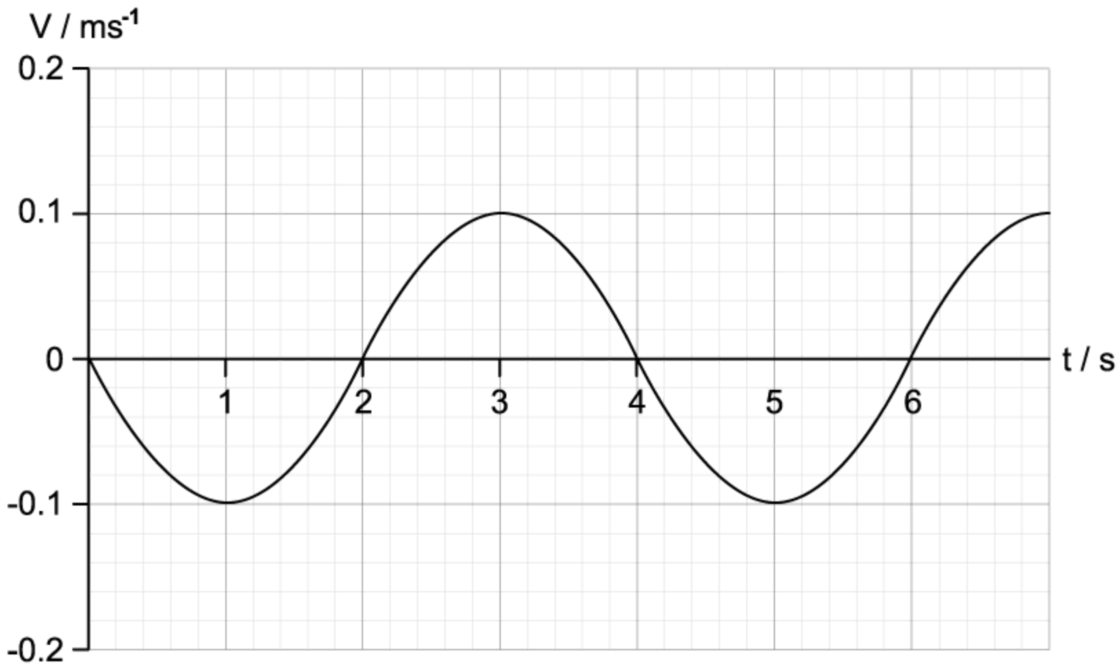

Determine the total energy of the system with this new mass.

(2 marks)

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

(1 mark)

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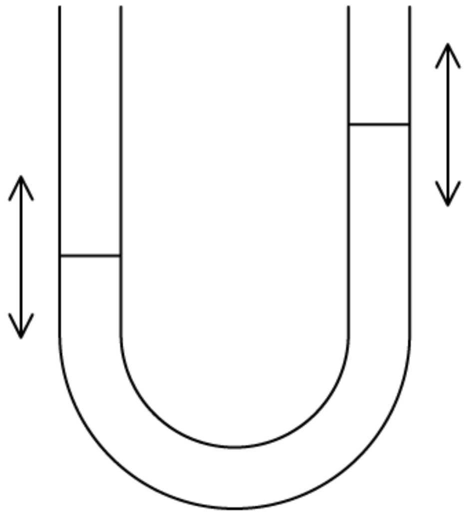
2 (a) A volume of water in a U-shaped tube performs simple harmonic motion.



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

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(2 marks)

(b) 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.

Sketch the graph the data logger would produce.

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(2 marks)

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

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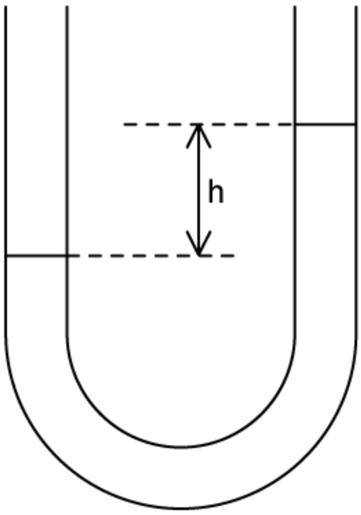


Construct an equation to find the restoring force, F, for the motion.

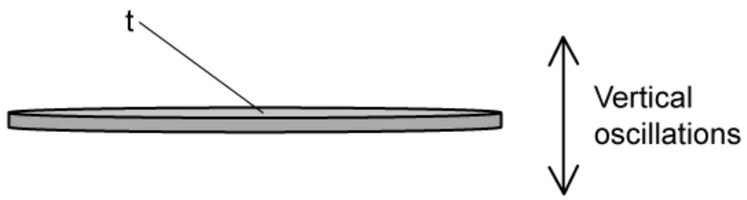
(3 marks)

(d) 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.

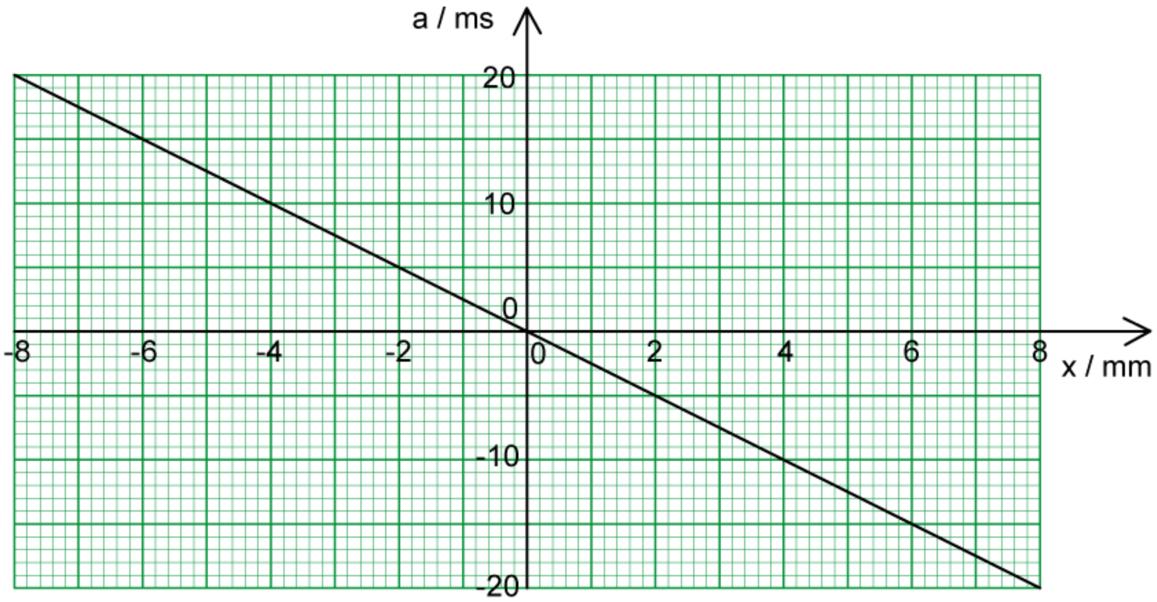
If L is 15 cm, determine the frequency of the oscillations.

(1 mark)

3 (a) 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*.



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

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(3 marks)

(b) Some grains of salt are placed onto the disk.

The amplitude of the oscillation is increased gradually from zero.

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]

....

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....

(4 marks)

(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]

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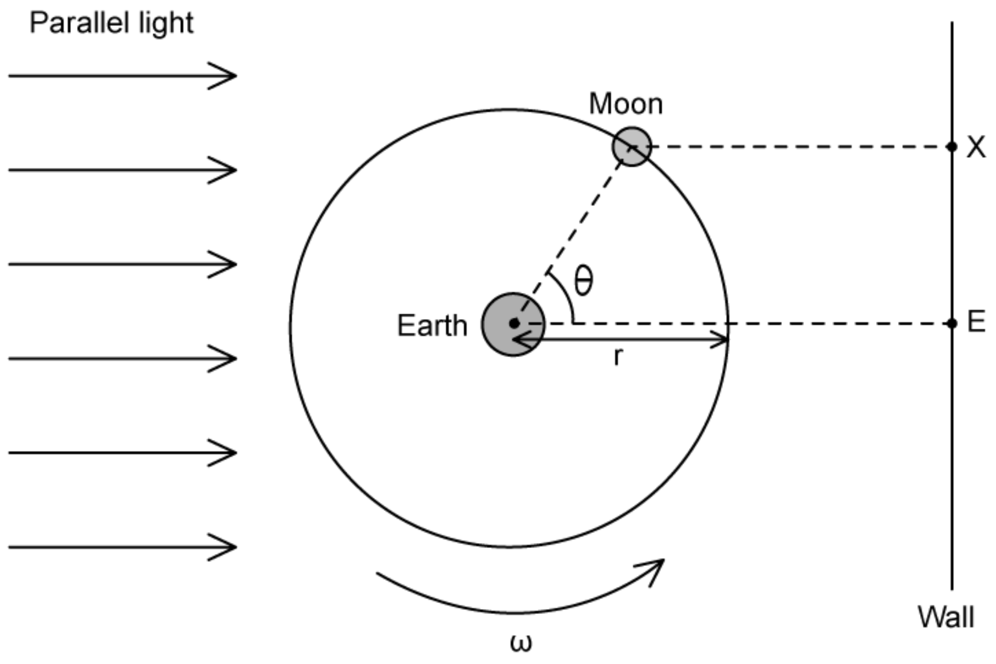
(3 marks)

4 (a) 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

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]

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

[1]

(3 marks)

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

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)

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

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

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)

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