Access Tuition

A-Level Physics

Forced Vibrations and Resonance

Question Paper

Time available: 78 minutes
Marks available: 43 marks

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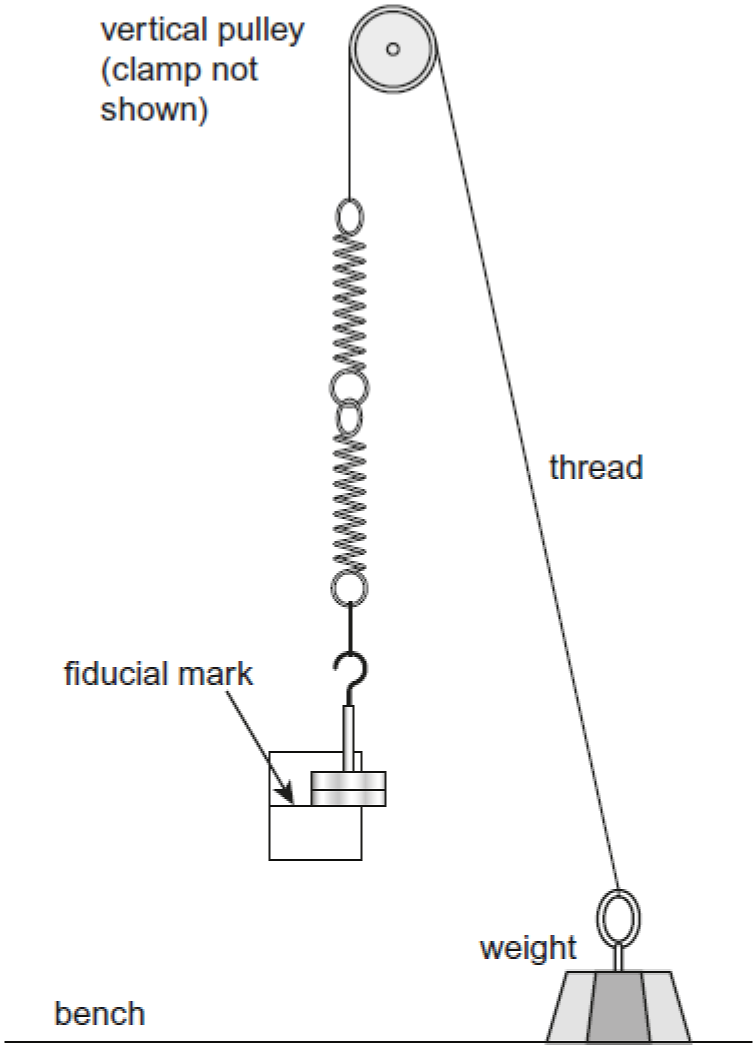
1. A student investigates the vertical oscillations of the mass–spring system shown in **Figure 1**.

Figure 1



The system is suspended from one end of a thread passing over a pulley.

The other end of the thread is tied to a weight.

The system is shown in **Figure 1** with the mass at the equilibrium position.

The spring constant (stiffness) is the same for each spring.

(a) Explain why the position of the fiducial mark shown in **Figure 1** is suitable for this experiment.

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____

____

(1)

The table below shows the measurements recorded by the student.

Time for 20 oscillations of the mass-spring system/s				
22.9	22.3	22.8	22.9	22.6

(b) (i) Determine the percentage uncertainty in these data.

percentage uncertainty = ______________________________

(3)

(ii) Determine the natural frequency of the mass-spring system.

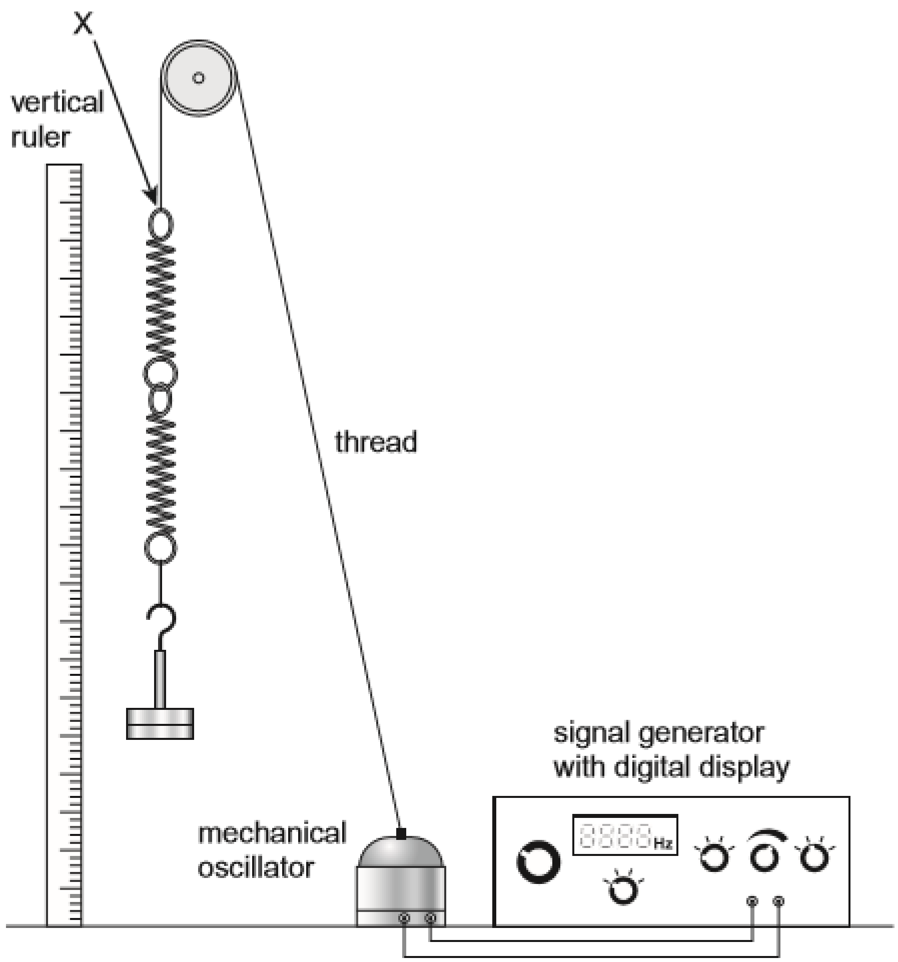
natural frequency = ______________________________

(1)

(c) The student connects the thread to a mechanical oscillator. The oscillator is set in motion using a signal generator and this causes the mass–spring system to undergo forced oscillations.

A vertical ruler is set up alongside the mass–spring system as shown in **Figure 2**. The student measures values of *A*, the amplitude of the oscillations of the mass as *f*, the frequency of the forcing oscillations, is varied.

Figure 2



A graph for the student's experiment is shown in **Figure 3**.

(i) Add a suitable scale to the frequency axis.
You should refer to your answer in part **(b)(ii)** and note that the scale starts at 0 Hz.

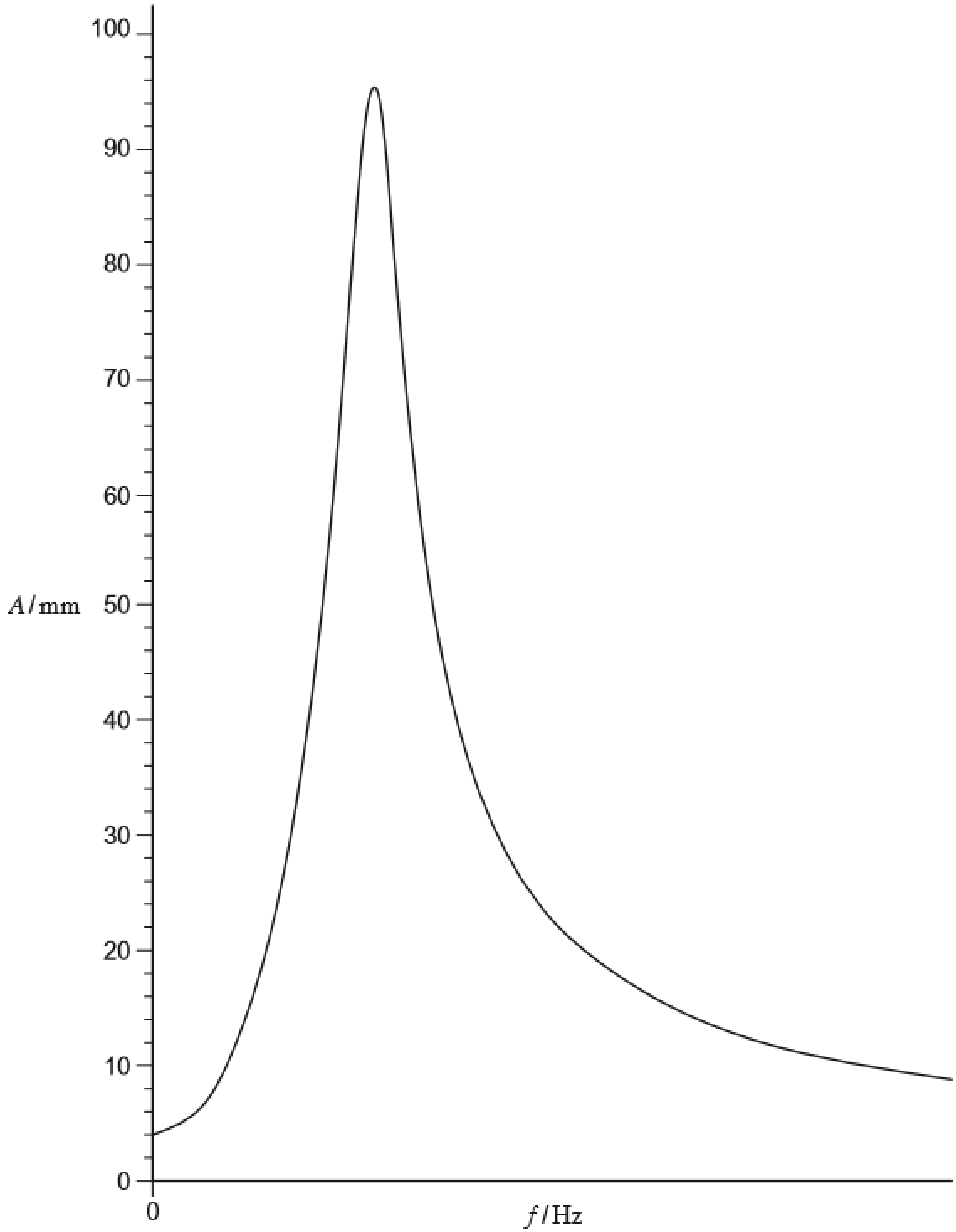
(1)

(ii) Deduce from **Figure 3** the amplitude of the oscillations of X, the point where the mass–spring system is joined to the thread.
You should assume that the length of the thread is constant.

amplitude of X = ____

(1)

Figure 3



(d) (i) State and explain how the student was able to determine the accurate shape of the graph in the region where *A* is a maximum.

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(2)

(ii) The student removes one of the springs and then repeats the experiment.

Add a new line to **Figure 3** to show the graph the student obtains.

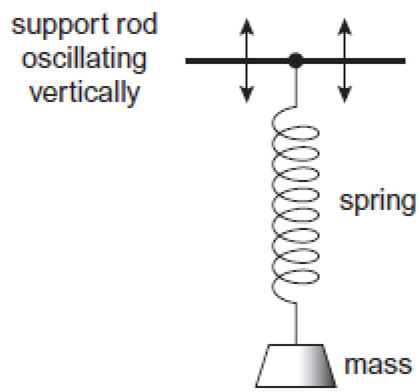
You may wish to use the equation $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

(2)

(Total 11 marks)

2. (a) A mass is attached to one end of a spring and the other end of the spring is suspended from a support rod, as shown in **Figure 1**.

Figure 1



The support rod oscillates vertically, causing the mass to perform forced vibrations. Under certain conditions, the system may demonstrate resonance.

Explain in your answer what is meant by forced vibrations and resonance. You should refer to the frequency, amplitude and phase of the vibrations.

forced vibrations ____

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____

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____

____

resonance ____

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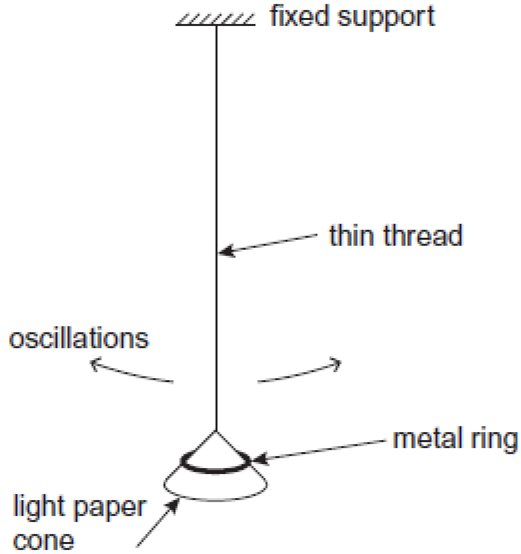
(4)

(b) A simple pendulum is set up by suspending a light paper cone (acting as the pendulum bob) on the end of a length of thin thread. A metal ring may be placed over the cone to increase the mass of the bob, as shown in **Figure 2**.

Figure 2



The bob is displaced and released so that it oscillates in a vertical plane. The oscillations are subject to damping.

(i) Are the oscillations of the pendulum more heavily damped when the cone oscillates with the metal ring on it, when it oscillates without the ring, or does the presence of the ring have no effect on the damping of the oscillations? Tick (✓) the correct answer.

cone oscillates with ring	
cone oscillates without ring	
ring has no effect	

(1)

(ii) Explain your answer to part (i).

(3)

(Total 8 marks)

3. To celebrate the Millennium in the year 2000, a footbridge was constructed across the River Thames in London. After the bridge was opened to the public it was discovered that the structure could easily be set into oscillation when large numbers of pedestrians were walking across it.

(a) What name is given to this kind of physical phenomenon, when caused by a periodic driving force?

(1)

(b) Under what condition would this phenomenon become particularly hazardous? Explain your answer.

(4)

(c) Suggest **two** measures which engineers might adopt in order to reduce the size of the oscillations of a bridge

measure 1 ____

____

measure 2 ____

____

(2)

(Total 7 marks)

4. (a) State the conditions necessary for a body to execute simple harmonic motion.

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(2)

(b) The front wheel of a motorcycle is attached to the frame via a combination of springs which has a spring constant of 4.2×10^3 N m^{-1}. You may consider this suspension system to be undamped. **Figure 1** shows the variation of displacement with time for the system when it is caused to oscillate after the wheel passes over a bump in the road.

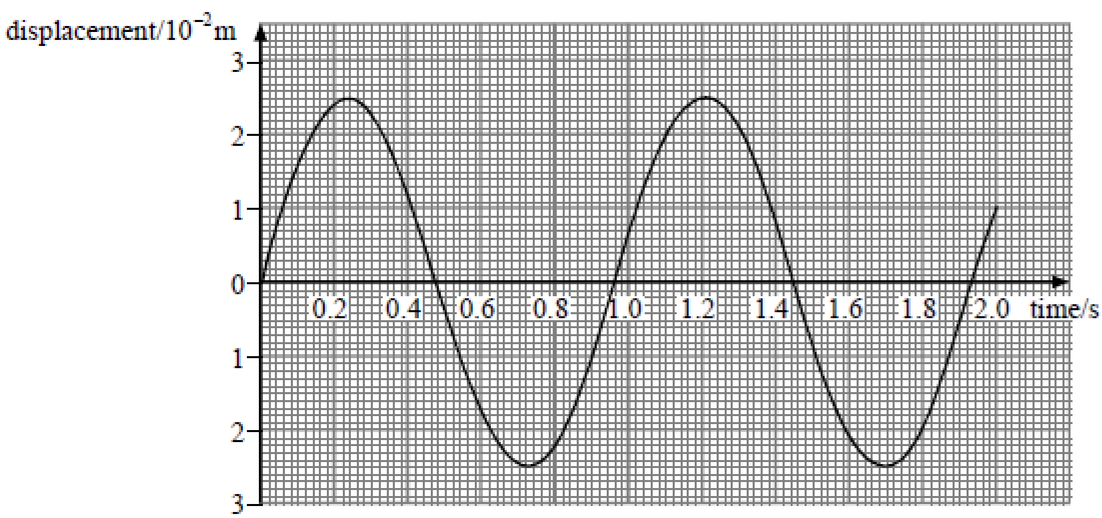

Figure 1

(i) State the periodic time for the oscillation of the system.

____

(1)

(ii) Calculate the frequency of oscillation of the system.

(1)

(iii) Calculate the effective mass which is attached to the suspension system.

(2)

(iv) Calculate the maximum acceleration of the wheel relative to the frame when the system oscillates as shown in **Figure 1**.

(2)

(c) When approaching a roundabout at a speed of 7.0 m s^{-1}, the motorcycle moves over raised road markings separated by a distance of 1.2 m. By making a suitable calculation, decide whether the front wheel system of the motorcycle is likely to experience resonance when it crosses the road markings. Explain your answer.

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(3)

(d) In practice, the system is damped by a shock absorber. **Figure 2** shows the oscillation of the damped system after the wheel goes over a bump in the road.

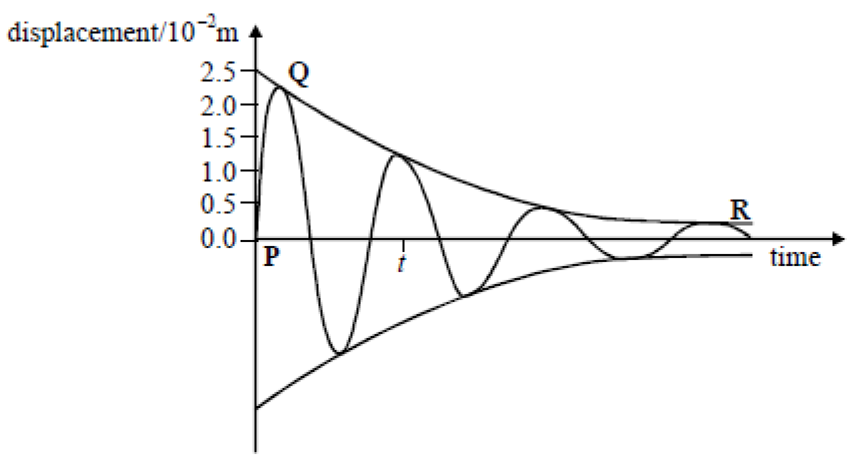

Figure 2

(i) Describe the energy changes that occur during the time covered by **Figure 2**, making reference to the types of energy involved at **P**, **Q** and **R**.

(3)

(ii) Use the graph to estimate the fraction of the energy absorbed by the shock absorbers by the time *t*.

(3)
(Total 17 marks)