

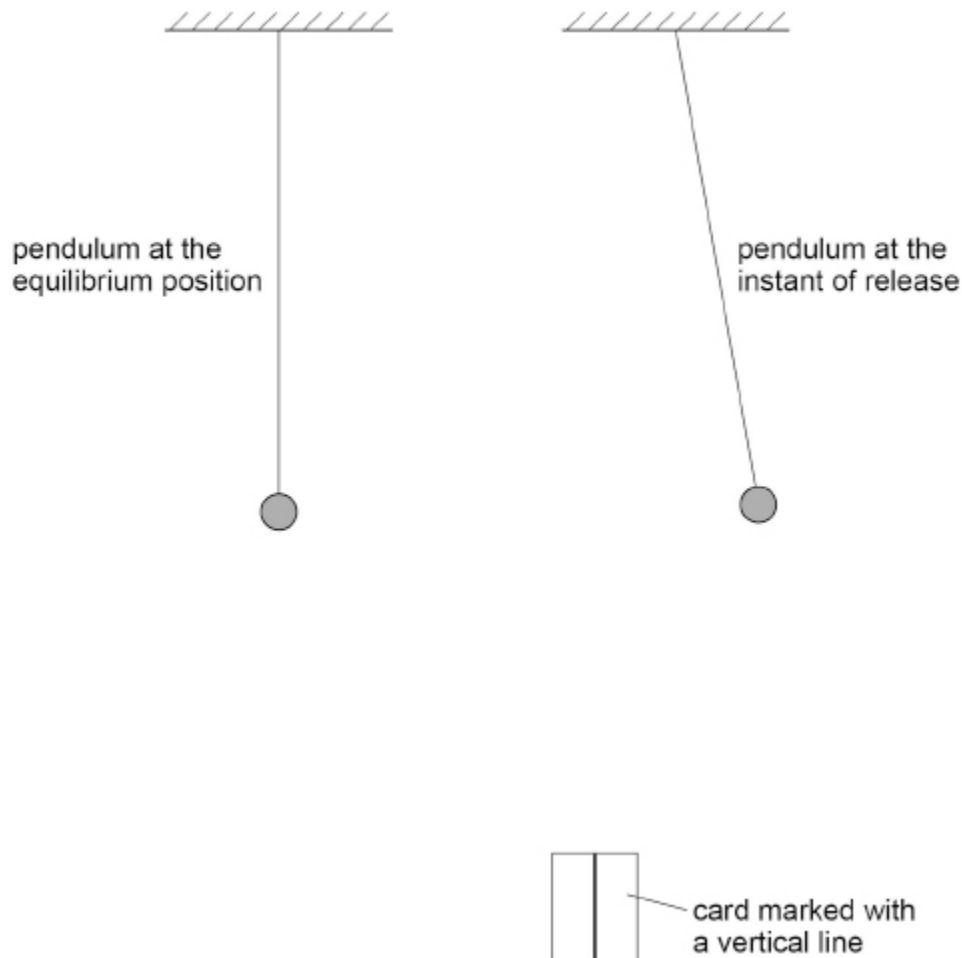
1.

A simple pendulum performs oscillations of period T in a vertical plane.

Figure 1 shows views of the pendulum at the equilibrium position and at the instant of release.

Figure 1 also shows a rectangular card marked with a vertical line.

Figure 1



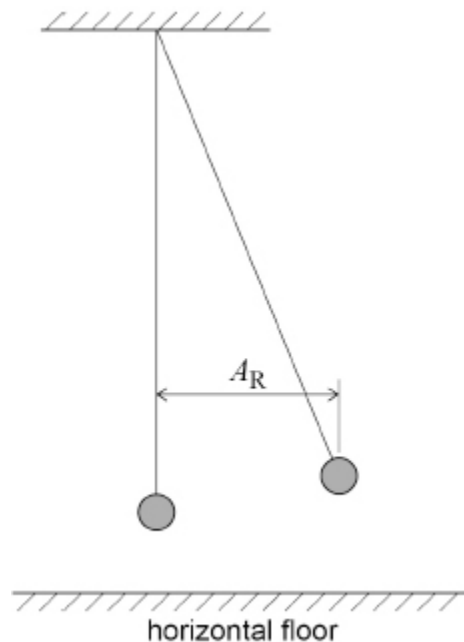
- (a) The card can be used as a fiducial mark to reduce uncertainty in the measurement of T .

Annotate **Figure 1** to show a suitable position for the fiducial mark. Explain why you chose this position.

(2)

- (b) The period of the pendulum is constant for small-amplitude oscillations. **Figure 2** shows an arrangement used to determine the maximum amplitude that can be considered to be small, by investigating how T varies with amplitude.

Figure 2



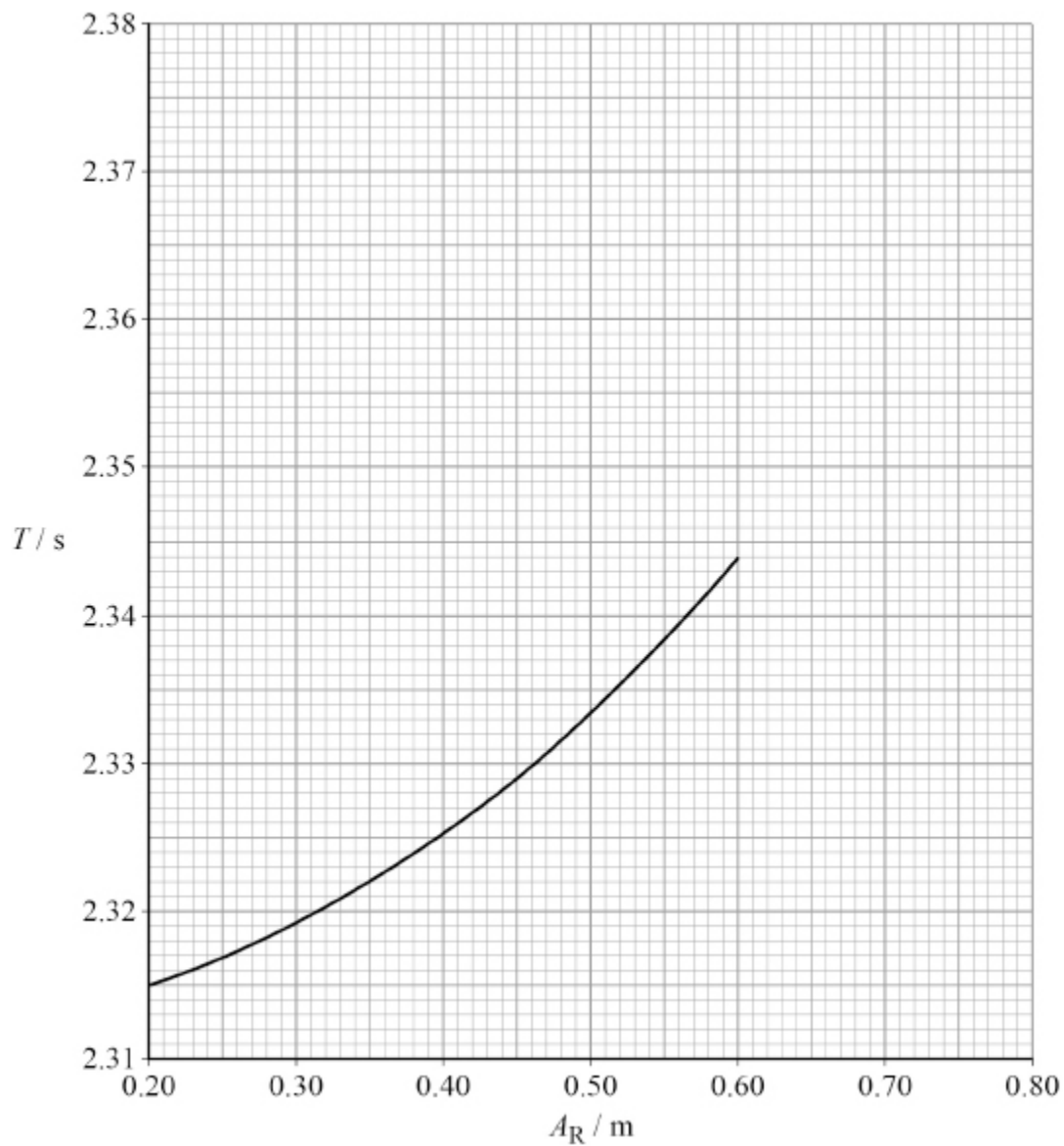
Describe a suitable procedure to determine A_R , the amplitude of the pendulum as it is released.

You may add detail to **Figure 2** to illustrate your answer.

(2)

- (c) **Figure 3** shows some of the results of the experiment.

Figure 3



Estimate, using **Figure 3**, the expected percentage increase in T when A_R increases from 0.35 m to 0.70 m.
Show your working.

percentage increase = _____ %

(3)

In another experiment the pendulum is released from a fixed amplitude.

The amplitudes A_n of successive oscillations are recorded, where $n = 1, 2, 3, 4, 5 \dots$.

Table 1 shows six sets of readings for the amplitude A_5 .

Table 1

A_5 / m	0.217	0.247	0.225	0.223	0.218	0.224
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- (d) Determine the result that should be recorded for A_5 .
Go on to calculate the percentage uncertainty in this result.

$$A_5 = \underline{\hspace{2cm}} \text{ m}$$

$$\text{percentage uncertainty} = \underline{\hspace{2cm}} \%$$

(3)

- (e) **Table 2** shows results for A_n and the corresponding value of $\ln(A_n / \text{m})$ for certain values of n .

Table 2

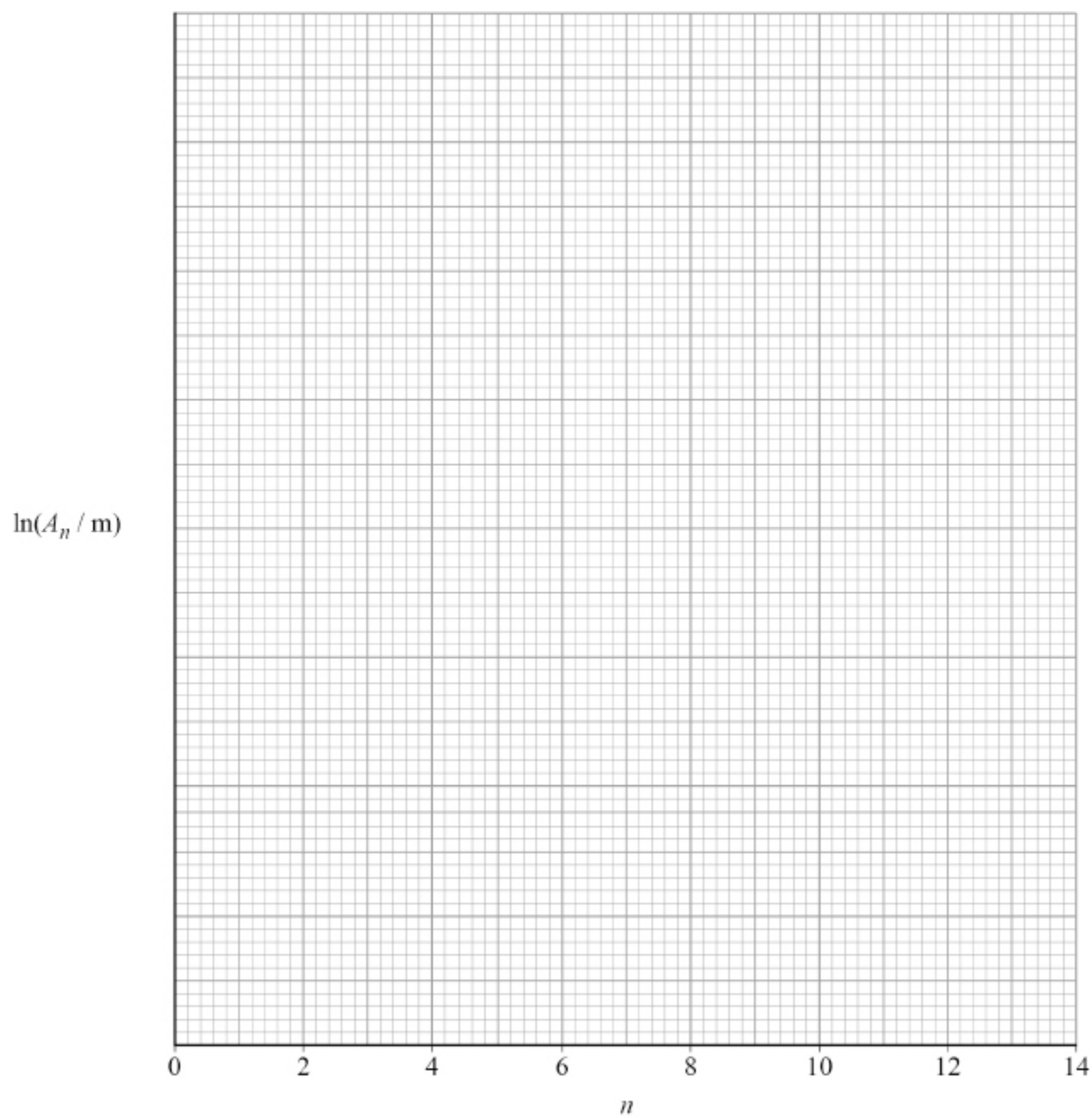
n	A_n / m	$\ln(A_n / \text{m})$
2	0.238	-1.435
4	0.225	
7	0.212	-1.551
10	0.194	-1.640
13	0.183	-1.698

Complete **Table 2**.

(1)

- (f) Plot on **Figure 4** a graph of $\ln(A_n / m)$ against n .

Figure 4



(g) It can be shown that

$$A_n = A_0 \delta^{-n}$$

where A_0 is the amplitude of release of the pendulum
 δ is a constant called the damping factor.

Explain how to find δ from your graph.
 You are **not** required to determine δ .

(2)

(Total 15 marks)

2.

A mass of 0.90 kg is suspended from the lower end of a light spring of stiffness 80 N m^{-1} .

When the mass is displaced vertically and released, it undergoes vertical oscillations of small amplitude.

What is the frequency of the oscillations?

A 0.071 Hz

☐

B 0.67 Hz

☐

C 1.50 Hz

☐

D 14 Hz

☐

(Total 1 mark)

3.

The period of a simple pendulum is doubled when the pendulum length is increased by 1.8 m.

What is the original length of the pendulum?

A 0.45 m

☐

B 0.60 m

☐

C 0.90 m

☐

D 3.6 m

☐

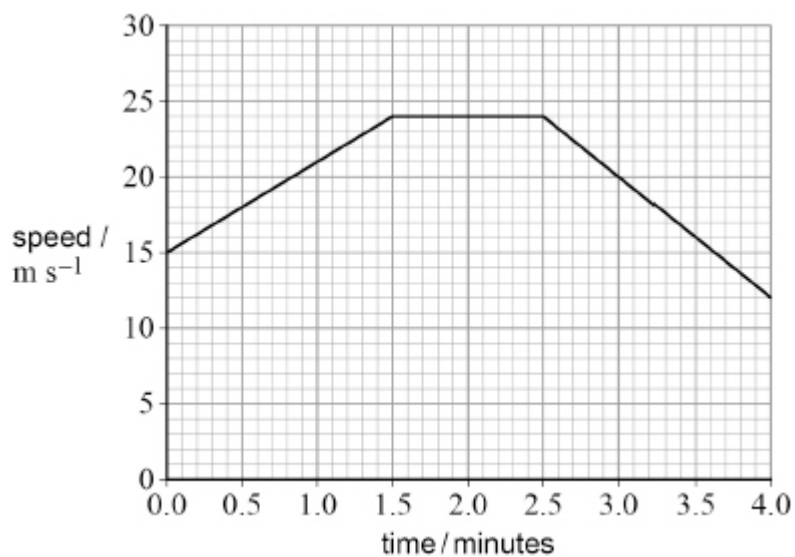
(Total 1 mark)

4.

A pair of cameras is used on a motorway to help determine the average speed of vehicles travelling between the two cameras.

Figure 1 shows the speed–time graph for a car moving between the two cameras.

Figure 1



- (a) The speed limit for the motorway between the two cameras is 22 m s^{-1} .

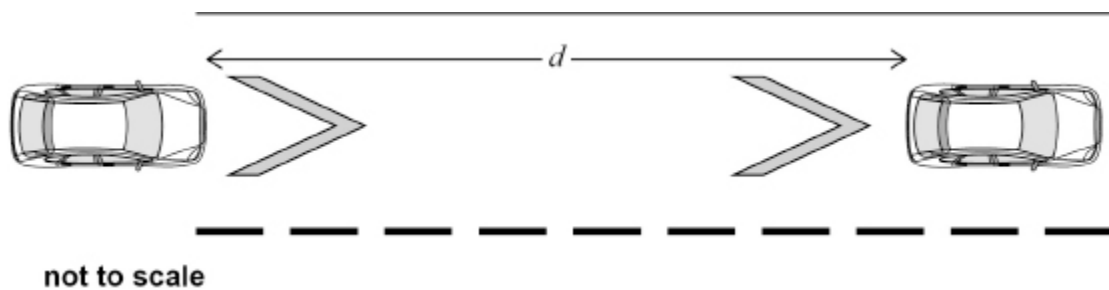
Determine whether the average speed of the car exceeded this speed limit.

(3)

- (b) Markings called chevrons are used on motorways.

The chevron separation is designed to give a driver time to respond to any change in speed of the car in front. The driver is advised to keep a minimum distance d behind the car in front, as shown in **Figure 2**.

Figure 2



Government research suggests that the typical time for a driver to respond is between 1.6 s and 2.0 s.

Suggest a value for d where the speed limit is 31 m s^{-1} .

$$d = \underline{\hspace{2cm}} \text{ m}$$

(2)

- (c) The chevron separation is based on the response time, not on the time taken for a car to stop.

The brakes of a car are applied when its speed is 31 m s^{-1} and the car comes to rest. The total mass of the car is 1200 kg.

The average braking force acting on the car is 6.8 kN.

Calculate the time taken for the braking force to stop the car **and** the distance travelled by the car in this time.

$$\text{time} = \underline{\hspace{2cm}} \text{ s}$$

$$\text{distance} = \underline{\hspace{2cm}} \text{ m}$$

(4)

- (d) Suggest why the chevron separation on motorways does not take into account the distance travelled as a car comes to rest after the brakes are applied.

(1)

- (e) At bends on motorways the road is sloped so that a car is less likely to slide out of its lane when travelling at a high speed.

Figure 3 shows a car of mass 1200 kg travelling around a curve of radius 200 m. The motorway is sloped at an angle of 5.0° .

Figure 4 shows the weight W and reaction force N acting on the car. The advisory speed for the bend is chosen so that the friction force down the slope is zero.

$$m = 1200 \text{ kg}$$

$$r = 200 \text{ m}$$

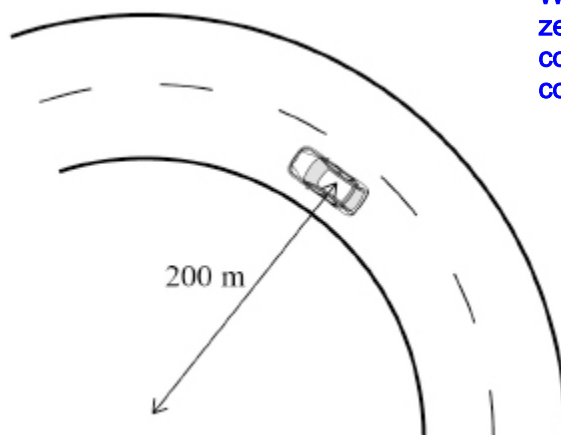
$$F_c = \frac{mv^2}{r}$$

$$W = N \cos 5^\circ \rightarrow N = \frac{W}{\cos 5^\circ} = \frac{mg}{\cos 5^\circ}$$

$$\frac{mv^2}{r} = N \sin 5^\circ \rightarrow v = \sqrt{\frac{N \sin 5^\circ \times r}{m}}$$

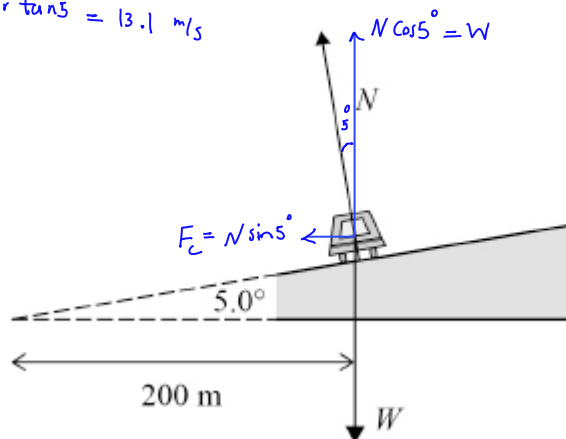
$$\rightarrow v = \sqrt{\frac{mg}{\cos 5^\circ} \times \frac{\sin 5^\circ \times r}{m}} = \sqrt{gr \tan 5^\circ} = 13.1 \text{ m/s}$$

Figure 3



When friction down the slope is zero, the only centripetal force is coming from the horizontal component of the reaction force.

Figure 4



Suggest an appropriate advisory speed for this section of the motorway.

advisory speed = _____ m s⁻¹

(4)

(Total 14 marks)

5.

A particle of mass m is oscillating with simple harmonic motion. The period of the oscillation is T and the amplitude is A .

What is the maximum kinetic energy of the particle?

A $\frac{mA^2}{2T^2}$

☐

B $\frac{\pi^2 mA^2}{2T^2}$

☐

C $\frac{2mA^2}{T^2}$

☐

D $\frac{2\pi^2 mA^2}{T^2}$

☐

(Total 1 mark)

6.

A simple pendulum and a mass–spring system each have a time period T on the Earth.

They are taken to the surface of a planet where the acceleration due to gravity is $\frac{g}{4}$.

What are the time periods of the pendulum and the mass–spring system on this planet?

	Simple pendulum	Mass–spring system	
A	$\frac{T}{2}$	T	☐
B	$2T$	T	☐
C	$\frac{T}{2}$	$2T$	☐
D	$2T$	$2T$	☐

(Total 1 mark)

7.

A particle of mass m undergoes simple harmonic motion with amplitude A and frequency f .

What is the total energy of the particle?

A $2\pi m f A^2$ ☐

B $2\pi^2 m f^2 A^2$ ☐

C $4\pi^2 m^2 f^2 A$ ☐

D $4\pi^2 m f^2 A^2$ ☐

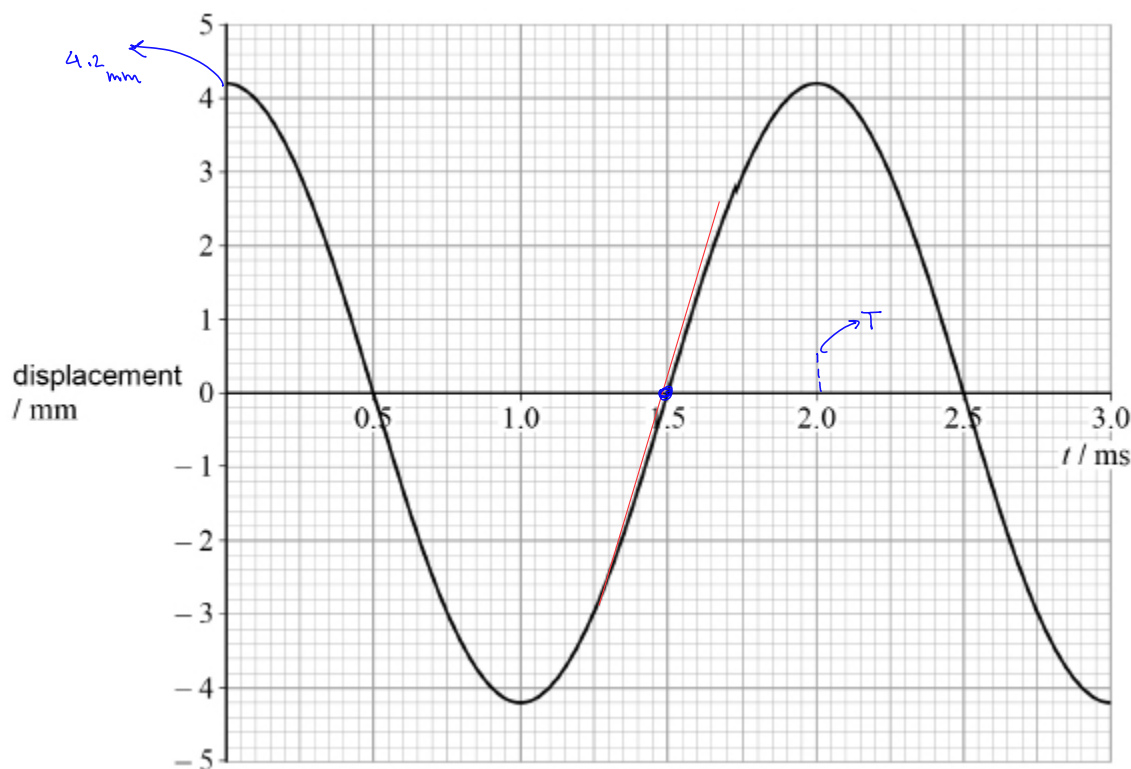
(Total 1 mark)

8.

A loudspeaker cone is driven by a signal generator (oscillator).

The graph shows the variation of displacement with time t for a point **P** at the centre of the cone.

P is oscillating with simple harmonic motion.



- (a) State the time, in milliseconds, when **P** is moving at its maximum positive velocity.

displacement - time graph $\Rightarrow$ gradient = velocity

time = 1.5 ms

(1)

- (b) Calculate the maximum acceleration of **P**.

$$a_{\max} = \omega^2 A$$

$$A = 4.2 \text{ mm}$$

$$T = 2 \text{ ms}$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2 \times 10^{-3}}$$

acceleration = _____ m s^{-2}

$$a_{\max} = \left(\frac{2\pi}{2 \times 10^{-3}} \right)^2 \times 4.2 \times 10^{-3} = 4.1 \times 10^4 \text{ m/s}^2$$

(3)

- (c) The loudspeaker creates variations in pressure and produces a sound wave in the air around it.

State the type of wave produced and describe the motion of the particles in this type of wave.

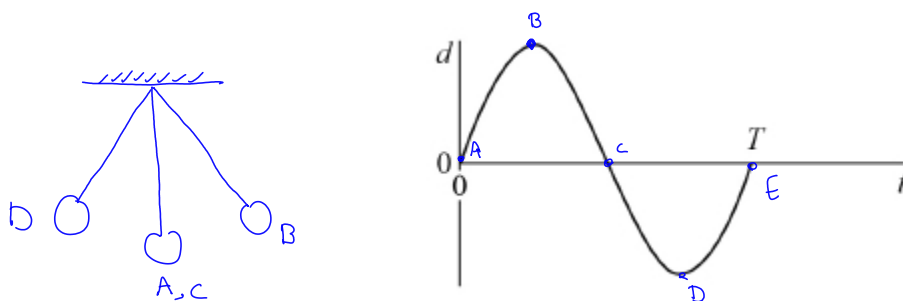
longitudinal

(1)

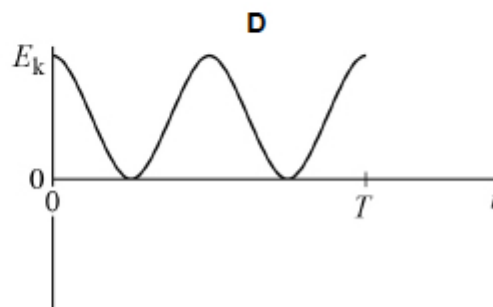
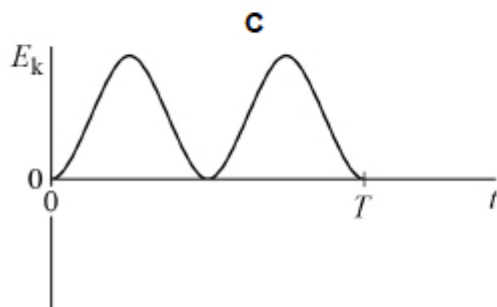
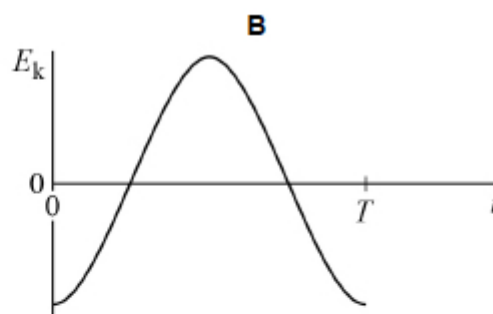
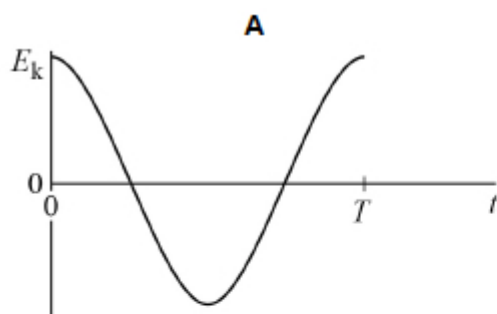
(Total 5 marks)

9.

The graph shows the variation of displacement d with time t for a particle moving with simple harmonic motion of period T .



Which graph shows the variation of kinetic energy E_k of the particle with time?



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

- 10.** Two pendulums **A** and **B** oscillate with simple harmonic motion. The time period of **A** is 2.00 s and the time period of **B** is 1.98 s.

A and **B** are released in phase.

What is the number of oscillations of **A** before **A** and **B** are next in phase?

- | | | |
|----------|-----|--------------------------|
| A | 49 | ☐ |
| B | 50 | ☐ |
| C | 99 | ☐ |
| D | 100 | ☐ |

(Total 1 mark)

- 11.** (a) State the conditions for simple harmonic motion.

SHM is when

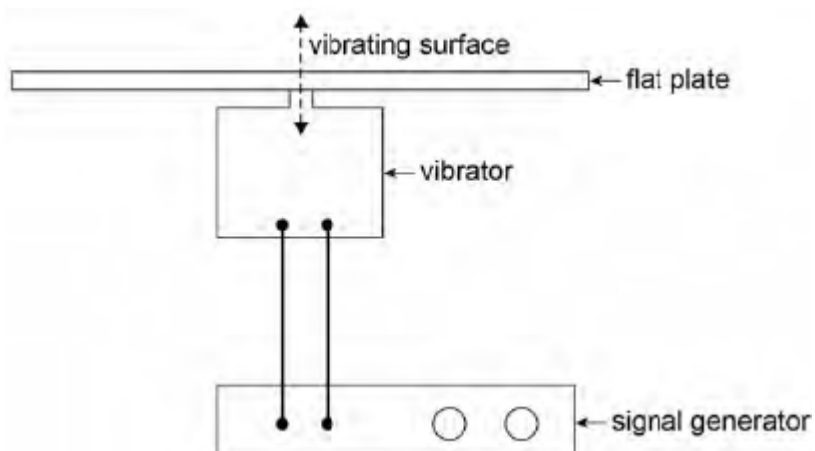
The acceleration is proportional to the displacement ✓

the acceleration is in opposite direction to displacement ✓

(2)

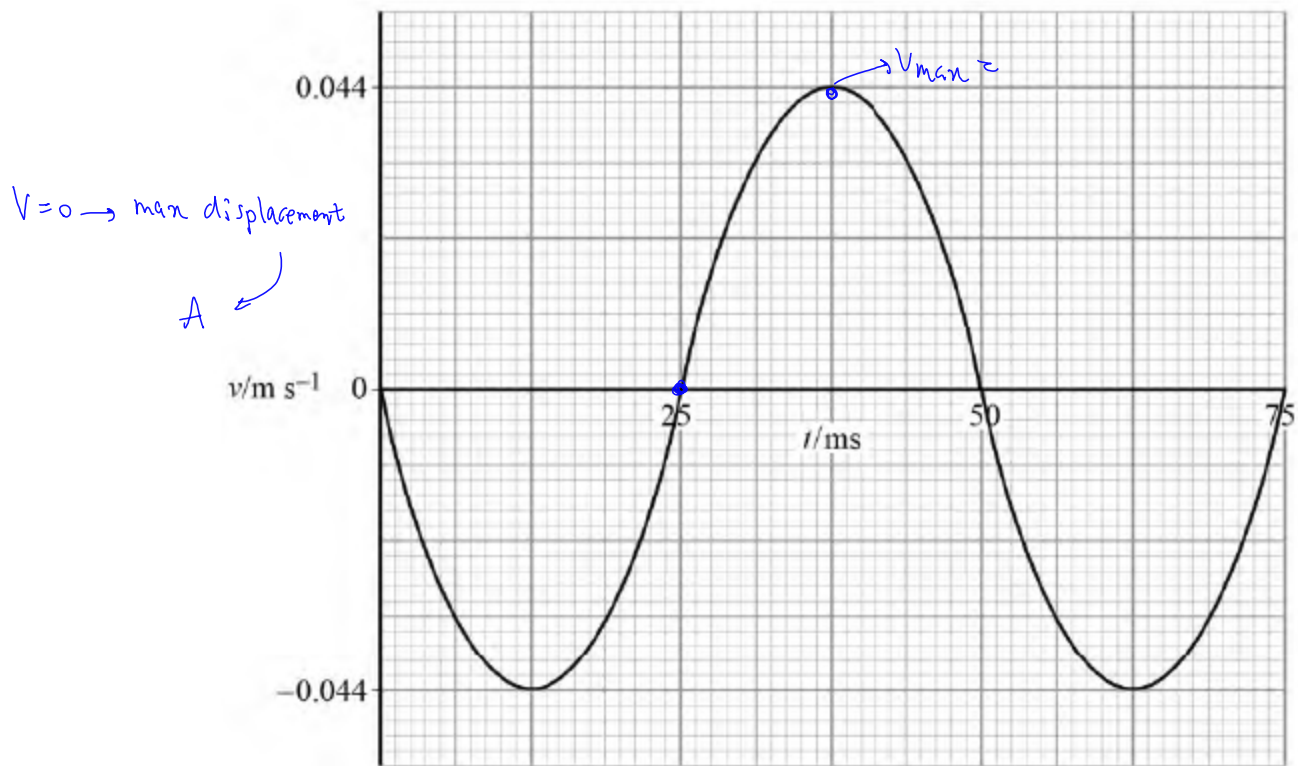
- (b) A rigid flat plate is made to vibrate vertically with simple harmonic motion. The frequency of the vibration is controlled by a signal generator as shown in **Figure 1**.

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.

$$V_{\max} = \omega A \quad ?$$

$$\omega = \frac{2\pi}{T} =$$

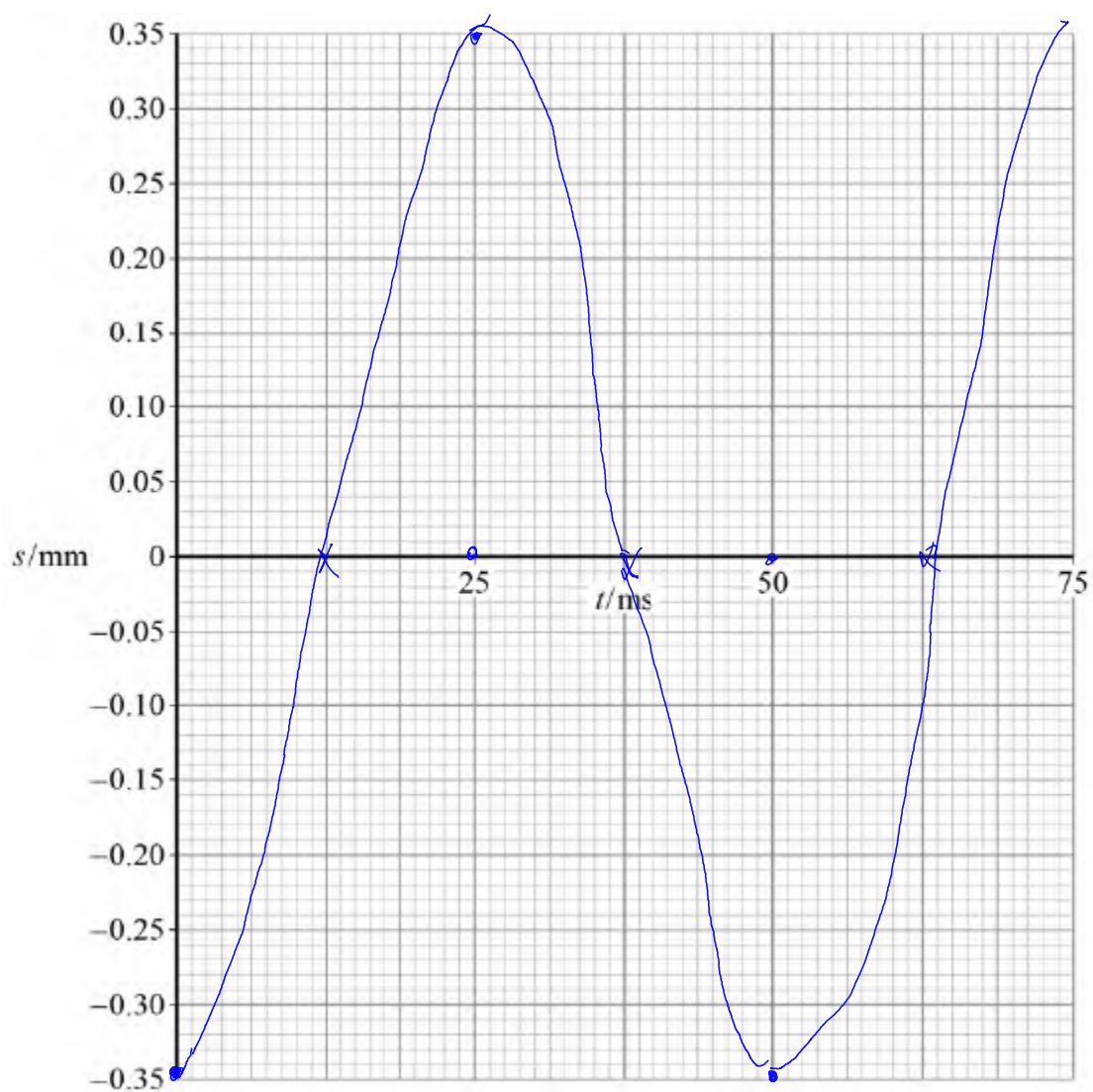
$$T = 50 \text{ ms}$$

$$V_{\max} \approx 0.044 \text{ m/s}$$

$$A = \frac{V_{\max}}{\omega} = \frac{0.044}{\frac{2\pi}{50 \times 10^{-3}}} = 3.5 \times 10^{-4} \text{ m} \quad (2)$$

- (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.

$$t = 0, 25, 50 \text{ ms}$$

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.

when the vibrating surface accelerates down with an acceleration less than the acceleration of free fall the sand stays in contact ✓

above a particular frequency, the acceleration is greater than g ✓
there is no contact force on the sand OR

sand no longer in contact when downwards acceleration of plate is greater than acceleration of sand due to gravity ✓

(3)

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

threshold $\rightarrow a = g$

$\omega = 2\pi f$

$a_{\max} = \omega^2 A$

$\omega^2 A = g \rightarrow 4\pi^2 f^2 A = g \rightarrow f = \sqrt{\frac{g}{4\pi^2 A}}$

$A = 3.5 \times 10^{-4} \text{ m}$

frequency = _____ Hz

(2)

(Total 11 marks)

$f = \sqrt{\frac{9.81}{4\pi^2 \times 3.5 \times 10^{-4}}} = 26.6 \text{ Hz}$

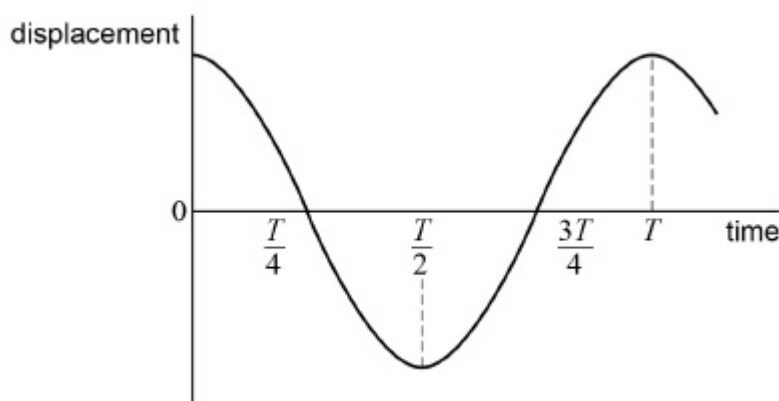
- 12.** A helicopter circles continuously at a constant speed around a horizontal path of diameter 800 m, taking 5.0 minutes to complete each orbit of the path.

What are the speed v and the centripetal acceleration a of the helicopter?

	$v / \text{m s}^{-1}$	$a / \text{m s}^{-2}$	
A	0.021	0.18	☐
B	8.4	0.088	☐
C	8.4	0.18	☐
D	17	0.35	☐

(Total 1 mark)

- 13.** The graph shows how the displacement of a particle performing simple harmonic motion varies with time.



Which statement is **not** correct?

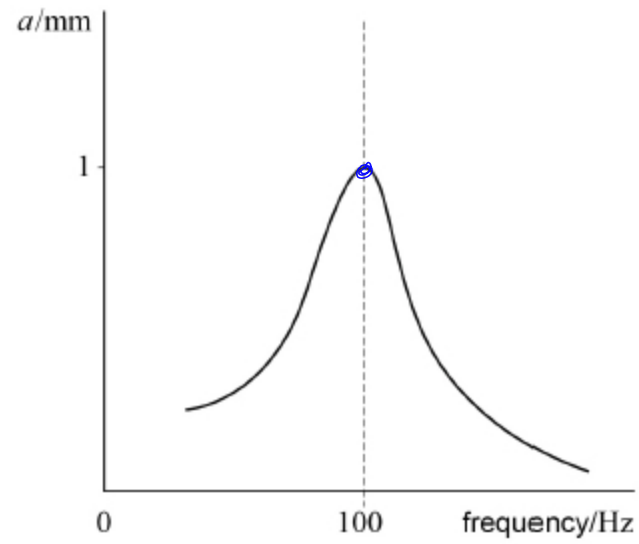
- A** The speed of the particle is a maximum at time $\frac{T}{4}$ ☐
- B** The potential energy of the particle is zero at time $\frac{3T}{4}$ ☐
- C** The acceleration of the particle is a maximum at time $\frac{T}{2}$ ☐
- D** The restoring force acting on the particle is zero at time T ☒

✓ $x = \text{max} \rightarrow a = \text{min}$
 $\rightarrow F \neq 0$

(Total 1 mark)

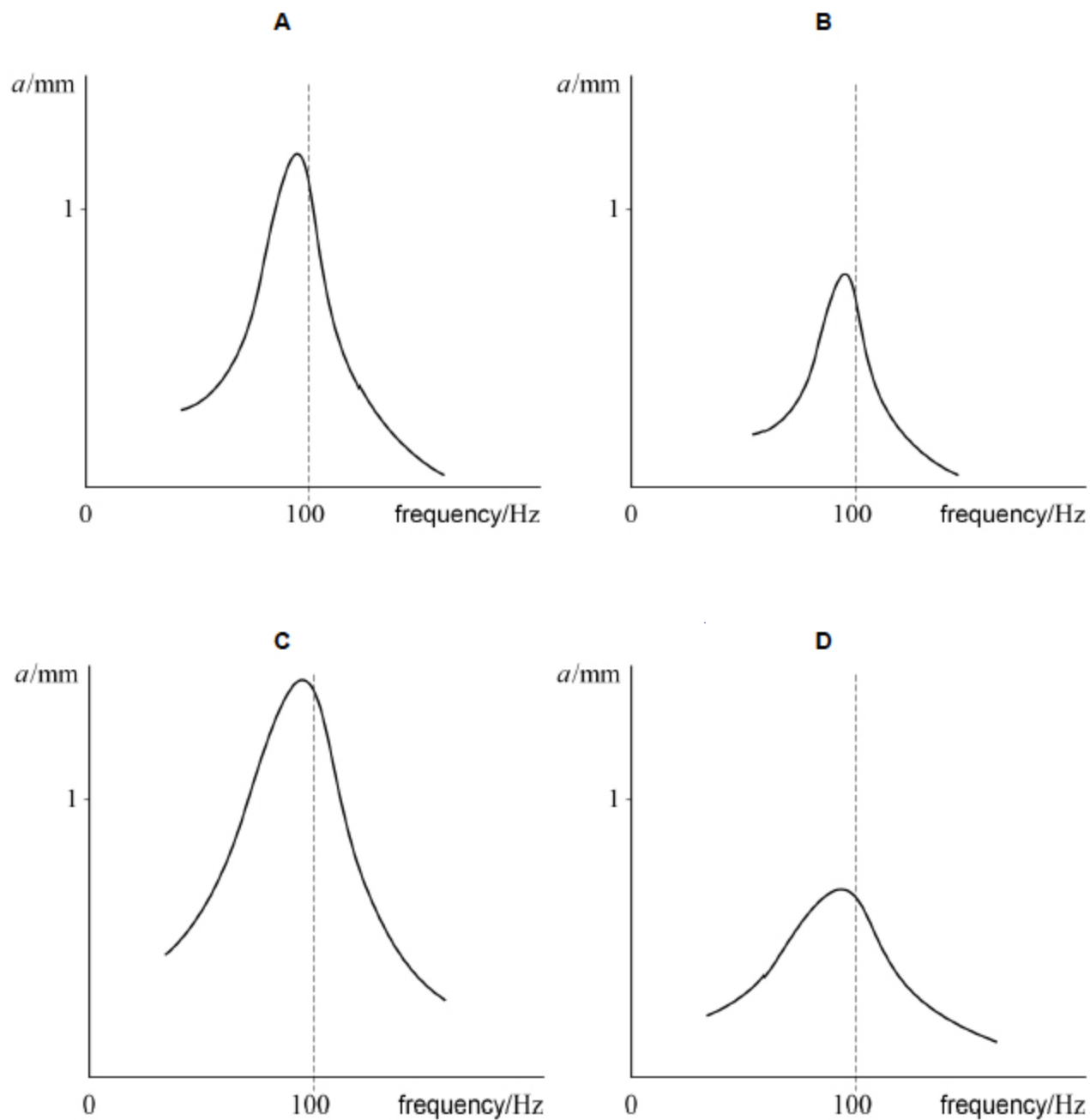
14.

A metal panel is driven to vibrate at different frequencies. The amplitude a of the vibration is measured at each frequency. The graph shows the variation of amplitude with driven frequency.



The damping of the metal panel is increased without changing the mass of the panel.

Which graph shows the variation of a with frequency with increased damping?



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

15.

The frequency of oscillation of a vertical spring is f when the mass hanging from the spring is m .

What is the relationship between f and m ?

A $f \propto m^{-1/2}$

☐

B $f \propto m^{-2}$

☐

C $f \propto m^{1/2}$

☐

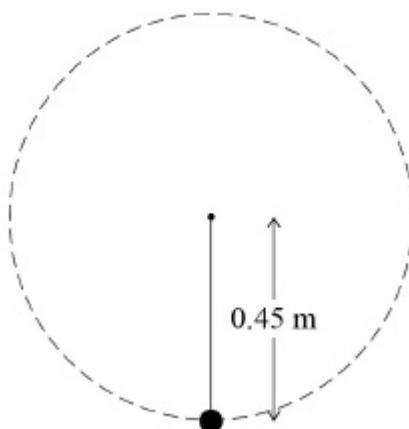
D $f \propto m^2$

☐

(Total 1 mark)

16.

A bob of mass 0.50 kg is suspended from the end of a piece of string 0.45 m long. The bob is rotated in a vertical circle at a constant rate of 120 revolutions per minute.



What is the tension in the string when the bob is at the bottom of the circle?

A 5.8 N

☐

B 31 N

☐

C 36 N

☐

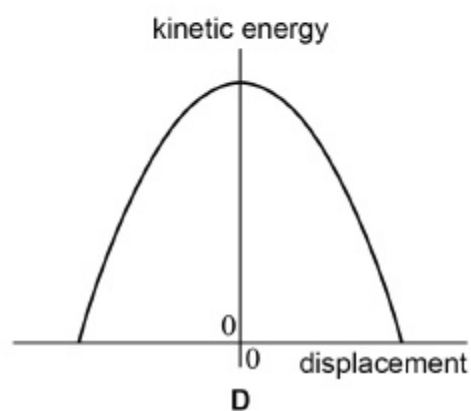
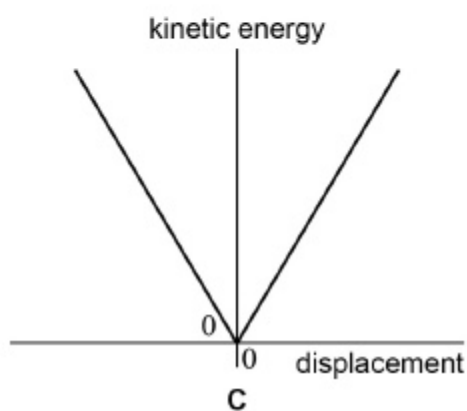
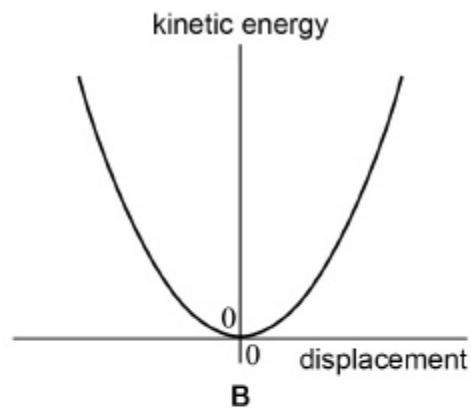
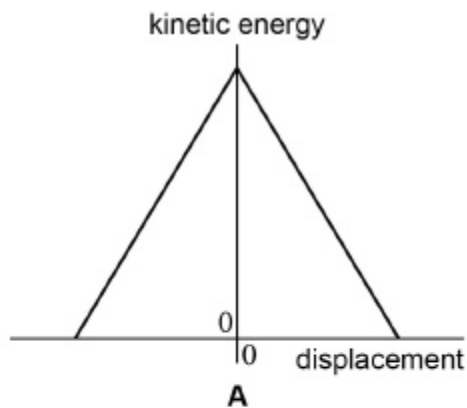
D 40 N

☐

(Total 1 mark)

17.

Which graph best shows how the kinetic energy of a simple pendulum varies with displacement from the equilibrium position?



A



B



C



D



(Total 1 mark)

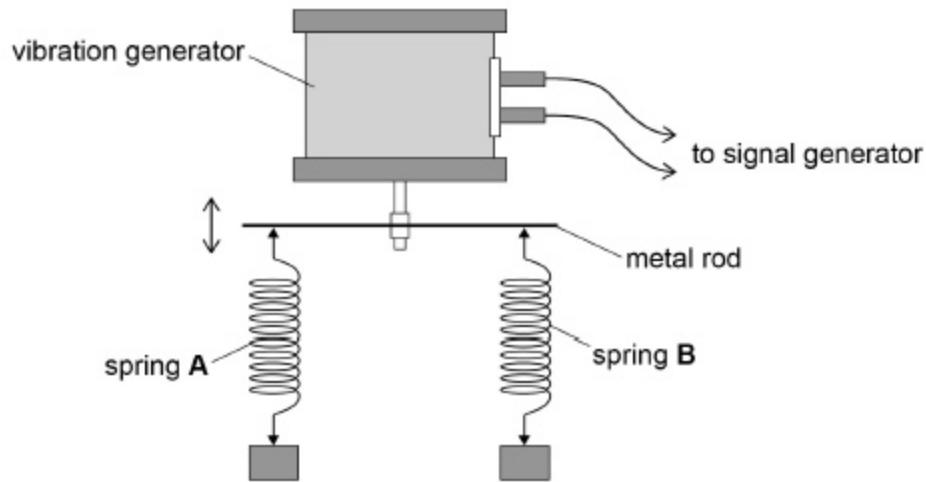
18.

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 2.0Hz , the mass attached to spring **A** oscillates with a maximum amplitude of $2.5 \times 10^{-2}\text{m}$ and has a maximum kinetic energy of 54mJ .

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

$$k = \text{_____} \text{ N m}^{-1}$$

$$m = \text{_____} \text{ kg}$$

(4)

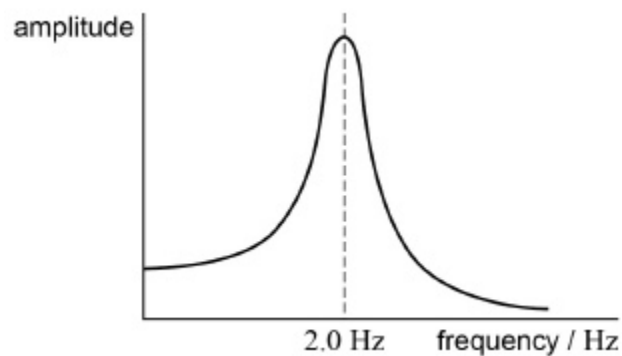
- (b) Calculate the frequency at which the mass attached to spring **B** oscillates with maximum amplitude.

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 _____

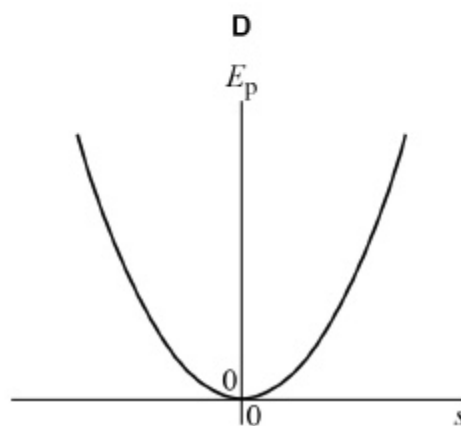
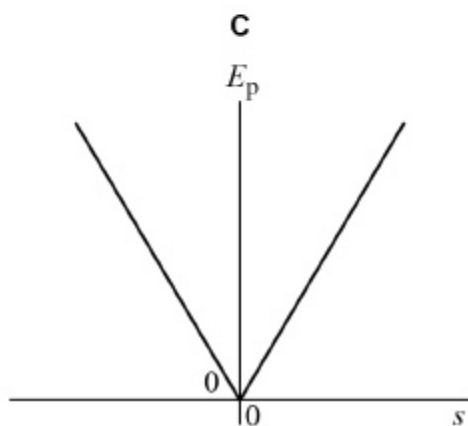
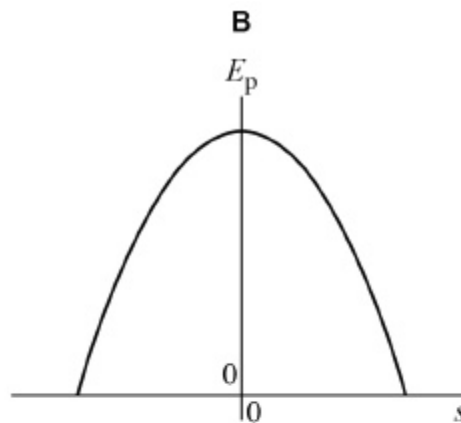
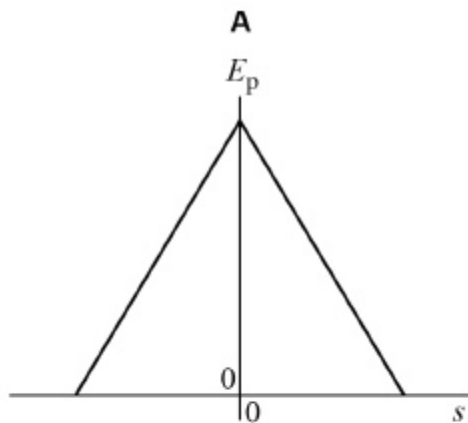
Difference 2 _____

(4)

(Total 10 marks)

19.

Which graph shows how the gravitational potential energy E_p of a simple pendulum varies with displacement s from the equilibrium position?



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

20.

A body performs simple harmonic motion.

What is the phase difference between the variation of displacement with time and the variation of acceleration with time for the body?

A 0

☐

B $\frac{\pi}{4}$ rad

☐

C $\frac{\pi}{2}$ rad

☐

D π rad

☐

(Total 1 mark)