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OCR A LEVEL PHYSICS A (H556): QUESTIONS BY TOPIC

Oscillations (5.3)

A Level Physics A (H556) · Module 5: Newtonian world and astrophysics

32 questions · 182 marks · Mark schemes included

OCR A Level Physics A (H556), June 2017 – June 2025

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HOW TO USE THIS BOOKLET

Questions run from the lowest mark tariff to the highest, so similar questions sit together.

Click any row below to jump straight to that question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

32 questions · 182 marks · lowest tariff first



MULTIPLE-CHOICE QUESTIONS

18 questions in this booklet



- 4 The acceleration a of a simple harmonic oscillator is related to its displacement x by the equation

$$a = -25x.$$

What is the frequency of the oscillator?

- A 0.80 Hz
- B 1.3 Hz
- C 4.0 Hz
- D 5.0 Hz

Your answer

[1]



- 9 A pendulum is oscillating in air and experiences damping.

Which of the following statements is/are correct for the damping force acting on the pendulum?

- 1 It is always opposite in direction to acceleration.
- 2 It is always opposite in direction to velocity.
- 3 It is maximum when the displacement is zero.

A Only 1 and 2

B Only 2 and 3

C Only 3

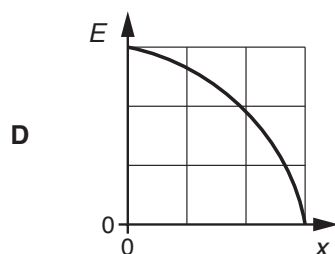
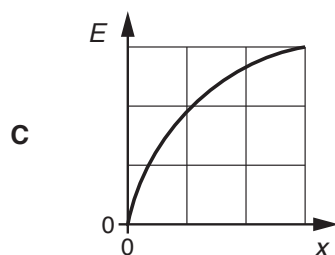
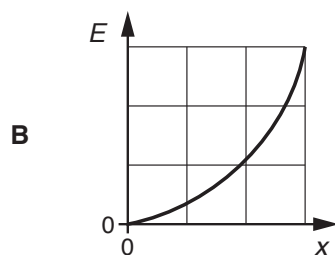
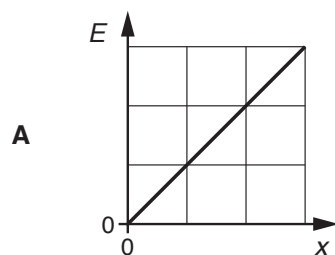
D 1, 2 and 3

Your answer

[1]

15 An object oscillates with simple harmonic motion.

Which graph **best** shows the variation of its potential energy E with distance x from the equilibrium position?



Your answer

[1]

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SECTION B

Answer **all** the questions.



- 3 A solid cylindrical glass rod has length 20.0 ± 0.1 cm and diameter 5.00 ± 0.01 mm.

What is the percentage uncertainty in the calculated volume of this rod?

- A** 0.1%
B 0.2%
C 0.7%
D 0.9%

Your answer

[1]

4 A solid cylindrical glass rod has length 20.0 ± 0.1 cm and diameter 5.00 ± 0.01 mm.

- 4 A simple harmonic oscillator has maximum speed 24 m s^{-1} and amplitude 5.6 cm .

What is its angular frequency?

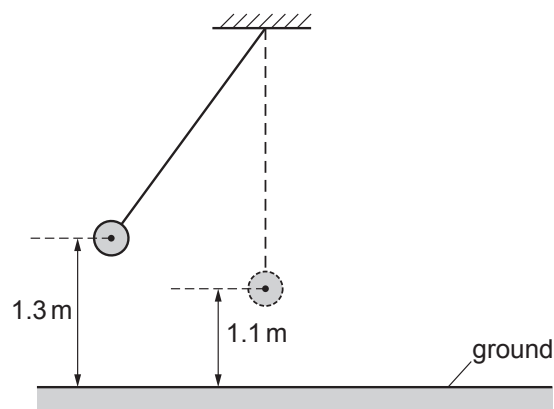
- A 0.23 rad s^{-1}
- B 21 rad s^{-1}
- C 68 rad s^{-1}
- D 430 rad s^{-1}

Your answer

[1]



- 7 A pendulum bob is oscillating in a vacuum.
The maximum height of the bob from the ground is 1.3 m and its minimum height is 1.1 m.



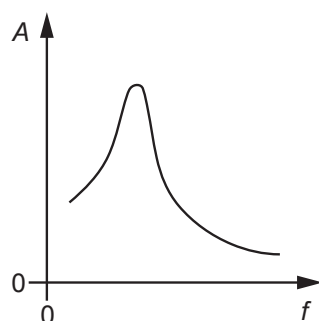
What is the maximum speed of the pendulum bob?

- A 2.0 ms^{-1}
- B 3.9 ms^{-1}
- C 5.1 ms^{-1}
- D 26 ms^{-1}

Your answer

[1]

- 4 An oscillator is forced to oscillate at different frequencies.
The graph of amplitude A against driving frequency f for this oscillator is shown.



The damping on the oscillator is now **decreased**.

Which of the following statements is/are correct?

- 1 The amplitude of the oscillations at any frequency decreases.
- 2 The maximum amplitude occurs at a lower frequency.
- 3 The peak on the graph becomes thinner.

A Only 1

B Only 2

C Only 3

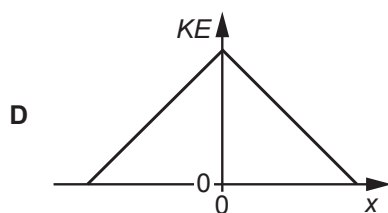
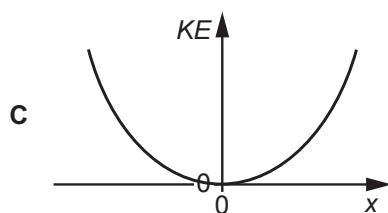
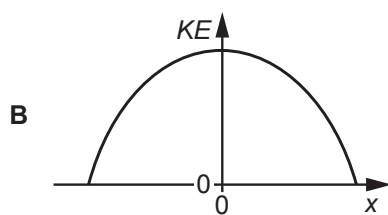
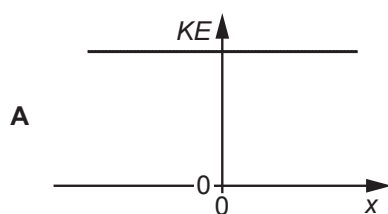
D 1, 2 and 3

Your answer

[1]

12 An oscillator is executing simple harmonic motion.

Which graph of kinetic energy KE against displacement x is correct for this oscillator?



Your answer

[1]

6 This question is about a progressive wave and a stationary wave.

Which statement is correct?

- A A progressive wave has at least one node.
- B All progressive waves are longitudinal.
- C All particles oscillating between two adjacent nodes in a stationary wave are in phase.
- D The superposition of two waves travelling in the same direction produces a stationary wave.

Your answer

[1]

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- 6 For a simple harmonic oscillator, the maximum speed is $v_{\max}$ when the amplitude is A . The frequency of the oscillations is f .

Which expression is correct for this oscillator?

A $v_{\max} = fA$

B $v_{\max} = 2\pi fA$

C $v_{\max} = f^2A$

D $v_{\max} = 4\pi^2 f^2 A$

Your answer

[1]

12 Oscillations of an object can either be **free** or **forced**.

Which of the following is an example of a **forced** oscillation?

- A A ball rolling to-and-fro on a curved track.
- B A loudspeaker oscillating and producing a continuous note.
- C A mass oscillating from the end of a suspended spring.
- D A pendulum bob oscillating from the end of a fixed length of string.

Your answer

[1]

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Turn over



- 10 A mass is attached to the bottom end of a spring which is fixed at its top end. The mass is displaced vertically, and then released. The mass oscillates with a simple harmonic motion.

Which row correctly describes the energy of this spring-mass system when the mass is at its **lowest** point in its oscillations?

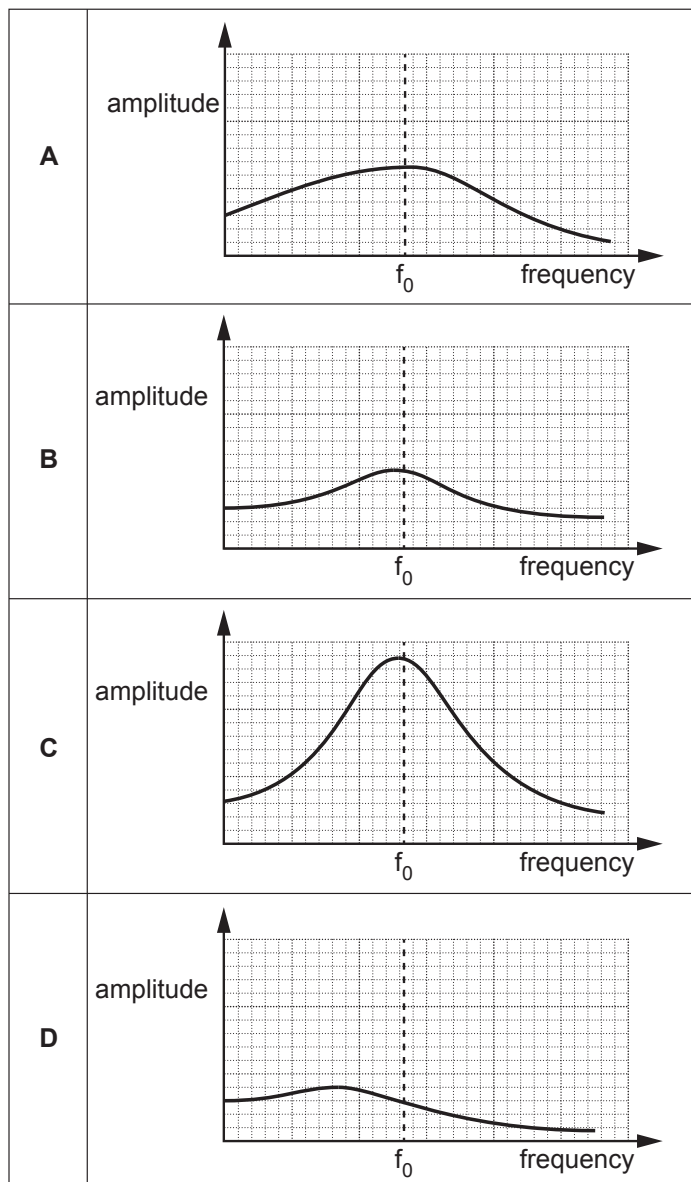
	Elastic potential energy	Gravitational potential energy	Kinetic energy
A	Maximum	Maximum	Maximum
B	Maximum	Minimum	Zero
C	Minimum	Maximum	Zero
D	Minimum	Minimum	Maximum

Your answer

[1]

- 12 Four different oscillator systems are forced to oscillate at various frequencies. The graphs show the amplitude of oscillation for each frequency. f_0 is the undamped resonant frequency for each oscillator. The vertical axes on the graphs are all to the same scale.

Which of the oscillators, **A** to **D**, is the most heavily damped?

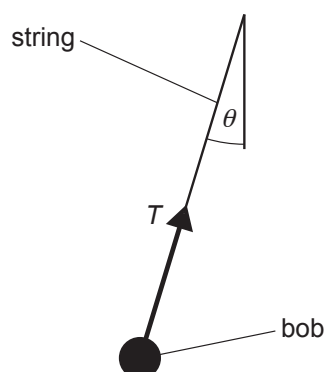


Your answer

[1]

- 8 The bob of a pendulum is displaced slightly so that the string forms a small angle $\theta < 10^\circ$ with the vertical.

The tension in the string is T . The small angle approximation applies.



Which of the following pairs of quantities would give approximately, within 2 significant figures, the same value for the horizontal component of T ?

- 1 $T \cos \theta$ and $T \sin \theta$
- 2 $T \cos \theta$ and $T \tan \theta$
- 3 $T \sin \theta$ and $T \tan \theta$

- A 1 only
- B 1 and 3
- C 3 only
- D 2 and 3

Your answer

[1]

- 9 A mass suspended from a spring is pulled down 0.05 m from the equilibrium point and released.

It oscillates in simple harmonic motion. The frequency of the motion is 2 Hz.

At time $t = 0$ the mass passes through the equilibrium point.

What is the displacement in metres from the equilibrium point at time t ?

- A $0.05 \cos 2t$
B $0.05 \cos 4\pi t$
C $0.05 \sin 2t$
D $0.05 \sin 4\pi t$

Your answer

[1]

10 The natural frequency of an oscillator vibrating in air is 20 Hz.

Which statement is correct about this oscillator?

- A** The natural period of the vibrating oscillator is 5.0 ms.
- B** The oscillator can be forced to vibrate at maximum amplitude at a frequency of about 20 Hz.
- C** The oscillator can be made to resonate at a frequency of about 40 Hz.
- D** The period of the freely vibrating oscillator gets smaller as its amplitude decreases.

Your answer

[1]

- 12 An object is released from rest and oscillates with simple harmonic motion. The maximum kinetic energy is U .

The object is stopped and the process is repeated with the initial displacement doubled.

What is the new maximum kinetic energy?

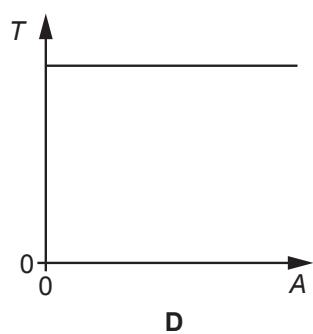
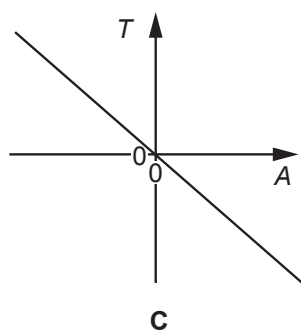
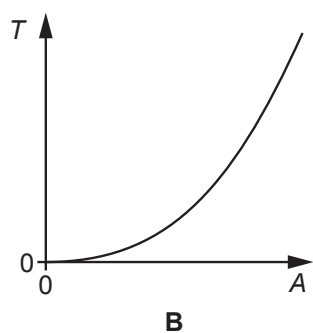
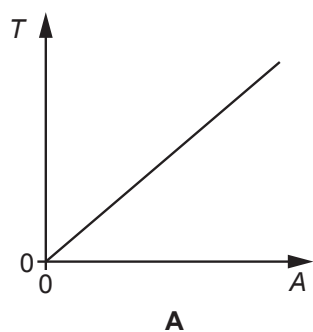
- A U
- B $1.4U$
- C $2U$
- D $4U$

Your answer

[1]

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- 14 A body moves with simple harmonic motion. Which graph shows the correct relationship between its period, T , and its amplitude, A ?



Your answer

[1]

4-MARK QUESTIONS

1 question in this booklet



18 Fig. 18 represents a tube open at both ends.

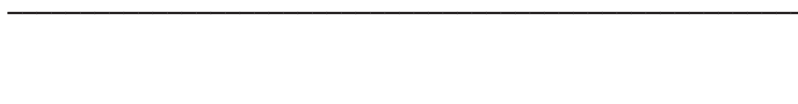
Air inside the tube is forced to oscillate by a speaker and produces a standing wave.

The length of the tube is 30.0 cm.

The wave speed inside the tube is 340 ms^{-1} .

(a) On Fig. 18 sketch the standing wave for the fundamental mode of vibration.

Fig. 18



[1]

(b) Calculate the frequency f_0 of the speaker that is producing the standing wave inside the tube.

$f_0 = \dots\dots\dots$ Hz [1]

(c) The frequency of the speaker is increased.

Calculate the next frequency f_1 that will produce a standing wave in this tube.

$f_1 = \dots\dots\dots$ Hz [2]

6-MARK QUESTIONS

1 question in this booklet



- 19*** A student makes a pendulum using a length of string with a ball of adhesive putty which acts as a bob. The mass of this bob is M .
A similar second pendulum is constructed with the same length of string but with a bob of a smaller mass. The mass of this bob is m .

The arrangement of the pendulums is shown below.



before collision

after collision

The bob of mass M is pulled back to a vertical height of H from its rest position. It is released and collides with the bob of mass m . The two bobs then stick together and reach a maximum vertical height h from the rest position.

The height h is given by the equation $h = \left(\frac{M}{M+m} \right)^2 H$.

Describe how to perform an experiment to test the validity of this equation and how the data can be analysed. **[6]**

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Additional answer space if required

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10-MARK QUESTIONS

3 questions in this booklet



- 2 The 500 m tall Taipei 101 tower is shown in Fig. 2.1. The tower has a massive sphere suspended across five floors near the top of the building to dampen down movement of the tower in high winds and earthquakes. The sphere is connected to pistons (not shown) which drive oil through small holes providing damping. The vibration energy of the sphere is converted to thermal energy.

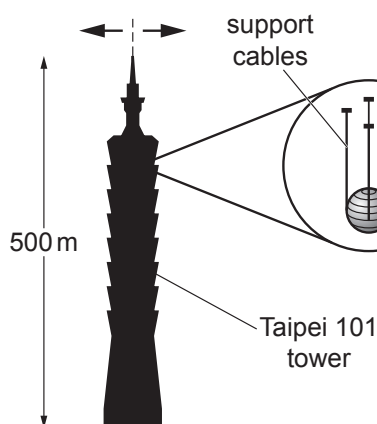


Fig. 2.1

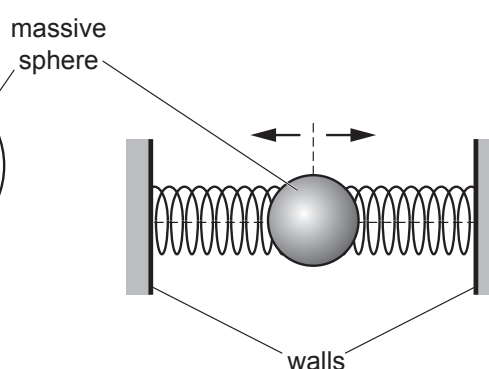


Fig. 2.2

Fig. 2.2 models the damper system as the sphere held between two springs. The movement of the walls of the tower forces the sphere to oscillate in **simple harmonic motion**.

In the strongest wind, the natural frequency of the oscillations of the tower is 0.15 Hz and the maximum acceleration of the sphere is 0.050 m s^{-2} .

- (a) Calculate the maximum displacement of the sphere in the strongest wind.

maximum displacement = ... m [3]

- (b) Explain why the natural frequency of the damper system must be about 0.15 Hz.

.....

 [2]

- (c) The acceleration a of the sphere is given by the equation

$$a = -\left(\frac{k}{m}\right)x$$

where k is the force constant of the spring combination, x is the displacement of the sphere and m is the mass of the sphere.

The mass of the sphere is $6.6 \times 10^5 \text{ kg}$. The natural frequency of the oscillations of the sphere is 0.15 Hz .

- (i) Show that the force constant k of the spring combination is about $6 \times 10^5 \text{ N m}^{-1}$.

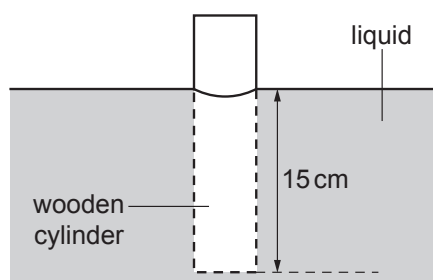
[3]

- (ii) The S-wave of an earthquake causes a sudden movement of the building displacing the sphere 0.71 m from its equilibrium position relative to the building.

Use your answer in (i) to calculate the energy transferred to the springs of the damper system.

energy transferred = ... J [2]

- 22 A long wooden cylinder is placed into a liquid and it floats as shown.



The length of the cylinder below the liquid level is 15 cm.

- (a) (i) State **Archimedes' principle**.

.....

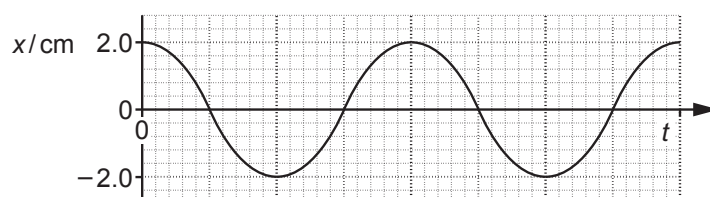
 [1]

- (ii) The pressure exerted by the liquid alone on the bottom of the cylinder is $1.9 \times 10^3 \text{ Pa}$.

Calculate the density ρ of the liquid.

$\rho = \dots\dots\dots \text{ kg m}^{-3}$ [2]

- (b) The cylinder is pushed down into the liquid and then allowed to oscillate freely. The graph of displacement x against time t is shown below.



The cylinder oscillates with simple harmonic motion with frequency of 1.4 Hz.

- (i) Calculate the displacement, in cm, at time $t = 0.60$ s.

displacement = ... cm [3]

- (ii) Calculate the maximum speed of the oscillating cylinder.

maximum speed = ... ms^{-1} [2]

- (iii) The cylinder is now pushed down further into the liquid before being released.
As before, the cylinder oscillates with simple harmonic motion.

State the effect this has on

- 1 the amplitude

.....

- 2 the period.

.....

[2]

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- 6 (a) Define the **time constant** of a circuit containing a capacitor of capacitance C and a resistor of resistance R .

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 [1]

- (b) The capacitor circuit shown in **Fig. 6.1** can be used to smooth oscillating electrical signals.

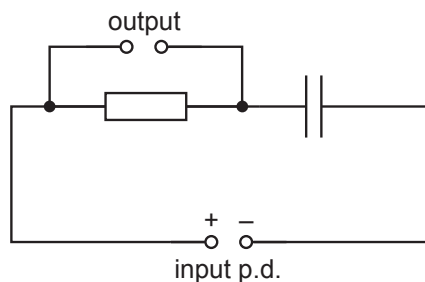


Fig. 6.1

- (i) **Fig. 6.2** shows the input signal of potential difference (p.d.) V against time t .

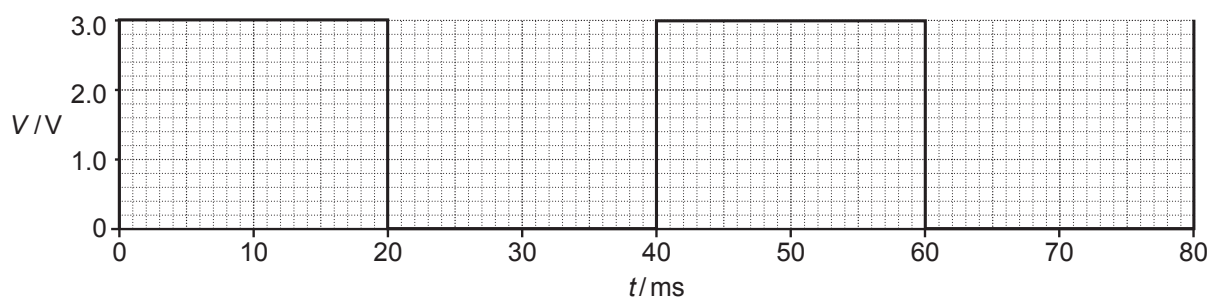


Fig. 6.2

Calculate the frequency f of this input signal.

$f =$ Hz [2]

- (ii) Fig. 6.3 shows the variation of the charge Q on the positive plate of the capacitor with time t .

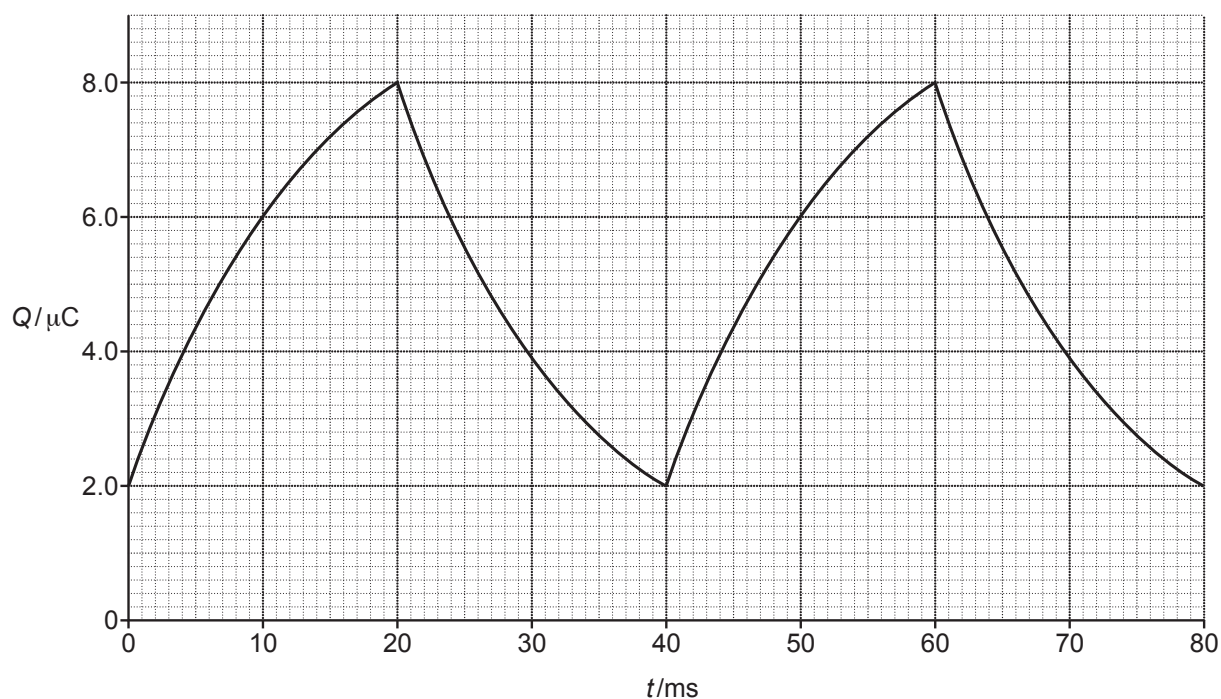


Fig. 6.3

Use a discharging section of the graph in Fig. 6.3 to determine the time constant of the circuit. Give your answer in ms.

time constant = ... ms [2]

- (iii) By drawing a suitable tangent to the graph in Fig. 6.3, calculate the maximum current in the resistor.

maximum current = ... A [2]

- (iv) On Fig. 6.4 below, sketch the variation of the current I in the resistor with time t . Include an appropriate label and scale on the vertical axis.

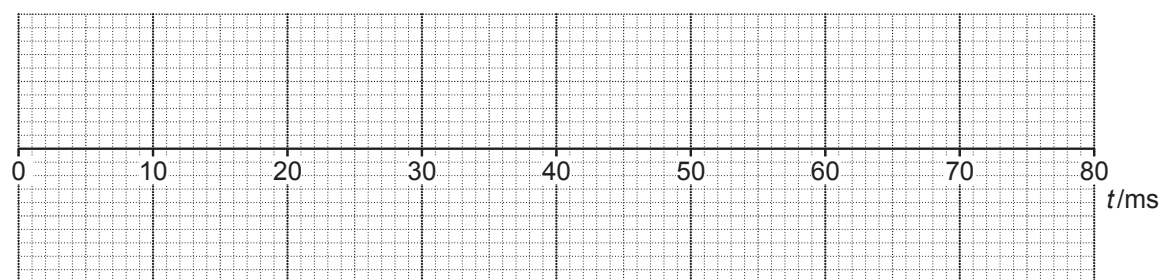


Fig. 6.4

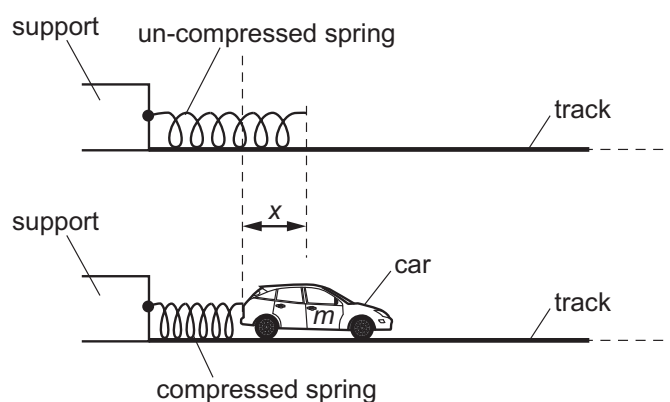
[3]

11-MARK QUESTIONS

1 question in this booklet



- 21 (a) One end of a spring is fixed to a support. A toy car, which is on a smooth horizontal track, is pushed against the free end of the spring. The spring compresses. The car is then released. The car accelerates to the right until the spring returns back to its original length.



The car moves with **simple harmonic motion** as the spring returns to its original length.

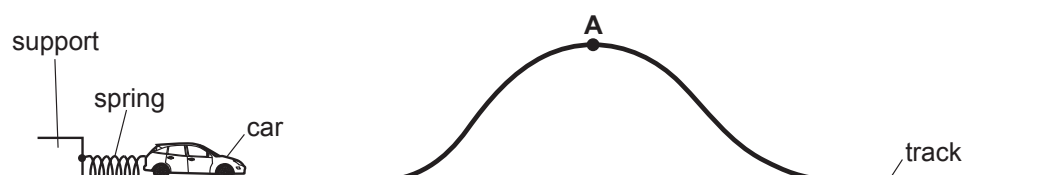
The acceleration of the car is given by the expression $a = -\left(\frac{k}{m}\right)x$, where m is the mass of the car, k is the force constant of the spring and x is the compression of the spring.

Use the data below to calculate the time t it takes for the spring to return to its original length after the car is released.

- mass of car $m = 80 \text{ g}$
- force constant k of the spring $= 60 \text{ N m}^{-1}$.

$t = \dots\dots\dots \text{ s}$ [4]

- (b) The arrangement in (a) is used to propel the toy car along a smooth track.



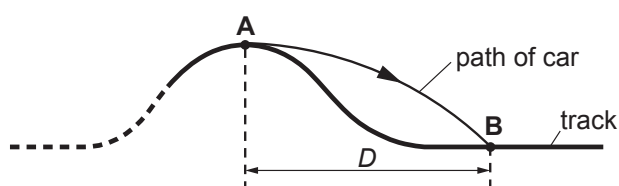
- (i) Point **A** is at the top of the track.
The launch speed of the car is now adjusted until the car just reaches **A** with zero speed.
The height of **A** is 0.20 m above the horizontal section of the track.

All the elastic potential energy of the spring is transferred to gravitational potential energy of the car.

Calculate the initial compression x of the spring.

$x = \dots\dots\dots$ m [3]

- (ii) At a specific speed, the car leaves point **A** horizontally and lands on the track at point **B**.
The horizontal distance between **A** and **B** is D .



Air resistance has negligible effect on the motion of the car between **A** and **B**.

- 1 Explain how the time of flight between **A** and **B** depends on the speed of the car at **A**.

.....

 [2]

- 2 Explain how the distance D depends on the speed of the car at **A**.

.....

 [2]

12-MARK QUESTIONS

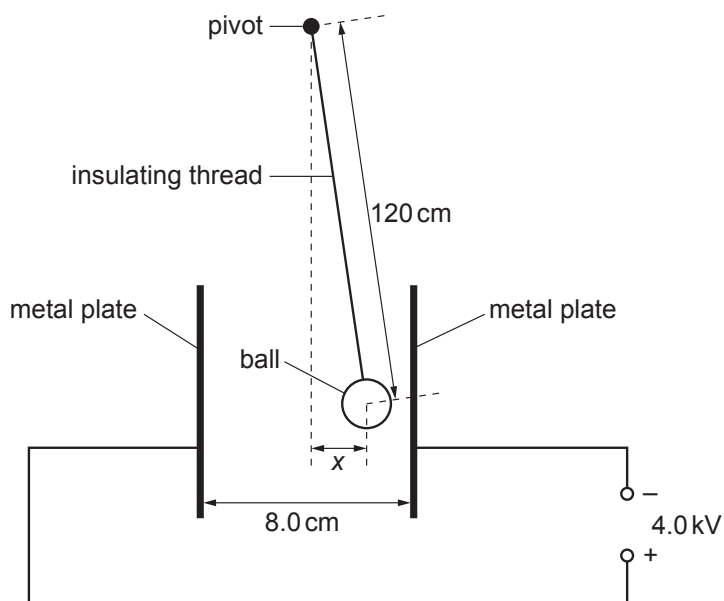
3 questions in this booklet



- 1 A ball coated with conducting paint has weight 0.030 N and radius 1.0 cm . The ball is suspended from an insulating thread. The distance between the pivot and the centre of the ball is 120 cm .

The ball is placed between two vertical metal plates. The separation between the plates is 8.0 cm . The plates are connected to a 4.0 kV power supply.

- (a) The ball receives a positive charge of 9.0 nC when it is made to touch the positive plate. It then repels from the positive plate and hangs in equilibrium at a displacement x from the vertical, as shown below. The diagram is **not** drawn to scale.



- (i) Show that the electric force acting on the charged ball is $4.5 \times 10^{-4}\text{ N}$.

[2]

- (ii) Draw, on the diagram above, arrows which represent the **three** forces acting on the ball. Label each arrow with the name of the force it represents.

[2]

(iii) By taking moments about the pivot, or otherwise, show that $x = 1.8 \text{ cm}$.

[2]

(b) The ball is still positively charged.

The plates are now moved slowly towards each other whilst still connected to the 4.0 kV power supply. The plates are stopped when the separation is 5.0 cm .

Explain the effect that this has on the deflection of the ball and explain why the ball eventually starts to oscillate between the plates.

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..... [4]

Question 1 continues on page 4

- (c) When the ball oscillates between the plates, the current in the external circuit is $3.2 \times 10^{-8} \text{ A}$.

A charge of 9.0 nC moves across the gap between the plates each time the ball makes one complete oscillation.

Calculate the frequency f of the oscillations of the ball.

$f = \dots\dots\dots \text{ Hz [2]}$

5 This question is about investigations involving an electromagnetic wave.

A vertical transmitter aerial emits a **vertically polarised** electromagnetic wave which travels towards a vertical receiver aerial. The wavelength of the wave is 0.60 m.

Fig. 5.1 shows a short section of the oscillating electric field of the electromagnetic wave.

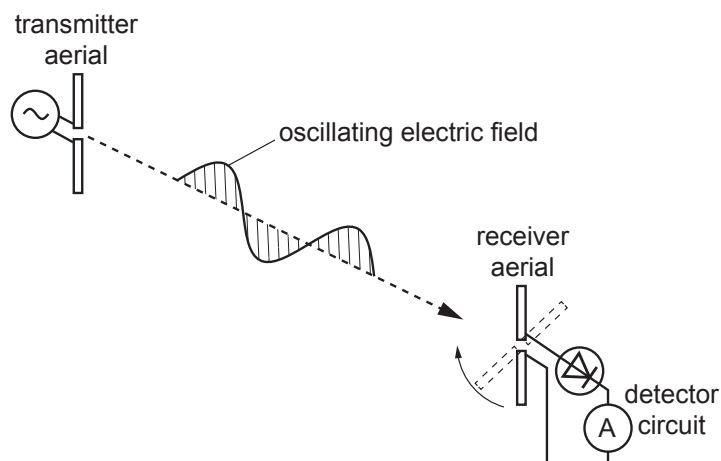


Fig. 5.1

(a) Calculate the frequency f of the transmitted wave.

$$f = \dots\dots\dots \text{ Hz [2]}$$

(b) The electromagnetic wave is caused by electrons oscillating in the transmitter aerial. Each electron oscillates with simple harmonic motion.

Calculate the maximum acceleration a_{max} of an electron which oscillates with an amplitude of $4.0 \times 10^{-6} \text{ m}$.

$$a_{\text{max}} = \dots\dots\dots \text{ ms}^{-2} [3]$$

- (c) Suggest why the diode in **Fig. 5.1** is necessary for an ammeter to detect a signal at the receiver aerial.

.....

 [1]

- *(d) A student carries out two investigations with these electromagnetic waves.

In **investigation 1**, the student rotates the receiver aerial about the horizontal axis joining the two aerals, as shown in **Fig. 5.1**.

In **investigation 2**, the student places a metal sheet behind the receiver aerial. The student moves the sheet backwards and forwards along the horizontal axis joining the two aerals, as shown in **Fig. 5.2**.

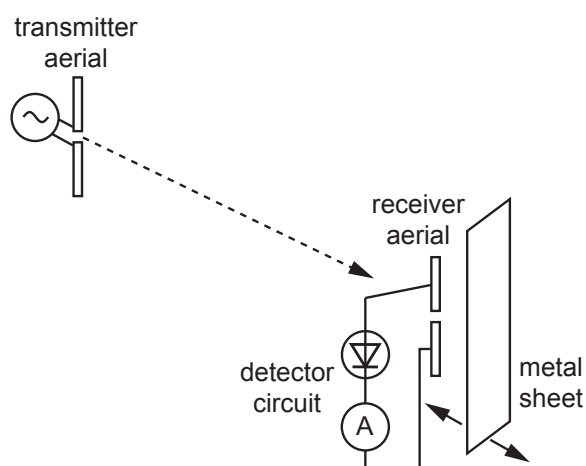


Fig. 5.2

For each of these two investigations:

- Explain why the ammeter sometimes gives a maximum reading and sometimes a zero (or near zero) reading.
- State the orientations of the receiver aerial in **investigation 1**, and the positions of the metal sheet in **investigation 2**, where these maximum and zero readings would occur.

[6]

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Additional answer space if required.

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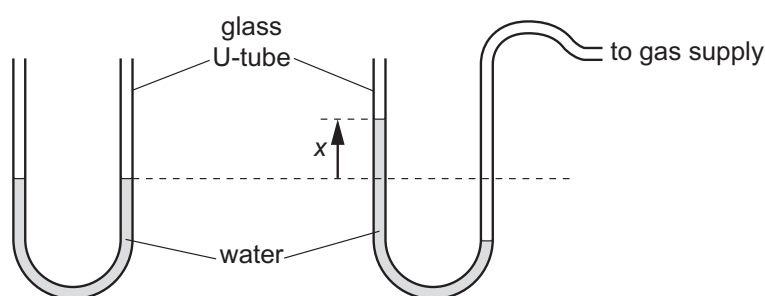
.....

- 20 (a) For a simple harmonic oscillator, the acceleration a is given by the equation $a = -\omega^2 x$, where ω is the angular frequency and x is the displacement.

Show that this equation is homogeneous by reducing both sides to S.I. base units.

[2]

- (b) The diagram shows a glass U-tube partially filled with a mass of water.



One end of the U-tube is connected to a gas supply of **constant** pressure and the other end is open to the atmosphere. The displacement of the water from its equilibrium position is x . The density ρ of water is 1000 kg m^{-3} .

- (i) The pressure from the gas supply raises the water in the U-tube. The vertical distance between the two levels of water in the two vertical sections of the U-tube is 10.0 cm ($x = 5.0 \text{ cm}$).

Δp is the difference between the gas pressure and atmospheric pressure. Calculate Δp .

$\Delta p = \dots\dots\dots \text{ Pa}$ [2]

- (ii) When the gas supply is disconnected, the water levels in the U-tube oscillates with simple harmonic motion. The acceleration a of the water level in the left-hand side of the U-tube is given by the equation

$$a = -\frac{2\rho g A}{m} x$$

where m is the mass of the water in the U-tube, A is the internal cross-sectional area of the U-tube, ρ is the density of water, g is the acceleration of free fall and x is the displacement of the water level in the left-hand side of the U-tube.

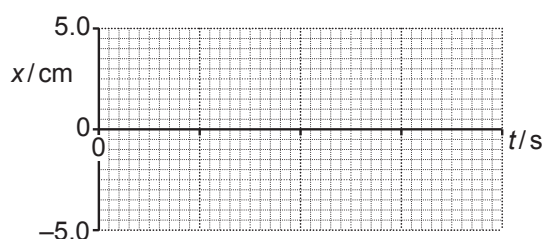
For this U-tube, $A = 1.0 \times 10^{-4} \text{ m}^2$ and $m = 0.052 \text{ kg}$.

- 1 Show that the period T of the oscillations is about 1 second.

[3]

- 2 The oscillations of the water level are slightly **damped**.
At time $t = 0$, $x = 5.0 \text{ cm}$.

Sketch a suitable graph of displacement x against time t for the oscillating water level. Add suitable values to the time t axis.



[3]

- 3 The U-tube is now connected to another gas supply where the pressure oscillates at a frequency of about 1 Hz.

Explain the effect this will have on the water in the U-tube.

.....

 [2]

14-MARK QUESTIONS

2 questions in this booklet



- 5 (a) A loudspeaker mounted on a bench is emitting sound of frequency 1.7 kHz to a microphone. Fig. 5.1 shows an illustration of the bulk movement of the air at one instant of time.



Fig. 5.1

The maximum displacement of the air particles from their mean positions is 2.0×10^{-6} m.

The speed of sound in air at 17°C is 340 ms^{-1} .

- (i) On Fig. 5.2, sketch the sinusoidal variation of the displacement of the air with distance between **C** and **R**.

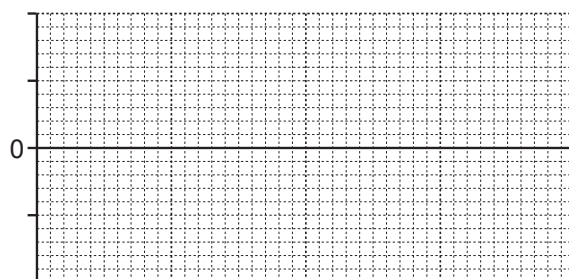


Fig. 5.2

- 1 Label the axes and include sensible scales.
- 2 On Fig. 5.2, mark one point where air particles are moving at maximum speed. Label it **X**.
- 3 On Fig. 5.2, mark one point where air particles are moving at maximum speed but travelling in the opposite direction to the air particles in 2. Label it **Y**.

[4]

- (ii) Calculate

- 1 the maximum speed v_{max} of the oscillating particles in the sound wave

$$v_{\text{max}} = \dots \text{ms}^{-1} \quad [2]$$

- 2 the root mean square speed $c_{\text{r.m.s.}}$ of the air molecules in the room.
The molar mass of air is $2.9 \times 10^{-2} \text{ kg mol}^{-1}$.

$$c_{\text{r.m.s.}} = \dots \text{ms}^{-1} \quad [2]$$

- (b)* Students are given the equipment in Fig. 5.1 together with a metre rule. They are also given a second loudspeaker connected to the same signal generator at 1.7 kHz. They are asked to design an experiment where they would need to take just **one** measurement and be able to determine the value of the speed of sound.

They set up the experiment in two different ways as shown in Fig. 5.3(a) and (b).

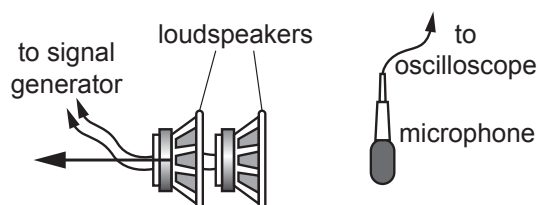


Fig. 5.3(a)

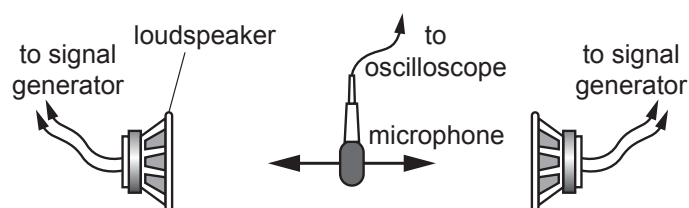


Fig. 5.3(b)

In method **(a)** the microphone is fixed and one loudspeaker is moved to the left as shown in Fig. 5.3(a).

In method **(b)** the microphone is moved to the left or to the right with the loudspeakers fixed a certain distance apart as shown in Fig. 5.3(b).

Describe and explain how both methods can be used to accurately determine the speed of sound. In your description, discuss how the uncertainty in the value for the speed of sound can be minimised in one of the methods, without using any other apparatus. [6]

[illegible]

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Turn over



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Question 6 begins on page 18.



- 18 A mass hanging from a vertical spring is pulled down. It is then released from rest at time $t = 0$. The mass oscillates vertically in a **vacuum** with simple harmonic motion about the equilibrium position. The spring is in tension at all times.

Fig. 18.1 shows the position of the mass at $t = 0$.

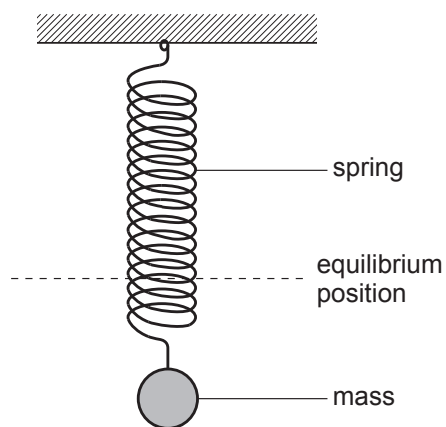


Fig. 18.1

At time $t = 6.5\text{ s}$ the magnitude of the acceleration a of the mass is 3.6 ms^{-2} and its displacement x is $4.6 \times 10^{-2}\text{ m}$.

- (a) (i) Use the defining equation for simple harmonic motion to show that the natural frequency f_0 of the mass-spring system is about 1.4 Hz .

[3]

(ii) Calculate the amplitude A of the oscillations.

$A = \dots\dots\dots$ m [2]

(b) The mass-spring system shown in Fig. 18.1 is now made to oscillate in **air**.

Different types of energy are involved in the oscillations of this mass-spring system.

Describe the energy changes that will take place as the mass moves from the lowest point in its motion through the equilibrium position to the highest point in its motion.

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..... [4]

Question 18 continues on page 16

- (c) Fig. 18.2 shows the mass and spring now attached to a mechanical vibrator, which can oscillate with variable frequency.

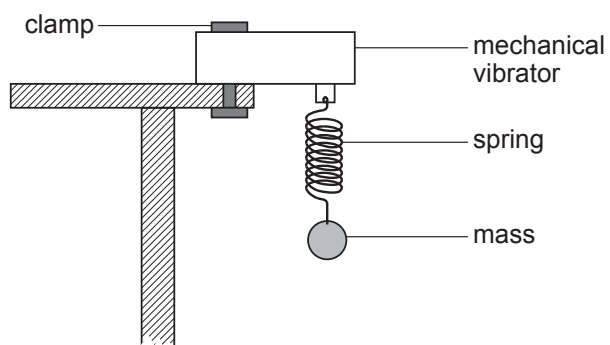


Fig. 18.2

The mass oscillates in air.

- (i) The vibrator frequency is varied from 0 Hz to 2.5 Hz.
On Fig. 18.3, sketch a graph to show the variation with vibrator frequency of the amplitude of the mass. Label your graph **K**.

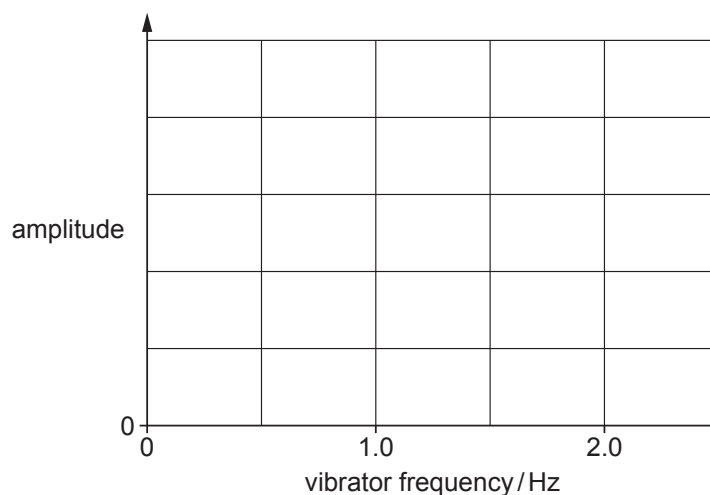


Fig. 18.3

[2]

- (ii) A light disc is now attached to the mass to increase the damping.
The vibrator frequency is again varied from 0 Hz to 2.5 Hz.
Sketch a second graph on Fig. 18.3 to show the new variation of the amplitude.
Label this graph **D**.

[1]

- (iii) Explain why the phenomenon demonstrated in this experiment can cause problems for engineers when designing suspended footbridges.

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..... [2]

15-MARK QUESTIONS

1 question in this booklet



- 19** This question is about a simple pendulum made from a length of string attached to a mass (bob). For oscillations of small amplitude, the acceleration a of the pendulum bob is related to its displacement x by the expression

$$a = -\left(\frac{g}{L}\right)x$$

where g is the acceleration of free fall and L is the length of the pendulum. The pendulum bob oscillates with simple harmonic motion.

- (a) (i)** Show that the period T of the oscillations is given by the expression

$$T^2 = \frac{4\pi^2}{g}L.$$

[3]

- (ii)** A student notices that the amplitude of each oscillation decreases over time. Explain this observation and state what effect this may have on T .

.....

 [2]

- (c) Another student conducts a similar experiment in the laboratory to investigate the small amplitude oscillations of a pendulum of a mechanical clock. Each 'tick' of the clock corresponds to **half** a period.

(i) Show that the length of the pendulum required for a tick of 1.0 s is about 1 m.

[2]

- (ii) If the pendulum clock were to be used on the Moon, explain whether this clock would run on time compared with an identical clock on the Earth.

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..... [2]

17-MARK QUESTIONS

2 questions in this booklet



- 5 A student experiments with microwaves emitted from a transmitter. The frequency f of the microwaves from the transmitter can be adjusted.

(a) The microwaves are produced by an alternating current in the transmitter.

In one experiment, f is 11 GHz. In a wire in the transmitter, the magnitude of the **maximum** alternating current is 20 mA. The wire has cross-sectional area $1.4 \times 10^{-8} \text{ m}^2$ and is made of a metal with free electron number density $8.0 \times 10^{28} \text{ m}^{-3}$.

- (i) Show that the maximum drift velocity of each free electron in the wire is about 0.1 mm s^{-1} .

[3]

- (ii) The student models the average motion of the free electrons in the wire as simple harmonic motion.

Use your answer to (i) to calculate the amplitude A of this motion.

$A = \dots\dots\dots \text{ m}$ [3]

- (iii) Without further calculation, explain how the maximum acceleration of a free electron varies as the frequency f is adjusted, provided that the maximum alternating current remains constant.

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 [2]



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Additional answer space if required

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- (ii) Transmitter **X** is rotated about the line **AB** and the experiment is repeated at different orientations until it has been rotated by 180° .

Describe and explain the observed patterns of maximum and minimum intensity.

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..... [3]

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21 (a) Fig. 21.1 shows a stationary glider of mass m on an air track.

The glider has identical springs with force constant k attached to each end which are secured to fixed posts.

The air track blower is turned on and the glider is displaced a small distance x_0 , as seen in Fig. 21.2. It is then released.

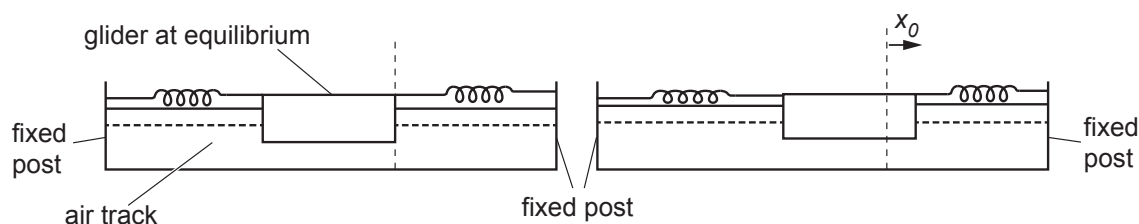
The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period T calculated.

Fig. 21.1

Fig. 21.2



The relationship between the period T , the mass of the glider m and the force constant k is described by the equation

$$T^2 = \frac{2\pi^2 m}{k}.$$

- (i) Show that the equation above is homogeneous by reducing the equation to SI base units.

[2]

- (ii) Explain why the magnitude of the resultant force F on the glider is given by $F = 2kx$ where x is the displacement at any time.

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 [2]

- (iii) State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

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 [2]

- (b) Masses are added to the glider, and the measurement of $20T$ repeated.

The results table is below.

m/kg	$20T/\text{s}$	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

- (i) Describe **two** different errors in the table.

1

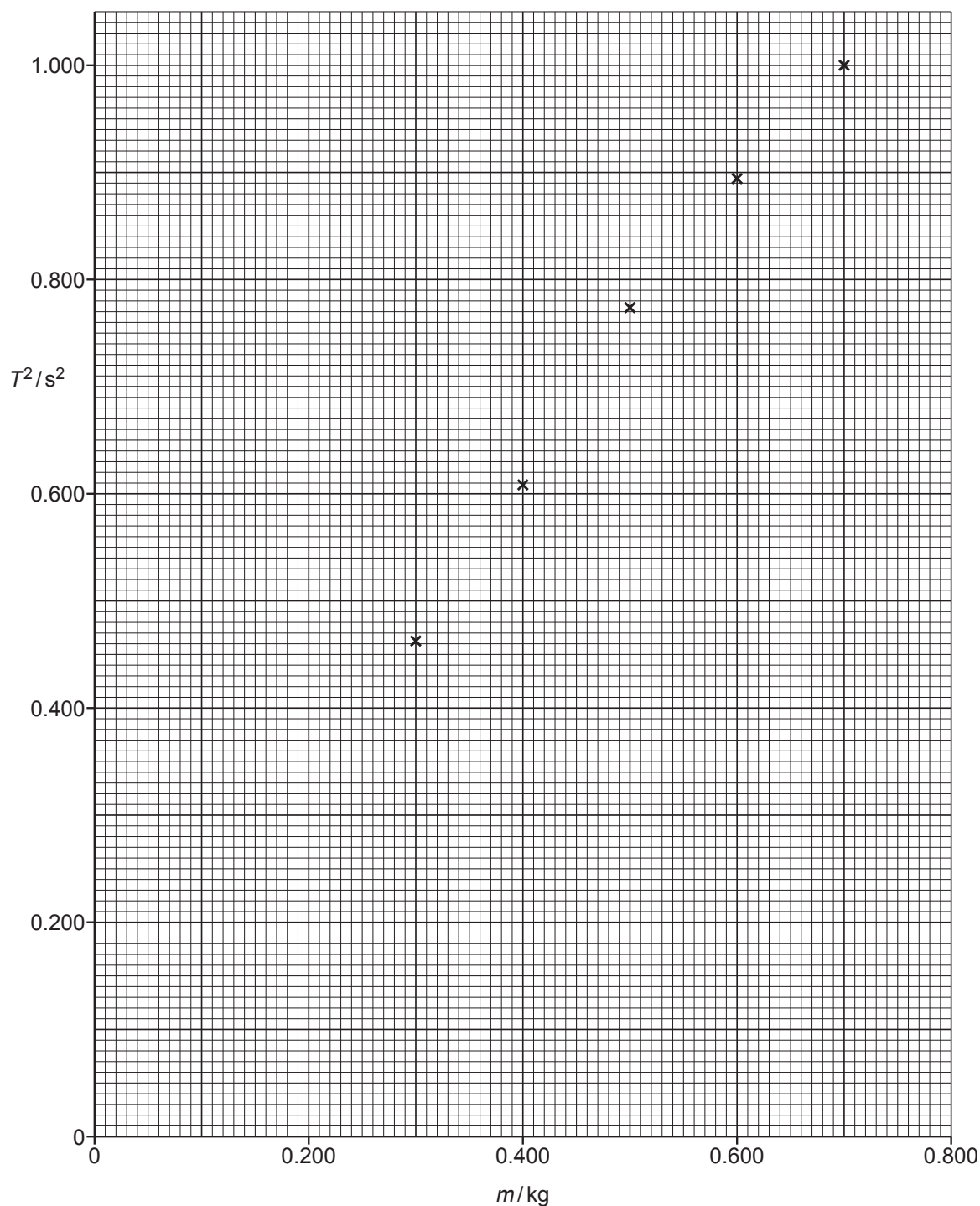
 2
 [2]

(ii) Plot the **first** data point from the table on the graph below.

The other points have all been plotted. The table of results is repeated on the opposite page.

Include on your graph a line of best fit.

[2]



m/kg	$20T/\text{s}$	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(iii) Use the graph to determine the value of k .

$k = \dots\dots\dots \text{Nm}^{-1}$ [3]

- (c) When the initial displacement is increased, one spring increases its extension while the extension of the other spring decreases.

Explain why the **maximum** kinetic energy of the motion increases.

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..... [4]

MARK SCHEMES

official OCR mark schemes



4	A		1	
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9	B	1	
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15	B	1	
	Total	15	

SECTION B

Question	Answer	Marks	Guidance
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3	D	1	
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4	D	1	
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7	A	1	
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4	C	1	
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12	B	1	
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6	C	1	
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6	B	1	
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12	B	1	
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10	B		1	
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12	D	1	
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8	C	1	
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9	D	1	
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10	B	1	
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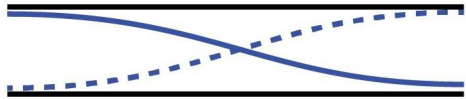


12	D		1	
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14	D	1	
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18	(a)		B1	Both parts needed – either dotted or solid. Correct curvature needed by eye. Middle node by eye. IGNORE lines outside of tube
	(b)	Frequency $f_0 = 340 / 0.600 = 567$ (Hz)	A1	Correct to at least 2 significant figures No ecf from 18(a)
	(c)	Next wavelength for standing wave is $\lambda = 0.300\text{m}$ Frequency = $340 / 0.300 = 1.13 \times 10^3$ (Hz)	C1 A1	Ecf from (b) if wavelength used is 0.600m Correct to at least 2 significant figures Special case: If wavelength drawn in (a) is 0.300m and f_0 in (b) = 1130 Hz, then allow ecf (C1) for next $\lambda = 0.200\text{m}$ and (A1) frequency as 1700 Hz for full credit.

19*		Level 3 (5–6 marks) Clear description of experiment and measurements and clear analysis. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Some description of experiment and some measurements and some analysis. <i>There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description of experiment or Limited measurements or Limited analysis <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1× 6	Indicative scientific points may include: Description • Release method • Ensure bob is not pushed • Repeat experiment for same H • Repeat for different H • Centre of mass of single bob and joined bob considered • Keep bob string taught Measurements • Measure heights h and H with ruler • Use centre of mass of bob or another suitable method • Use video camera to record motion • Use of datalogger and appropriate sensor to measure H and h • Measure mass with (top pan) balance Analysis • Construct a table of h and H • Plot graph of h against H • LoBF should pass through origin. • Determine gradient or calculate h/H repeatedly • $\text{gradient} = \left(\frac{M}{M+m}\right)^2$ (gradient must be consistent with the plot) • Masses substituted into above expression and checked against experimental gradient
		Total	6	

Question	Answer	Mark	Guidance
2 (a)	$\omega = (2\pi f) = 2\pi \times 0.15$ or $0.3\pi (= 0.942 \text{ rad s}^{-1})$ $a_{\max} = (-\omega^2 A) = 4\pi^2 f^2 A = 0.050$ $A = 0.05/(2\pi \times 0.15)^2$ $A = 5.6 \times 10^{-2} \text{ (m)}$	C1 C1 A1	ω mark can be implicit in calculation $\omega^2 = 0.88$ or 0.89 using 0.942 or 0.94 allow 0.057 (m) ; N.B. answer is 0.053 if use ω instead of ω^2 mark as a TE max 2/3
(b)	Maximum energy is transferred between tower (driver) and sphere when sphere (driven) is at/close to the natural frequency <u>of the tower</u> or in this forced oscillation/resonance situation	B1 B1	allow causes maximum damping <u>of the tower</u> or maximum amplitude <u>of the sphere/AW</u> allow AW e.g. sphere must be driven close to/at the natural/resonance frequency <u>of the tower</u>
(c) (i)	$\omega^2 = k/m$ or $(2\pi f)^2 = k/m$ or $kA = ma_{\max}$ $k = (m4\pi^2 f^2) = 6.6 \times 10^5 \times (2\pi \times 0.15)^2$ or $(k = ma_{\max}/A) = 6.6 \times 10^5 \times 0.05/0.056$ $k = 5.9 \times 10^5 \text{ (N m}^{-1}\text{)}$	C1 M1 A1	allow ω or $\omega^2 = 0.88$ or 0.89 quoted from (a) ecf value of A from (a) as this is a 'show that' question some definite evidence of working must be shown. not $k = 6 \times 10^5$ allow answer to 2 or more SF.
(c) (ii)	$E = \frac{1}{2}kA^2 = 0.5 \times 5.9 \times 10^5 \times 0.71^2$ $E = 1.5 \times 10^5 \text{ (J)}$	C1 A1	allow value from (c)(i) or 6; or $a = (k/m)A$, $F = ma$, $E = \frac{1}{2}FA$ accept 1.48 to 1.51 or value from ecf special case: give $1/2$ for $E = 3(.0) \times 10^5 \text{ (J)}$ where it is clear that $2k$ has been used as the spring constant
	Total	10	

22	(a)	(i)	The upthrust (on an object in a fluid) is equal to the <u>weight</u> of fluid (it displaces)	B1	Note 'fluid' or 'liquid' must be mentioned at least once. Allow a named fluid, e.g. water
		(ii)	$(p = h\rho g)$ $1.9 \times 10^3 = 0.15 \times \rho \times 9.81$ $\rho = 1.3 \times 10^3 \text{ (kg m}^{-3}\text{)}$	C1 A1	
	(b)	(i)	$x = A \cos(\omega t)$ or $x = A \cos(2\pi ft)$ $x = 2.0 \cos(2\pi \times 1.4 \times 0.60)$ displacement = 1.1 (cm)	C1 C1 A1	Note: Treat use of sine as TE Note answer is 1.07 (cm) to 3SF Note answer if calculator left in degrees of 1.99cm scores 2 marks.
		(ii)	$(v_{\max} =) 2\pi \times 1.4 \times 0.02$ maximum speed = 0.18 (m s ⁻¹)	C1 A1	
		(iii)	1 Larger (amplitude) 2 Same (period)	B1 B1	
			Total	10	

Question	Answer	Marks	Guidance
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6	(a)		time taken for current (or charge or voltage) to fall to $1/e$ of <u>its initial value</u>	B1	Not capacitance Not to fall <u>by</u> (a factor of) $1/e$ Allow to decrease <u>to</u> 37% of its initial value Allow to decrease <u>by</u> 63% Ignore time constant = CR
	(b)	(i)	$f (= 1/T) = 1 / (40 \times 10^{-3})$ $f = 25$ (Hz)	B1 B1	Allow $f = 1/T$ and $T = 40 \times 10^{-3}$ (s)
		(ii)	EITHER Calculation of Q_0 / e time constant (read from graph) = 14 (ms) OR Use of $Q = Q_0 e^{-t/CR}$ time constant = 14 (ms)	C1 A1 (C1) (A1)	Allow any initial value of charge e.g. $8.0 / e = 2.9$ (μC) or $37\% \times 8.0 = 3.0$ (μC) Allow 14 ± 1 (ms) e.g. $2.0 = 8.0 e^{-0.02/CR}$ gives $CR = 0.02 / \ln 4$ Using the decay equation may incur two POT errors
		(iii)	tangent drawn to graph <u>at steepest part of curve</u> maximum current in range 5.0×10^{-4} to 7.0×10^{-4} (A)	M1 A1	Judge by eye, no daylight between curve and tangent Allow a negative answer Allow answer to 1sf

Question			Answer	Marks	Guidance
6	(b)	(iv)	vertical axis labelled as current with the correct unit and at least one positive and one negative scale marking and scale should allow for their maximum current to be plotted exponential decay of current in each section sign of current alternates at 20, 40, 60 and 80 ms	B1 M1 A1	For example I / mA , $I (\text{mA})$, $I / 10^{-4} \text{ A}$, current in mA etc All scale markings shown must be correct Allow any curve with a decreasing gradient in each section Ignore value of minimum current but not zero Ignore sign of current for this marking point All curves should start at the correct maximum current value. However, If B1 mark has not been scored, allow any value of maximum current as long as it remains consistent across all four sections
			Total	10	



21	(a)		$\omega^2 = k/m$ or 60/0.080 or $\omega^2 = 750$ $T = 2\pi/27.39$ or $T = 0.2295$ (s) $t = \frac{1}{4} \times 0.2295$ $t = 0.057$ (s)	C1 C1 C1 A1	Allow correct algebraic expression for T Allow incorrect value for omega Allow incorrect value of T
	(b)	(i)	$E = \frac{1}{2}kx^2$ or $E = mgh$ or $0.080 \times 9.81 \times 0.20$ or $\frac{1}{2} \times 60 \times x^2$ $0.080 \times 9.81 \times 0.20 = \frac{1}{2} \times 60 \times x^2$ $x = 0.072$ (m)	C1 C1 A1	
		(ii)1	Time of flight is independent of speed/AW Because distance of fall is the same and initial velocity vertically is zero / velocity is horizontal at X	B1 B1	Allow algebraic answers that assume initial vertical velocity is zero/velocity is horizontal at X.
		(ii)2	D increases as speed at X increases because the time of flight is constant/AW D is directly proportional to speed at X	M1 A1	Allow $d = vt$ idea “ D is directly proportional to speed at X because the time of flight is constant” scores 2.
			Total	11	

Question	Answer	Marks	Guidance
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Question	Answer	Mark
1 (a) (i)	$F = QE = QV/d$ or $E = 5(0) \times 10^4 \text{ (Vm}^{-1}\text{)}$ $F = 9.0 \times 10^{-9} \times 4000 / 8.0 \times 10^{-2} (= 4.5 \times 10^{-4} \text{ N})$	C1 A1
(ii)	weight; arrow vertically downwards tension; arrow upwards in direction of string electric (force); arrow horizontally to the <u>right</u> (not along dotted line)	B1 x 2 All correct, 2 marks; 2 correct, 1 mark 1 mark maximum if more than 3 arrows are drawn Ignore position of arrows Allow W or 0.030(N) (not gravity or g) Allow T Allow F or E or $4.5 \times 10^{-4} \text{ (N)}$ or electrostatic Ignore repulsion or attraction Not electric field / electric field strength / electromagnetic
(iii)	$Wx = F l$ 0.03 x $= 4.5 \times 10^{-4} \times 120$ or $= 4.5 \times 10^{-4} \times 1.2$ $x = 1.8 \text{ cm}$ or $x = 0.018 \text{ m}$	M1 M1 A0

H556/03

Mark Scheme

November 2020

	(b)	Electric force/field (strength) increases Ball deflected further from vertical / moves to the right / touches negative plate Ball acquires the charge of the (negative) plate when it touches (Oscillates because) constantly repelled from (oppositely) charged plate	B1 B1 B1 B1	Must be clear which force is increasing Must have the idea of a repeating cycle
	(c)	$I = Qf$ or $Q = It$ $f = 3.2 \times 10^{-8} / 9.0 \times 10^{-9} = 3.6 \text{ (Hz)}$	C1 A1	
		Total	12	



H556/03**Mark Scheme****November 2020**

Question	Answer	Marks	Guidance
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5	(a)	$c = f\lambda$ or $f = 3.0 \times 10^8 / 0.60$ $f = 5.0 \times 10^8$ (Hz)	C1	Allow $v = f\lambda$
			A1	Allow 5×10^8
	(b)	$a_{\max} = -\omega^2 A$ or $a_{\max} = -(2\pi f)^2 A$ $\omega = 2 \times \pi \times 5.0 \times 10^8 = 3.1(4) \times 10^9$ (rad s ⁻¹) or $10^9 \pi$ $a_{\max} (= \pi^2 \times 10^{18} \times 4.0 \times 10^{-6}) = 3.9 \times 10^{13}$ (m s ⁻²)	C1	Allow without the minus sign
			C1	ECF from (a)
			A1	Not $4.0 \times 10^{12} \pi^2$
	(c)	the current (induced in the aerial) is alternating (5×10^8 times per second) (so the meter would register zero) / AW or the diode (half-)rectifies the current / changes the current (from a.c.) to d.c. / AW	B1	Allow 'a diode only lets current pass through in one direction' AW
	(d)	see next page	B1 x 6	
		Total	12	

H556/03

Mark Scheme

November 2020

Question			Answer	Marks	Guidance
5	(d)	*	Level 3 (5 - 6 marks) Response shows clear distinction between investigations; clear and correct reasoning is given for the situations which give maximum/minimum readings in <u>both</u> cases, including correct numerical values <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Response refers to both investigations; some reasoning is given for the situations which give maximum/minimum readings in <u>both</u> investigations, including some numerical values <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Limited reasons are given for the situations which give maximum/minimum readings in <u>either</u> investigation <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: explanation 1 • receiver aerial vertical – electrons are driven (maximum distance) up and down along the length of the aerial because the oscillations (of the electric field) are vertical, causing maximum (a.c.) current • receiver aerial horizontal – electrons are driven (minimum distance) across the aerial because the oscillations (of the electric field) are only in the vertical plane (no oscillation along the aerial to cause current), so zero / minimum current • rotation of receiver aerial by $\pm 90^\circ$ (or 90° and 270°) from vertical leads to zero current explanation 2 • reflected wave superposes with incident wave at receiver aerial • coherent waves as from same source • constructive interference/waves in phase gives max current • reflected wave has travelled $n\lambda$ further, $n = 0, 1$, etc • so max current when plate is at $\lambda/2$, $2\lambda/2$, etc from receiver aerial, i.e. 30, 60 cm • destructive interference/waves 180° (π rad) out of phase gives zero current • reflected wave has travelled $(2n + 1)\lambda/2$ further, $n = 0, 1$, etc • so zero current when plate is at $\lambda/4$, $3\lambda/4$, etc from receiver aerial, i.e. 15, 45 cm • reflected signal will be weaker the further it has to travel so no longer complete cancellation (ammeter reads close to zero) Note: Give full credit to candidates who take the 180° (π rad) phase change on reflection into account, which gives max current at 15, 45 cm etc and zero current at 30, 60 cm etc.

H556/03**Mark Scheme****November 2020**

Question	Answer	Marks	Guidance
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20	a			$\omega \rightarrow \text{s}^{-1}$ or $\omega^2 \rightarrow \text{s}^{-2}$ LHS = m s^{-2} and RHS = m s^{-2} clearly shown by unit algebra	M1 A1	Allow $\omega \rightarrow (\text{radians}) \text{s}^{-1}$ Allow $\omega^2 = (2\pi f)^2$ or $(2\pi/T)^2$ with some evidence of units afterwards e.g. RHS = $\text{m} \cdot (\text{s}^{-1})^2$
	b	i		$\Delta p = 0.10 \times 1000 \times 9.81$ $\Delta p = 980 \text{ (Pa)}$	C1 A1	Allow 1 mark for 490 Pa; 5.0 cm used
		ii	1	$\omega^2 = \frac{2\rho g A}{m}$ or $\omega^2 = 37.7 \text{ (rad}^2 \text{ s}^{-1})$ $\omega = 6.1$ $T = \frac{2\pi}{6.1}$ $T = 1.02 \text{ (s)}$	C1 C1 C1 A0	NOT $\omega = 37.7$ Alternative route: • Substitution of expression for omega • Re-arrangement to make T subject • Evidence of evaluation to $T = 1.02 \text{ (s)}$
			2	Oscillation is isochronous starting from (0,5) Correct value(s) on the horizontal axis At least 2 oscillations shown and amplitude is decreasing	B1 B1 B1	Period same by eye. Note scale must be linear and increasing Amplitude of 2nd oscillation smaller by eye.
			3	The (driving) frequency is close to the natural frequency (of the system) / resonance will occur (Level of) water will oscillate with large amplitude	B1 B1	Allow a description of consequence such as water leaving the tube or being unable to measure the height of liquid
				Total	12	

Question	Answer	Mark	Comments
5	(i) sin or cos wave with 1.5 wavelengths (between C and R) y-axis showing scale ,i.e. (amplitude) $2.(0) \times 10^{-6}$ (m) correct scale on x-axis showing $\lambda = 0.2$ (m) X and Y labelled at adjacent intercepts on x-axis	B1 B1 B1 B1	unit must be present, e.g 10^{-6} m NOT if axis labelled time
	(ii)1 $v = A\omega$ or $2\pi fA$ $v = (2 \times 10^{-6} \times 2 \times 3.14 \times 1.7 \times 10^3 \Rightarrow) 2.1 \times 10^{-2}$ (m s ⁻¹ .) (ii)2 $\frac{1}{2}Mv^2 = \frac{3}{2}RT$ and $T = 290$ $v = \sqrt{(3 \times 8.31 \times 290/0.029)}$ $v = 5(.0) \times 10^2$ (m s ⁻¹ .)	C1 A1 C1 A1	 or $\frac{1}{2}mv^2 = \frac{3}{2}kT$ so $v^2 = 3$ (k/m) 290 N.B. remember to record a mark out of 4 here
	(b) see page 14	B1 x 6	
	Total	14	

Question		Answer	Marks	Guidance
5	(b)	Level 3 (5 - 6 marks) Clear description and explanation for both experiments and some discussion of uncertainty <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.</i> Level 2 (3 – 4 marks) Some description and explanation for both experiments or clear description and explanation for one experiment and some discussion of uncertainty <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Limited description and explanation for one experiment <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1 x 6	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. Indicative scientific points may include: Description and explanation Experiment (a) • Coherent signals/(sound) waves • Interference / superposition • Maximum signal / minimum signal • Idea of how wavelength is determined (e.g. distance between adjacent max positions = λ) • $v = f \times \lambda$ Experiment (b) • Stationary/standing wave produced • Superposition of waves travelling in opposite directions • Nodes / antinodes • Idea of how wavelength is determined (e.g. distance between adjacent nodes = $\lambda/2$) • $v = f \times \lambda$ Uncertainty • Measure multiples of λ • to reduce % uncertainty (by factor n) • move from minimum signal to minimum signal • so can increase sensitivity of scope to get better fix on each minimum position/ increase loudness from speaker • Lower frequency from signal generator • so increases λ with (%) uncertainty reduced • Do experiment outside • to reduce background reflections from room (so that sharper minima should be observed)

18	(a)	(i)	$a = -\omega^2 x$ seen Suitable linking $a = -\omega^2 x$ and either $\omega = 2\pi f$ or $\omega = 2\pi/T$ with substitution $f = 1.41$ (Hz)	B1 M1 A1	e.g. $4\pi^2 f^2 = 78.3$ or $f = \sqrt{3.6/4\pi^2 \times 4.6 \times 10^{-2}}$ or $f = 8.85/2\pi$ or $T = 0.71\dots$ Allow $f = 1.408\dots$ (Hz)
		(ii)	$A = \frac{x}{\cos \omega t}$ or $A = \frac{4.6 \times 10^{-2}}{\cos(2 \times \pi \times 1.4 \times 6.5)}$ (Any subject) $A = 0.057$ (m)	M1 A1	Not: sine for cosine. Note $A = 0.090(4)$ (m) if 1.41 used Note $A = 0.0796$ (m) if 1.408 used Allow 1 mark for cosine used with calculator in degrees

Question			Answer	Marks	Guidance
	(b)		EPE decreases (from bottom to top)	B1	Not EPE becomes 0 (or negative) Allow for the first two marking points: description that refers to total potential energy starts at maximum, is minimum at equilibrium point and max again at top, provided total potential energy is stated to be the sum of EPE and GPE Allow as alternative for first three marks: EPE to KE and GPE in bottom half EPE and KE to GPE in top half EPE at start to GPE at top
			GPE increases (from bottom to top)	B1	
			KE starts at zero, finishes at zero and max at equilibrium point.	B1	
			Air gains thermal energy / Total energy (of mass and spring) decreases over time	B1	
	(c)	(i)	(Smooth) curve showing amplitude increases and then decreases	B1	Not: more than 1 peak Allow: asymptote instead of peak
			maximum at 1.4 Hz by eye	B1	
		(ii)	Curve similar shape yet lower at all non-zero f points with peak shifted slightly to <u>left</u> (of 1.4 Hz)	B1	Allow: curve without shifted peak i.e. peak at 1.4 Hz ECF their K curve
		(iii)	Bridge close to <u>resonance</u> if frequency of driver is close to natural frequency of bridge	B1	Allow: footfall/people walking/wind for driver Allow: <u>resonance</u> (occurs) when frequency of driving force is at natural frequency of bridge Allow: Maximum for larger
			(Close to resonance) giving larger amplitude which causes damage or other named consequence	B1	
			Total	14	

Question	Answer	Mark	Guidance
19 (a) (i)	$\omega^2 = g/L$ $\omega = \frac{2\pi}{T}$ Correct substitution $\frac{4\pi^2}{T^2} = \frac{g}{L}$ and rearranging to give correct expression	M1 M1 A1	Note: Both M1 marks are required to score this A1 mark
(ii)	Transfer of energy to air / retort stand (because of air resistance / friction) No effect on T (as T is independent of amplitude in SHM for small amplitude oscillations of pendulum)	B1 B1	Allow 'loss of energy from pendulum (due to friction)' Allow 'work done' for 'energy' Allow 'isochronous'

Question	Answer	Marks	Guidance
(b)*	Level 3 (5–6 marks) Clear description including steps to obtain high quality data and analysis <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Clear description and some analysis <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited description and analysis Or limited description <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit.	B1 × 6	Indicative scientific points may include: Experiment Description • Pendulum string clamped / fixed (can be shown on diagram) • Use a stopwatch to determine time period T • Time multiple oscillations to determine T • Use a ruler to measure L • Vary length L and determine T Quality of Data • Method used to ensure small oscillations • Small angles i.e. <10 degrees • Idea of fiducial mark • Start/stop timing at the centre of the oscillation • Measure from the fixed point to the centre of the bob Analysis • Correct plotting of graph, e.g. T^2 against L or T against $\sqrt{L}$ or $\lg T$ against $\lg L$ • Analysis of data table showing $T^2/L = \text{constant}$

Question			Answer	Marks	Guidance
					- Expect a straight line through the <u>origin</u> - Correct gradient of the line e.g. $4\pi^2/g$ Use only L1, L2 and L3 in RM Assessor.
	(c)	(i)	Correct substitution of $T = 2(.0 \text{ s})$ into $T^2 = \frac{4\pi^2}{g} L$ length = 0.99 (m)	C1 A1	Note: 1 (m) here cannot score this A1 mark
		(ii)	Lower g / gravitational field strength / acceleration (of free fall) on Moon. T is longer (on Moon) and justified by $T^2 = \frac{4\pi^2}{g} L$ or $T^2 \propto 1/g$ or $\frac{4\pi^2}{g}$ is larger	B1 B1	Accept 'g is a sixth of g on Earth' AW Not gravity (is less)
			Total	15	

5	(a)	(i)	$I_{\max} = nAv_{\max}e$ $v_{\max} = \frac{20 \times 10^{-3}}{8 \times 10^{28} \times 1.6 \times 10^{-19} \times 1.4 \times 10^{-8}}$ $v_{\max} = 1.1 \times 10^{-4} \text{ (m s}^{-1}\text{)}$	B1 Allow v for $v_{\max}$ throughout M1 Allow I for $I_{\max}$ Allow q or Q for e/a for A/V for v but not N for n A1 Substitution must be shown in full Answer must be given initially to 2 or more sf (but may later be rounded to 1sf)
		(ii)	$\omega = 2\pi f$ $A (= v_{\max}/\omega) = \frac{1.1 \times 10^{-4}}{2\pi \times 11 \times 10^9}$ or $A (= v_{\max}/\omega) = \frac{1.1 \times 10^{-4}}{6.9 \times 10^{10}}$ $A = 1.6 \times 10^{-15} \text{ (m)}$	C1 May be inferred from working $\omega = 2\pi \times 11 \times 10^9 = 6.9 \times 10^{10} \text{ (rad s}^{-1}\text{)}$ C1 Allow use of $v_{\max} = 1 \times 10^{-4} \text{ (m s}^{-1}\text{)}$ Allow $v_{\max}$ from (a)(i) given to more than 2sf but not ECF from any value which does not round to $1 \times 10^{-4} \text{ (m s}^{-1}\text{)}$ A1 Allow use of $v_{\max} = 1 \times 10^{-4} \text{ (m s}^{-1}\text{)}^1$ giving $A = 1.4 \times 10^{-15} \text{ (m)}$ to 2sf or $1.45 \times 10^{-15} \text{ (m)}$ to 3sf Special case: Allow $A = 1 \times 10^{-15} \text{ (m)}$ to 1 sf if $v_{\max} = 1 \times 10^{-4} \text{ (m s}^{-1}\text{)}$ is used
		(iii)	$(a_{\max} = \omega^2 A \text{ and } v_{\max} = \omega A)$ $a_{\max} = 2\pi f v_{\max}$ Since $v_{\max}$ is constant, $a_{\max} \propto f$	M1 Allow $a_{\max} = \omega v_{\max}$ Allow a for $a_{\max}$ and v for $v_{\max}$ A1

Question			Answer	Marks	Guidance
5	(b)*	(i)	Level 3 (5–6 marks) Clear explanation and clear description <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Clear explanation or clear description (but not both) or Some explanation and some description <i>There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.</i> Level 1 (1–2 marks) Limited explanation or Limited description <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks <i>No response or no response worthy of credit.</i>	B1x 6	Use level of response annotations in RM Assessor Indicative scientific points may include: Explanation of pattern • Interference / superposition occurs • Path difference a whole number of wavelengths • means waves are (exactly) in phase (or $\Delta\phi = 0$) • giving (maximum) constructive interference • which leads to maximum intensity • Path difference an odd number of half wavelengths (or $\Delta\phi = \pi$ radians) • means waves are in antiphase • giving (maximum) destructive interference • which leads to minimum intensity Description of relationship between f and x • $\lambda = ax/D$ and $c = f\lambda \rightarrow x = cD/af$ • so $x \propto 1/f$ (provided a and D remain constant) • Use ruler along QP to measure x (or $10x/10$, say) • Connect oscilloscope to transmitter or detector to measure f • Vary f (keeping a and D constant) and measure corresponding x • Calculate fx which should remain constant • Or plot graph of $1/x$ against f (or x against $1/f$) • Should give straight line <u>through the origin</u>

Question			Answer	Marks	Guidance
5	(b)	(ii)	At 90° rotation, (interference) pattern disappears At 180° rotation, intensities are the same as at 0° but the maximum/minimum positions are switched / reversed Waves with polarisations at 90° to each other do not interfere / only waves with same polarisation interfere / only waves with a component in the same plane interfere	B1 B1 B1	Allow constant intensity along PQ Not zero intensity along PQ Allow <u>from 0 to 90°</u> the intensities of the maxima decrease (and the minimum intensities increase) Allow <u>from 90° to 180°</u> the intensities of the maxima increase (and the minimum intensities decrease) but the maximum/minimum positions are switched / reversed from between 0 and 90° Allow waves must <u>oscillate</u> in same plane to interfere Ignore at 90° rotation, only waves from Y are detected at D because D can only detect vertical polarised waves
			Total	17	

21	(a)	(i)	newton in base units is kg m s^{-2} Substitution and cancelling of kg and m arriving at $\text{s}^2 \rightarrow \text{s}^2$	C1 A1	
		(ii)	One force is increased by kx and one is reduced by kx /AW Some working to include $kx - (-kx)$	B1 B1	reject 2 springs in series or 2 springs in parallel idea XP. accept one extension is reduced by x and one is increased by x / AW
		(iii)	period is independent of <u>amplitude</u> / AW No effect	M1 A1	Allow isochronous
	(b)	(i)	Units omitted from T and T^2 Valid statement about significant figures	B1 B1	allow correct statement about individual data points or decimal place or "precision" e.g. sf of T does not match sf of $20T$ or sf of T not consistent throughout column or idea that 1 sf never enough
		(ii)	Correct plotting within half a small square Correct line of best fit	B1 B1	ECF for incorrect plotting. NB Same number of points above and below the line AND fair distribution of distances from line

		(iii)	Gradient between 1.22 and 1.44	C1	reject use of data table
			$k=2\pi^2 \div \text{gradient}$	C1	ECF use of candidate's line
			k between 13.7 and 16.2	A1	ECF use of candidate's gradient as per rubric
	(c)		maximum four from: EPE gain (in stretched spring) > EPE lost (in relaxed spring) EPE is dependent on x^2 Total energy increases (and so KE increases since EPE → KE) Max KE when the system has minimum EPE / at equilibrium position/when $x=0$ Minimum EPE is unchanged Omega is same, amplitude has increased $v_{\max}$ when $x=0$ so $v_{\max}$ has increased ($\omega^2 = \sqrt{A^2 - x^2}$) $v_{\max}$ increased so $KE_{\max}$ increased	4 x B1	Allow EPE max is dependent on A^2 NOT EPE dependent on x alone Allow EPE dependent on x and F which is dependent on x (EPE = $\frac{1}{2}Fx$ idea) KE = $\frac{1}{2}kx^2$ is XP
			TOTAL	17	