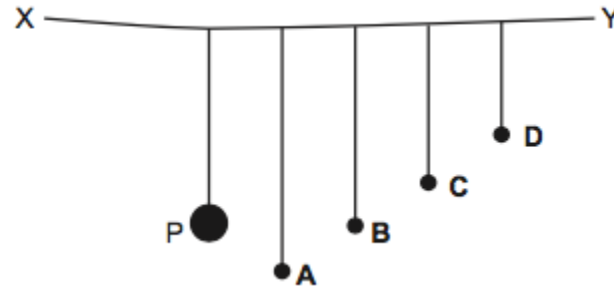


1

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)

2

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

(2)

(b) The front wheel of a motorcycle is attached to the frame via a combination of springs which has a spring constant of $4.2 \times 10^3 \text{ N m}^{-1}$. 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.

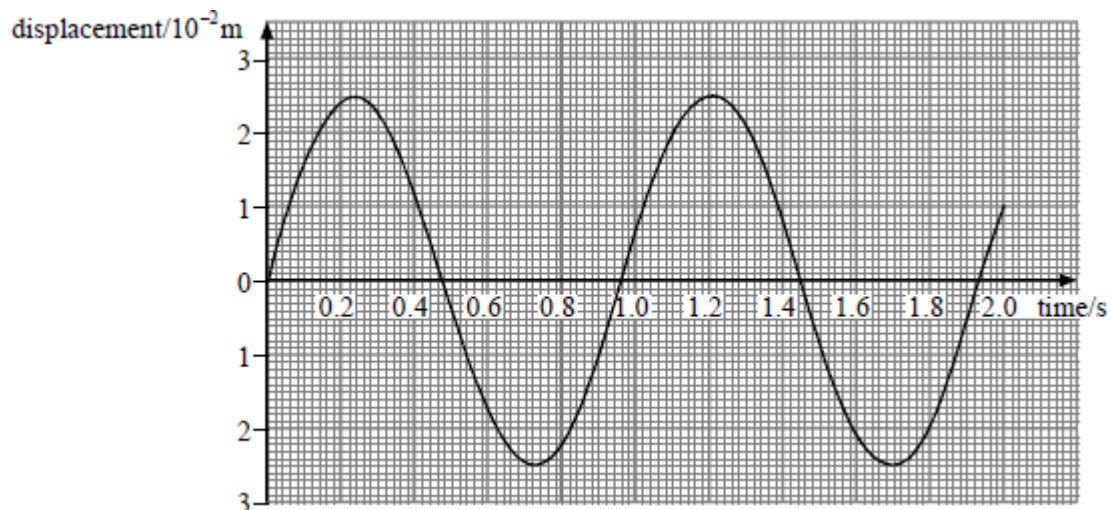


Figure 1

(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.

(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.

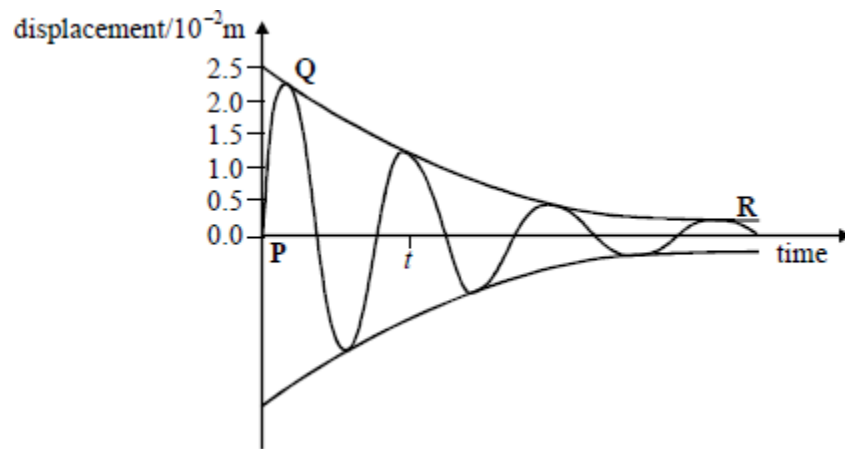


Figure 2

- (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)

3

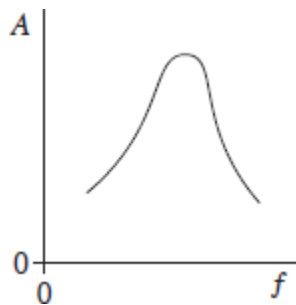
Which one of the following statements about an oscillating mechanical system at resonance, when it oscillates with a constant amplitude, is **not** correct?

- 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)

4

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?

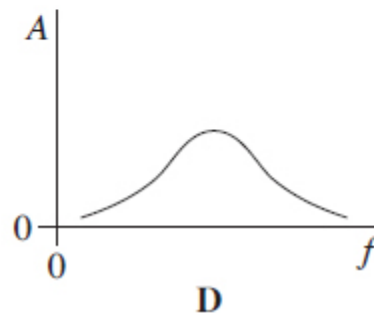
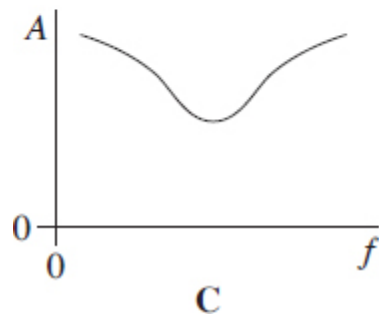
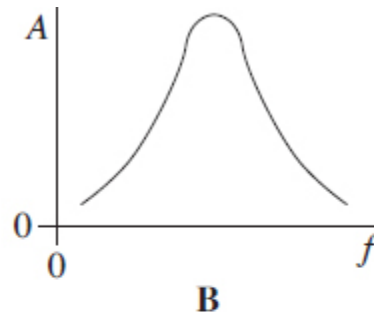
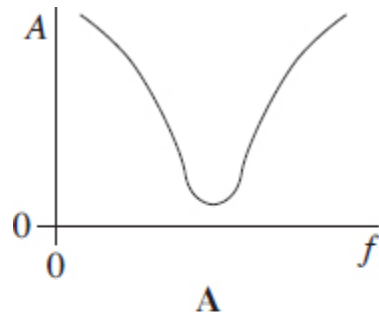
- A the curve would be lower at all frequencies
- B the curve would be higher at all frequencies
- C the curve would be unchanged except at frequencies above the resonant frequency where it would be lower
- D the curve would be unchanged except at frequencies above the resonant frequency where it would be higher

(Total 1 mark)

5

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)

6

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)

7

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)

8

Figure 1 shows three stages during the oscillations of a loaded spring. The positions shown are when the mass attached to the spring is at the top, equilibrium (middle) position and bottom of its motion.

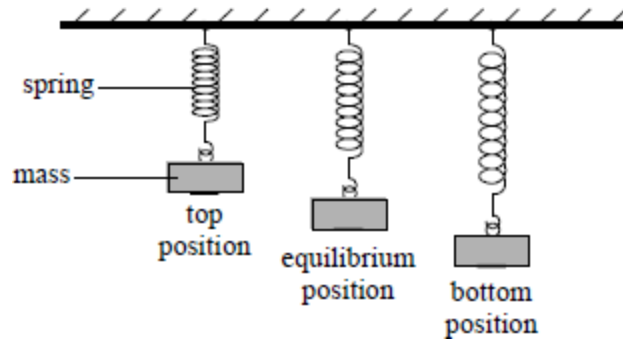


Figure 1

- (a) (i) Describe what is meant by the *period* of this oscillation.

(1)

- (ii) Mark and label the *amplitude* of the oscillation on **Figure 1**.

(1)

- (b) Explain how you would determine an accurate value for the period of the oscillation.

(2)

- (c) The mass is displaced from its equilibrium position in the air and then released. The graph in **Figure 2** shows the displacement-time graph from the moment of release. The mass-spring system is then submerged in water and set oscillating with the same initial displacement.

Sketch **on the same set of axes** the displacement-time graph for the motion in the water.

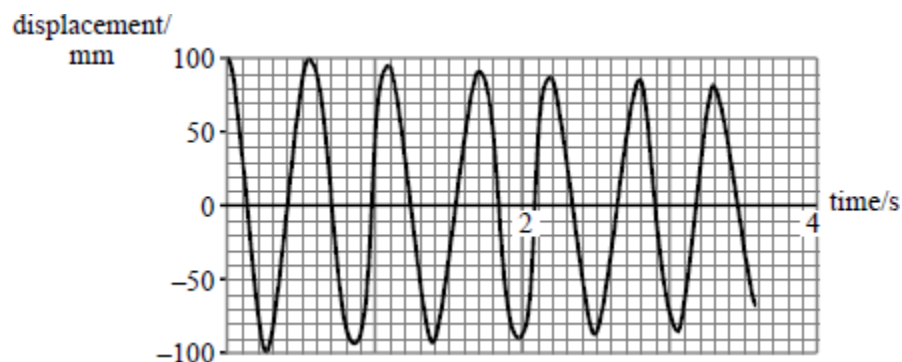


Figure 2

(2)

(Total 6 marks)

9

Figure 1 shows an apparatus for investigating forced vibrations and resonance of a mass-spring system. **Figure 2** shows the displacement-time graph when the system is resonating.

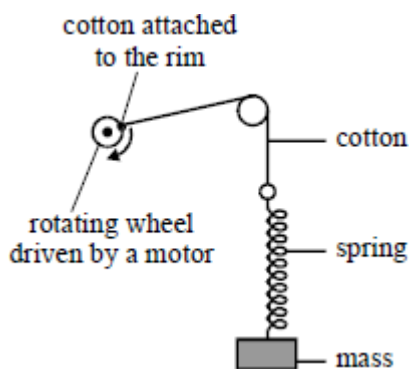


Figure 1

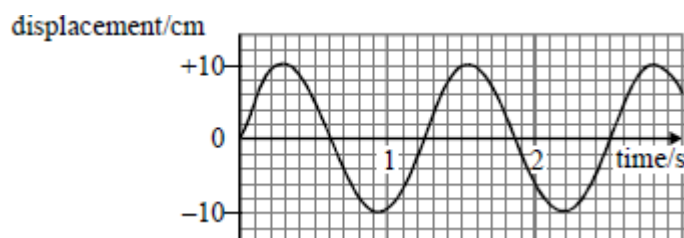


Figure 2

- (a) (i) State what is meant by a forced vibration.

(1)

- (ii) Under what condition will resonance occur in the system shown in **Figure 1**?

(1)

- (b) The spring constant of the spring used in the experiment was 9.0 N m^{-1} . Using information from **Figure 2**, determine the value of the mass suspended from the spring.

(3)

- (c) When the rotating wheel stops, **Figure 3** shows how the amplitude of the oscillations of the mass subsequently varies with time.

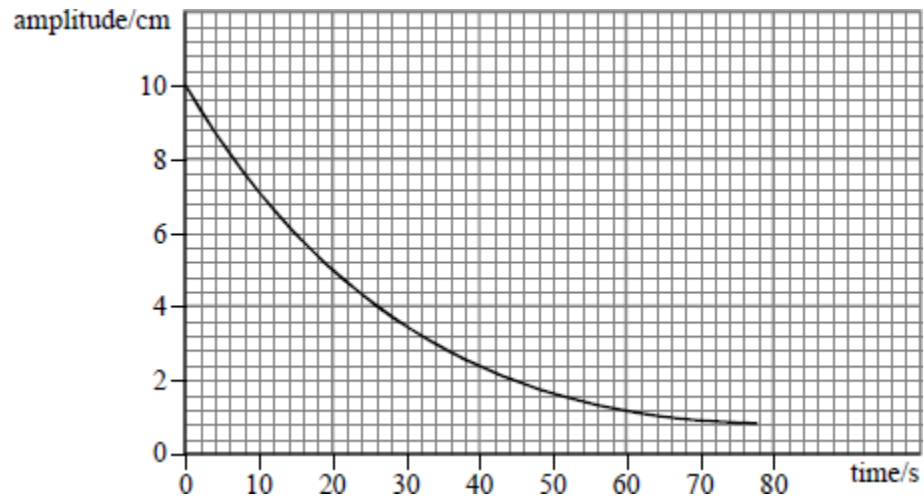


Figure 3

- (i) Explain whether the graph supports the suggestion that the amplitude of the damped oscillations varies exponentially with time. Show your reasoning clearly.

(3)

- (ii) Determine the ratio:

$$\frac{\text{energy of the oscillator after twenty oscillations}}{\text{energy of the oscillator at time } t = 0}$$

(2)

(Total 10 marks)

Mark schemes

1	B				[1]
2	(a)	force / acceleration proportional to displacement / distance from mean position		B1	
		directed towards mean / fixed position		B1	(2)
	(b)	(i)	0.96 s to 0.98 s	B1	(1)
		(ii)	1.02 Hz to 1.04 Hz e.c.f. 1 / (i)	B1	(1)
		(iii)	$T = 2\pi\sqrt{m/k}$ or $m = T^2k / 4\pi^2$ in symbols or numbers, seen or used	C1	
			98 kg to 102 kg e.c.f. $10^6 \times (i)^2$	A1	(2)
		(iv)	$a = (-)\omega^2 A$	C1	
			1.03 m s ⁻² to 1.07 m s ⁻² e.c.f. $0.99(ii)^2$	A1	(2)
	(c)	time period (of oscillation caused by road markings) = s/v or $1.2/7$ or 0.17 s		C1	
		frequency = $1/T$ or 5.8 Hz			
		(use of $v = f\lambda$ loses both of the 1st two marks)		A1	
		applied frequency / time period is different from natural / resonant frequency so no resonance		B1	(3)
	(d)	(i)	KE at P		
			PE at Q	B1	
			at R , (nearly all of) energy absorbed by shock absorber / dissipated as internal energy (condone heat) in shock absorber / surroundings (allow lost in damping)	B1	(3)

(ii) energy proportional to (amplitude)²

C1

at **P**, $A = 2.5$;

at t , $A = 1.0$ or 0.9

C1

$5.3 / 6.3 = 0.84$ of energy absorbed at t (or 0.90 , consistent with value of A at t)

A1

(3)

[17]

3

D

[2]

4

A

[1]

5

B

[1]

6

B

[1]

7

C

[1]

8

(a) *period* time for one **complete** oscillation

B1

amplitude maximum displacement from undisturbed
(equilibrium) position

B1

(2)

(b) clear description + repeat at least 10 times overall + averaging process

B1

beginning or end measurement at equilibrium / use of datalogger
(explicit) / fiducial mark

B1

(2)

(c) same time period

B1

significant and gradual reduction in amplitude compared to original

B1

(2)

[6]

9

- (a) (i) system made to oscillate by a periodic external force / energy source
or system made to oscillate by another oscillator it is connected to
or another oscillator forcing the system to vibrate
or an oscillator forcing another oscillator to vibrate
due to its own vibrations

A1

(1)

not made to oscillate by an external force
not when its vibrations are not at its natural frequency
not when it is made to oscillate by another system

- (ii) frequency of wheel (motor)= natural frequency of system
condone 'fundamental or resonant frequency' of the system
or rotating wheel rotates at the resonant / fundamental
frequency of the system

must be reference to the wheel or motor or driver oscillator
not just when it vibrates at its natural frequency

B1

(3)

- (b) $T = 1.25 \text{ s}$

B1

$$T = 2\pi(m/k)^{1/2} \text{ or numerical substitution}$$

C1

0.36 kg

allow e.c.f. for T ; 0.6 s gives 0.82 kg

A1

(1)

- (c) (i) correct process using ratios
(eg times to halve marked on the graph)

B1

three amplitudes read correctly
or
two times to halve read correctly

B1

ratios determined and conclusion drawn that it is exponential
or

a clear statement that the time to halve is the same for points indicated and
conclusion that it is exponential

B1

(3)

- (ii) amplitude correct for 25 s , i.e. 4 to 4.2 cm
or energy proportional to A^2 (allow $0.5 kA^2$ or $0.5 kx^2$)

C1

allow e.c.f. from (b); $T = 0.6$ s leads to amplitude = 6.8 cm ; ratio = 0.46

0.16-0.19 or 17/100 (2 s.f. only)

A1

(3)

[10]