LONDON SCIENCE COLLEGE

Name:

Date:

FORCED & DAMPED VIBRATIONS TEST 1

A2-Level

Mark	Grade

PHYSICS

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

Instructions

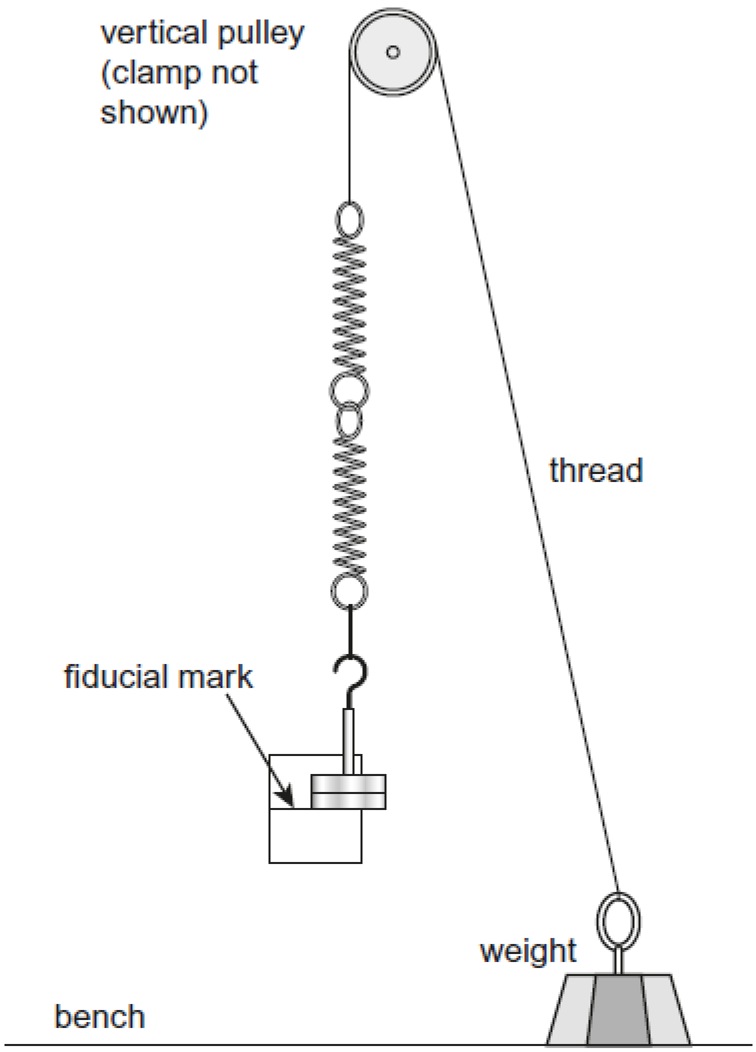
- Answer all questions
- Answer questions in the space provided
- All working must be shown

Information

- The marks for the questions are shown in brackets

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.

(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.

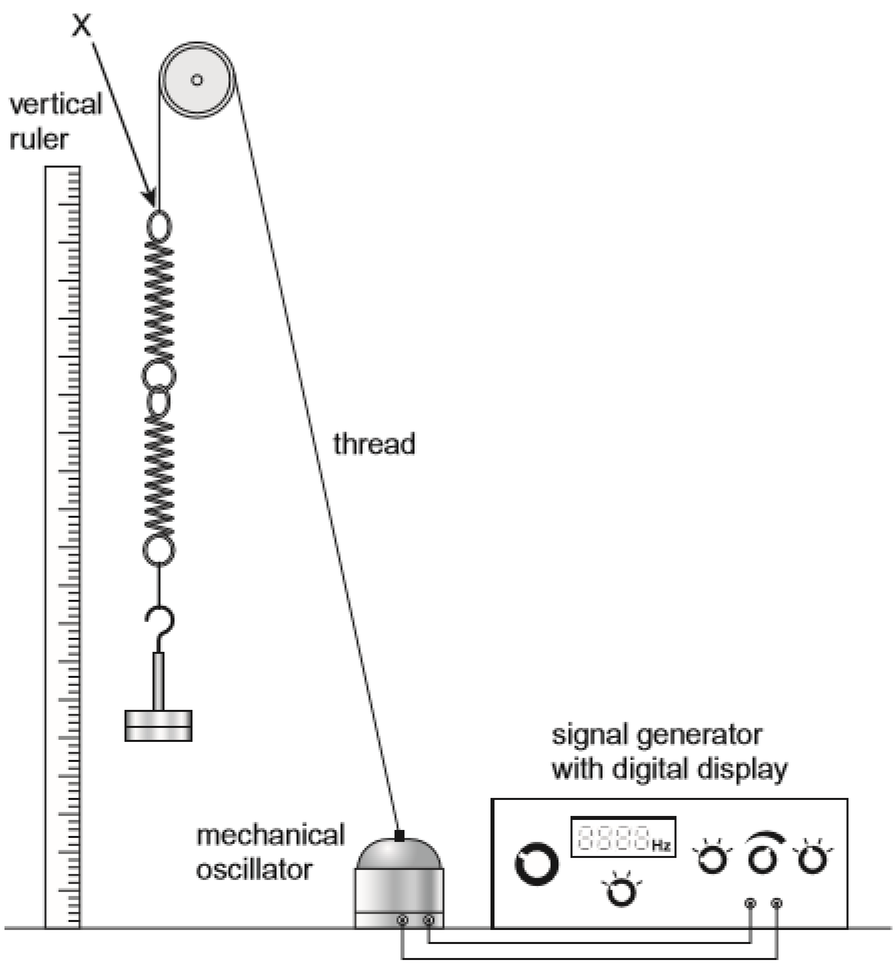
natural frequency = ____

(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.

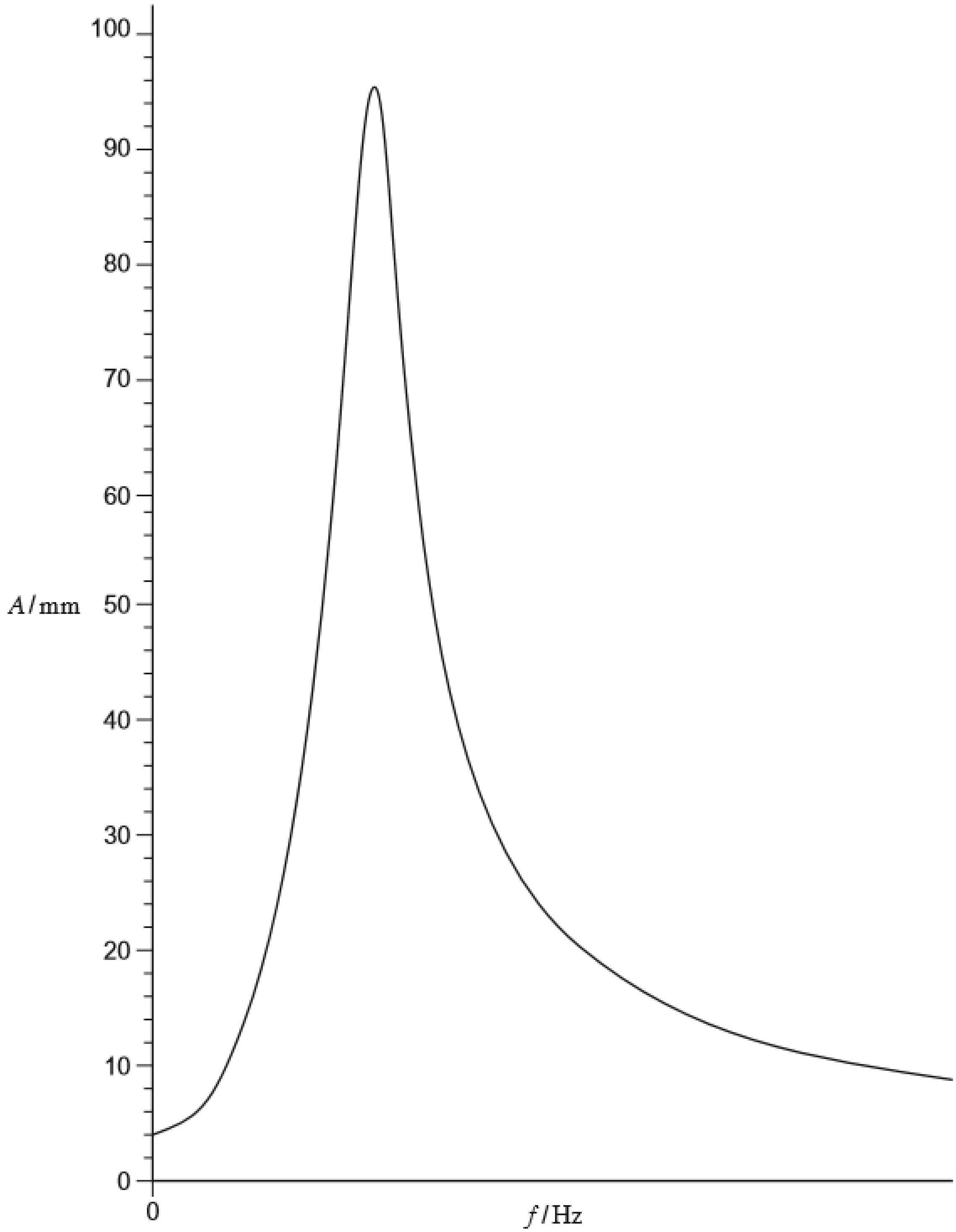
(1)

(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.

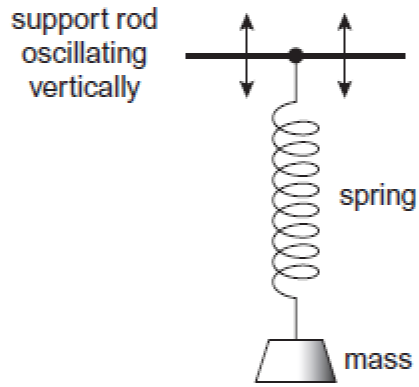
You may wish to use the equation $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$.

(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 ____

____

____

____

____

____

resonance ____

____

____

____

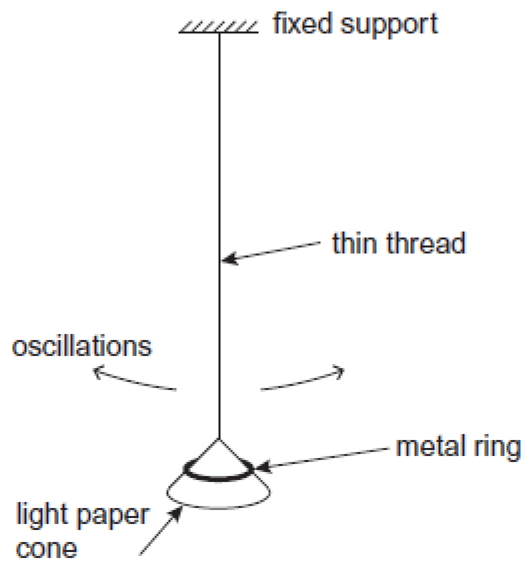
____

____

(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) A vibrating system which is experiencing forced vibrations may show *resonance*.

Explain what is meant by

forced vibrations ____

____

resonance ____

____

____

____

(3)

(b) (i) Explain what is meant by *damping*.

____

____

(ii) What effect does damping have on resonance?

____

____

(2)
(Total 5 marks)

5 (a) State what is meant by

(i) a free vibration,

____

____

(ii) a forced vibration.

____

____

(2)

(b) A car and its suspension can be treated as a simple mass-spring system. When four people of total weight 3000 N get into a car of weight 6000 N, the springs of the car are compressed by an extra 50 mm.

(i) Calculate the spring constant, k, of the system.

____

____

(ii) Show that, when the system is displaced vertically and released, the time period of the oscillations is 0.78 s.

____

____

____

(3)

(c) The loaded car in part (b) travels at 20 m s^{-1} along a road with humps spaced 16 m apart.

(i) Calculate the time of travel between the humps.

____

____

(ii) Hence, state and explain the effect the road will have on the oscillation of the car.

____

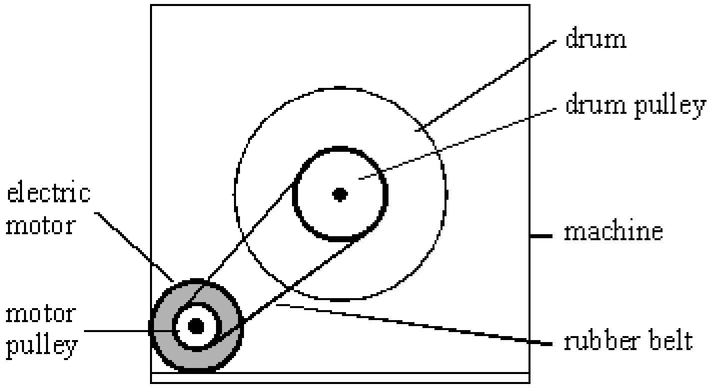
____

____

(3)

(Total 8 marks)

6 An electric motor in a machine drives a rotating drum by means of a rubber belt attached to pulleys, one on the motor shaft and one on the drum shaft, as shown in the diagram below.



(a) The pulley on the motor shaft has a diameter of 24 mm. When the motor is turning at 50 revolutions per second, calculate

(i) the speed of the belt,

____

____

____

____

(ii) the centripetal acceleration of the belt as it passes round the motor pulley.

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____

(5)

(b) When the motor rotates at a particular speed, it causes a flexible metal panel in the machine to vibrate loudly. Explain why this happens.

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(2)

(Total 7 marks)

7 (a) **Figure 1** and **2** show a simple version of a sensor designed to measure acceleration. In **Figure 1**, which shows the sensor at rest, a mass, M, is held centrally between two identical springs. When the sensor is fixed to a body which is accelerating parallel to the dashed line AB the mass takes up a position to the right of centre, as shown by **Figure 2**.

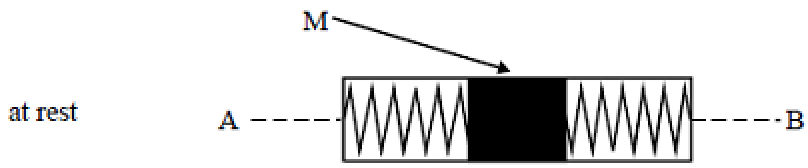


Figure 1

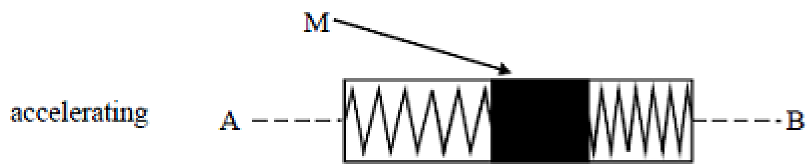


Figure 2

State the direction in which the body is accelerating and explain your answer.

___

___

___

(2)

(b)

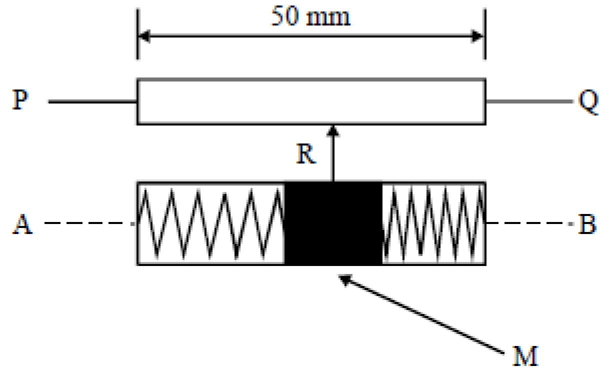


Figure 3

In practice, the mass in the sensor is connected to the slider, R, of a wire-wound potential divider across which there is a fixed potential difference of 5.0 V. At rest the slider is positioned midway along the **uniform** track of the potential divider. When accelerating, the slider moves a distance of 8.0 mm to the right of centre, as shown in **Figure 3**.

Calculate the change in potential difference between the points PR which result from this movement.

___

___

___

___

(4)

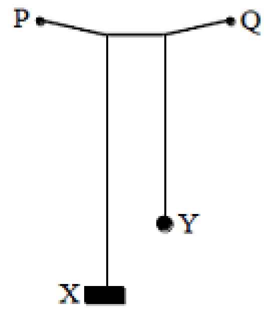
(c) On such devices, the sensor compartment is filled with oil and a hole is drilled in the mass to allow passage of oil between the two spring compartments. Explain why the oil is present.

___

___

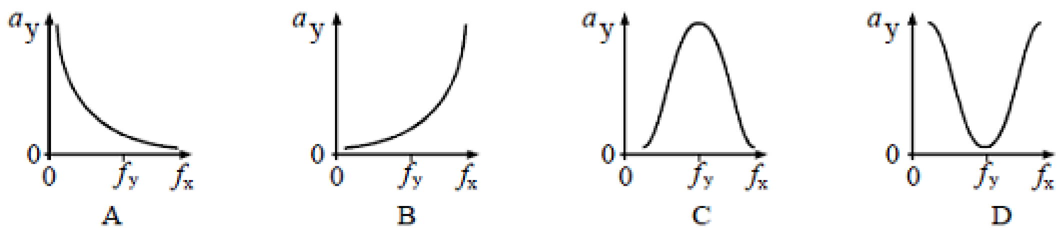
(2)
(Total 8 marks)

8 The diagram shows two pendulums suspended from fire same thread, **PQ**.



X is a heavy pendulum, the frequency f_x of which can be varied. **Y** is a lighter pendulum of fixed frequency f_y. As the frequency of oscillation of **X** is increased by shortening the thread, the amplitude of the oscillation of **Y** changes.

Which one of the following graphs best represents the relationship between the amplitude a_y of the oscillation of **Y** and the frequency f_x of **X**?



(Total 1 mark)

9 A mechanical oscillator is set into motion by a periodic driving force whose frequency is steadily increased from a low value.

What is correct for this system?

A Forced vibrations occur only at particular frequencies.

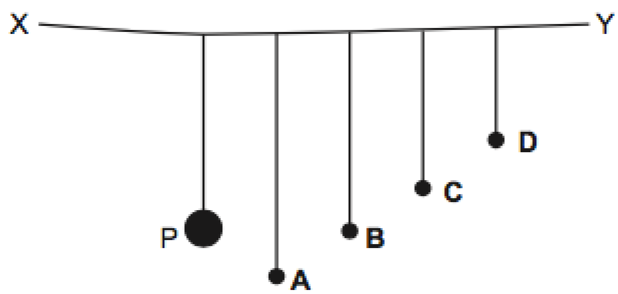
B The oscillator is subject to damping only at the resonant frequency.

C When resonance occurs the damping force is a minimum.

D The oscillator will not continue to resonate when the periodic driving force is removed.

(Total 1 mark)

10 The diagram shows a string XY supporting a heavy pendulum P and four pendulums **A**, **B**, **C** and **D** of smaller mass.

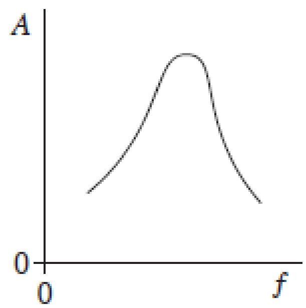


Pendulum P is set in oscillation perpendicular to the plane of the diagram.

Which one of the pendulums, **A** to **D**, then oscillates with the largest amplitude?

(Total 1 mark)

11 A periodic force is applied to a lightly-damped object causing the object to oscillate. The graph shows how the amplitude A of the oscillations varies with the frequency f of the periodic force.



Which one of the following statements best describes how the shape of the curve would differ if the damping had been greater?

A the curve would be lower at all frequencies

B the curve would be higher at all frequencies

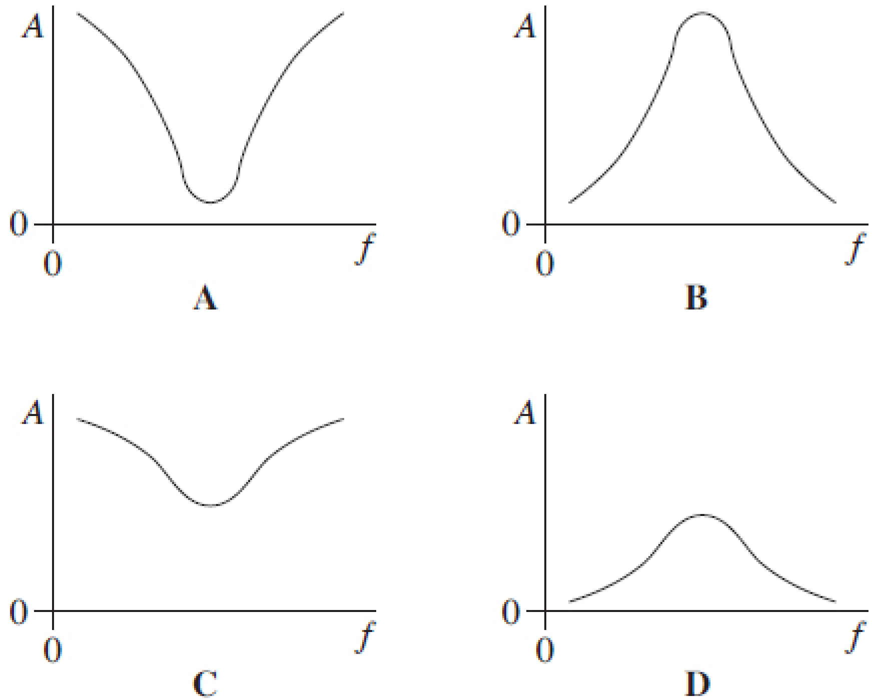
C the curve would be unchanged except at frequencies above the resonant frequency where it would be lower

D the curve would be unchanged except at frequencies above the resonant frequency where it would be higher

(Total 1 mark)

12 An oscillatory system, subject to damping, is set into vibration by a periodic driving force of frequency *f*. The graphs, **A** to **D**, which are to the same scale, show how the amplitude of vibration *A* of the system might vary with *f*, for various degrees of damping.

Which graph best shows the lightest damping?



(Total 1 mark)

13 A mechanical system is oscillating at resonance with a constant amplitude. Which one of the following statements is **not** correct?

A The applied force prevents the amplitude from becoming too large.

B The frequency of the applied force is the same as the natural frequency of oscillation of the system.

C The total energy of the system is constant.

D The amplitude of oscillations depends on the amount of damping.

(Total 1 mark)

14 Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is in the same direction as the acceleration.

B It is in the same direction as the displacement.

C It is in the opposite direction to the velocity.

D It is proportional to the displacement.

(Total 1 mark)

15 Which one of the following statements concerning forced vibrations and resonance is correct?

A An oscillating body that is not resonating will return to its natural frequency when the forcing vibration is removed.

B At resonance, the displacement of the oscillating body is 180° out of phase with the forcing vibration.

C A pendulum with a dense bob is more heavily damped than one with a less dense bob of the same size.

D Resonance can only occur in mechanical systems.

(Total 1 mark)

16 Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is in the same direction as the acceleration.

B It is in the opposite direction to the velocity.

C It is in the same direction as the displacement.

D It is proportional to the displacement.

(Total 1 mark)

17 Which one of the following statements about an oscillating mechanical system at resonance, when it oscillates with a constant amplitude, is **not** correct?

A The amplitude of oscillations depends on the amount of damping.

B The frequency of the applied force is the same as the natural frequency of oscillation of the system.

C The total energy of the system is constant.

D The applied force prevents the amplitude from becoming too large.

(Total 1 mark)

18 Which one of the following statements always applies to a damping force acting on a vibrating system?

A It is in the same direction as the acceleration.

B It is in the same direction as the displacement.

C It is in the opposite direction to the velocity.

D It is proportional to the displacement.

(Total 1 mark)