A-Level Physics

Simple Harmonic Motion

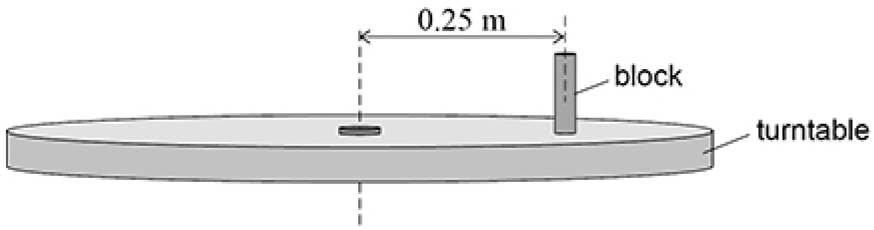
Question Paper

Time available: 58 minutes
Marks available: 42 marks

1. A teacher sets up a demonstration to show the relationship between circular motion and simple harmonic motion (SHM).

She places a block on a turntable at a point 0.25 m from its centre, as shown in **Figure 1**.

Figure 1



The turntable rotates with an angular speed of 1.8 rad s^{-1} and the block does not slip.

(a) Calculate the time taken for the turntable to complete one revolution.

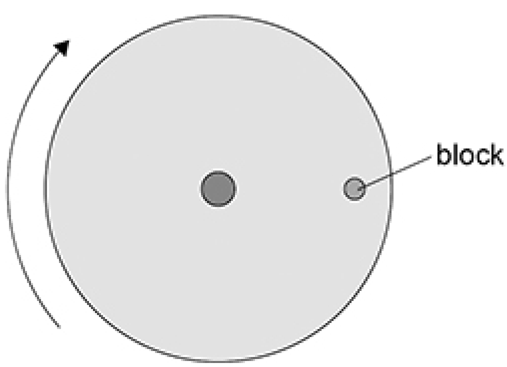
time = _______________ s

(2)

(b) **Figure 2** shows a plan view of the turntable and block.
The turntable rotates in a clockwise direction.

Draw an arrow on **Figure 2** to show the direction of the resultant force on the block.

Figure 2



(1)

(c) The mass of the block is $0.12\ \text{kg}$.

Calculate the magnitude of the resultant force on the block.

magnitude of force = ________________ N

(2)

(d) Describe, with reference to one of Newton's laws of motion, the evidence that a resultant force is acting on the block.

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(2)

(e) The teacher adjusts the angular speed of the turntable so that the block completes one rotation every 2.50 s.
She sets up a simple pendulum above the centre of the turntable so that it swings in phase with the movement of the block.

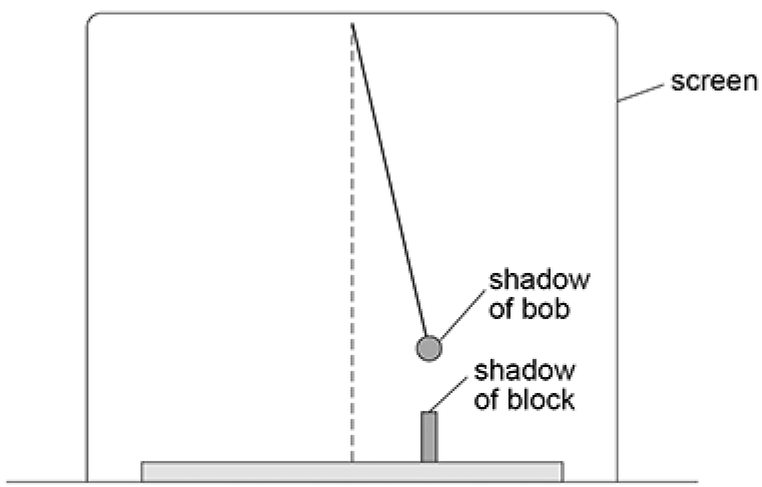
Calculate the length of the simple pendulum.

length = _______________ m

(2)

(f) A lamp is used to project shadow images of the block and pendulum bob on a screen.
Both shadows appear to move with SHM across the screen.
Figure 3 shows the images on the screen at one instant.

Figure 3



Initially the shadows move in phase with the same amplitude.

Air resistance affects the motion of the pendulum.

Suggest the effect this has on the amplitude relationship and the phase relationship between the moving shadows.

amplitude ____

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phase ____

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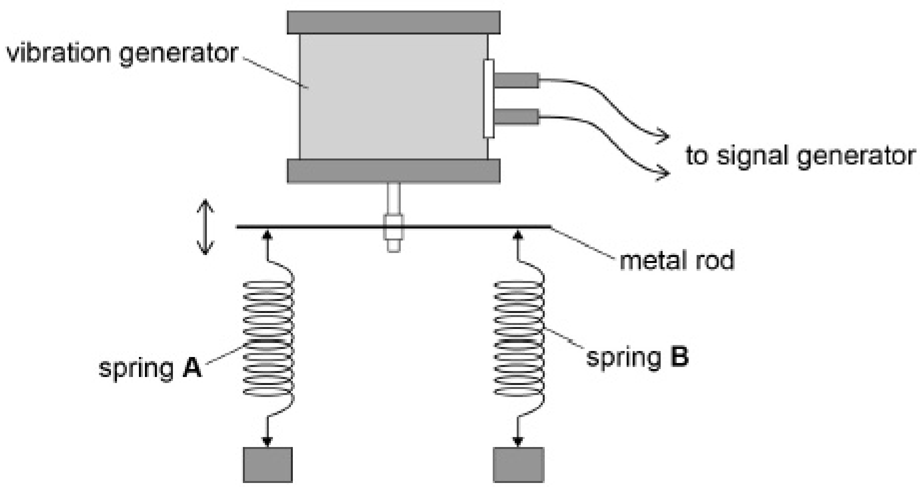
(2)
(Total 11 marks)

2. A student is investigating forced vertical oscillations in springs.
Two springs, **A** and **B**, are suspended from a horizontal metal rod that is attached to a vibration generator. The stiffness of **A** is k, and the stiffness of **B** is $3k$.
Two equal masses are suspended from the springs as shown in **Figure 1**.

Figure 1



The vibration generator is connected to a signal generator. The signal generator is used to vary the frequency of vibration of the metal rod. When the signal generator is set at 2.0 Hz, the mass attached to spring **A** oscillates with a maximum amplitude of 2.5×10^{-2} m and has a maximum kinetic energy of 54 mJ.

(a) Deduce the spring constant k for spring **A** and the mass m suspended from it.

k = ____________________ N m^{-1}

m = ____________________ kg

(4)

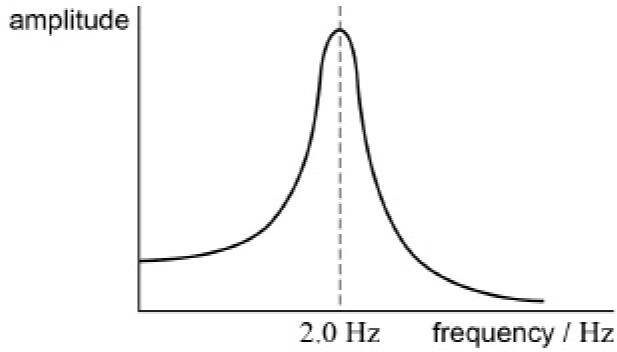
(b) Calculate the frequency at which the mass attached to spring **B** oscillates with maximum amplitude.

frequency = ____________________ Hz

(2)

(c) **Figure 2** shows how the amplitude of the oscillations of the mass varies with frequency for spring **A**.

Figure 2



The investigation is repeated with the mass attached to spring **B** immersed in a beaker of oil.

A graph of the variation of the amplitude with frequency for spring **B** is different from the graph in **Figure 2**.

Explain **two** differences in the graph for spring **B**.

Difference 1 ____

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Difference 2 ____

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(4)

(Total 10 marks)

3. (a) State the conditions for simple harmonic motion.

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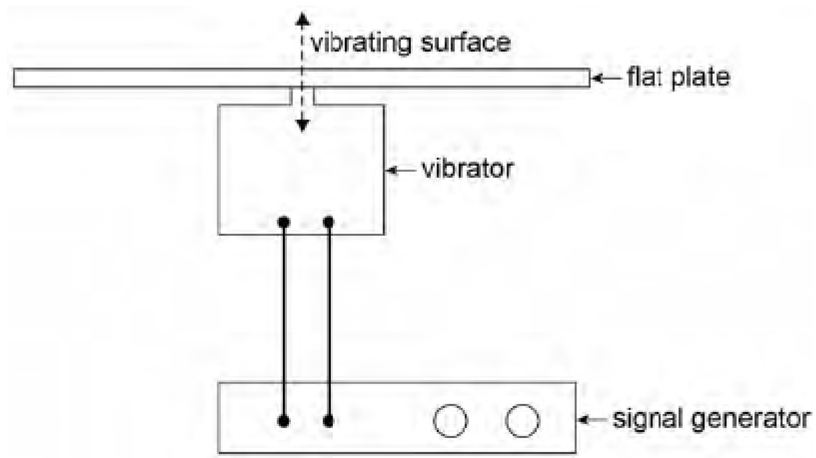
(2)

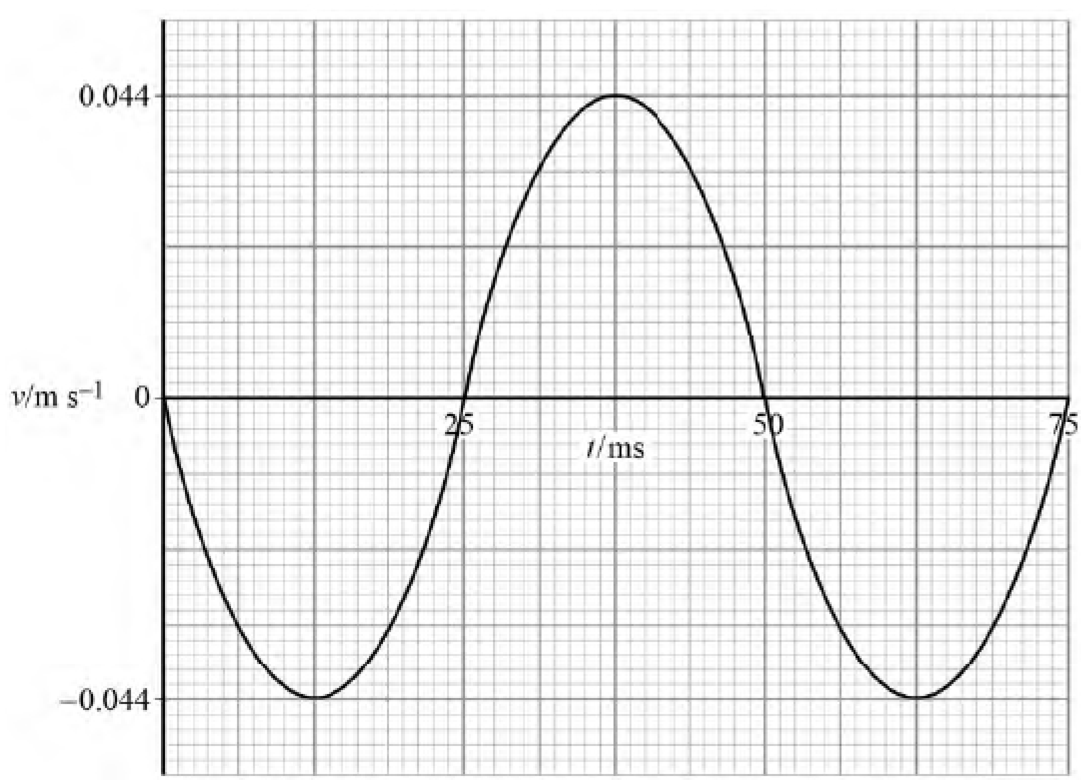
(b) A rigid flat plate is made to vibrate vertically with simple harmonic motion. The frequency of the vibration is controlled by a signal generator as shown in **Figure 1**.

Figure 1



The velocity−time (v−t) graph for the vibrating plate at one frequency is shown in **Figure 2**.

Figure 2

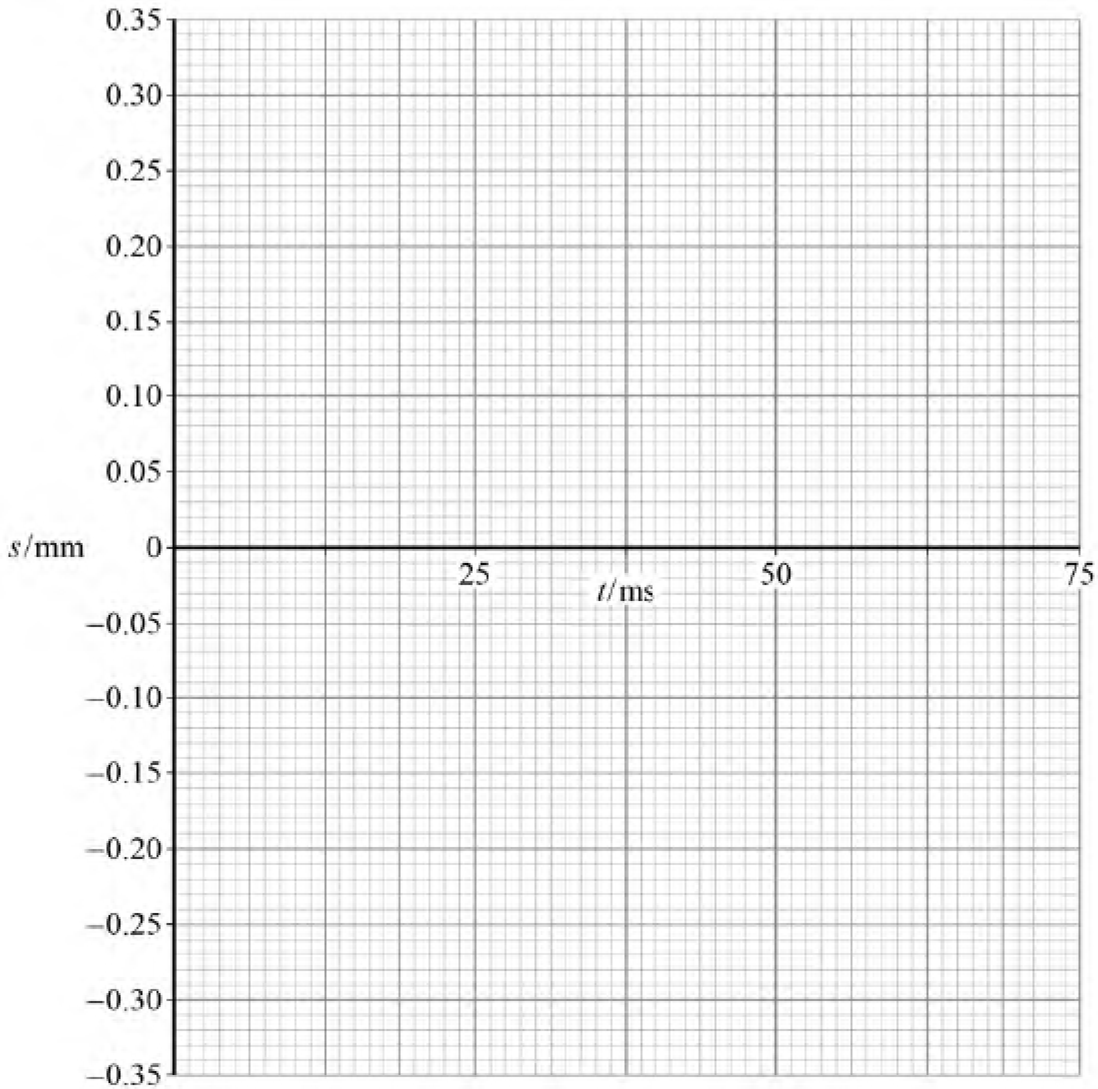


Show that the maximum displacement of the plate is 3.5×10^{-4} m.

(2)

(c) Draw on **Figure 3** the displacement−time (s−t) graph between 0 and 75 ms.

Figure 3



(1)

(d) State **one** time at which the plate has maximum potential energy.

time = ______________________ s

(1)

(e) A small quantity of fine sand is placed onto the surface of the plate. Initially the sand grains stay in contact with the plate as it vibrates. The amplitude of the vibrating surface remains constant at 3.5×10^{-4} m over the full frequency range of the signal generator. Above a particular frequency the sand grains lose contact with the surface.

Explain how and why this happens.

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(3)

(f) Calculate the lowest frequency at which the sand grains lose contact with the surface of the plate.

frequency = ______________________ Hz

(2)

(Total 11 marks)

4. (a) A simple pendulum is given a small displacement from its equilibrium position and performs *simple harmonic motion*.

State what is meant by simple harmonic motion.

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(2)

(b) (i) Calculate the frequency of the oscillations of a simple pendulum of length 984 mm. Give your answer to an appropriate number of significant figures.

frequency ____________________ Hz

(3)

(ii) Calculate the acceleration of the bob of the simple pendulum when the displacement from the equilibrium position is 42 mm.

acceleration ____________________ ms^{-2}

(2)

(c) A simple pendulum of time period 1.90 s is set up alongside another pendulum of time period 2.00 s. The pendulums are displaced in the same direction and released at the same time.

Calculate the time interval until they next move in phase. Explain how you arrive at your answer.

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time interval ____________________ s

(3)

(Total 10 marks)