Wave Properties and Stationary Waves

Q1.

The photograph shows a guitar. The strings of the guitar are at the same tension.

When a string is plucked, a standing wave is set up on the string.

* Explain how a standing wave is set up on a string.

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(Total for question = 6 marks)

Q2.

Two students are carrying out an investigation to determine a value for the speed of sound in air.

They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval *t* between the two pieces of wood being hit and the echo being heard. The procedure is repeated. The students also measure the air temperature.

(a) Explain how a sound wave travels through air.

(2)

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(b) The students repeat the investigation on a different day. The results are shown in the table.

	temperature / °C	t_1 / s	t_2 / s	t_3 / s	mean t / s
Day 1	12	0.51	0.43	–	0.47
Day 2	18	0.44	0.69	0.48	0.46

(i) Deduce why the students thought it necessary to make a third measurement on day 2.

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(ii) Calculate the percentage uncertainty in the mean value of time on day 1.

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Percentage uncertainty = ...

(iii) Calculate the difference in the value for the speed of sound between day 1 and day 2 obtained from these results.

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Difference in speed = ...

(iv) The students state that the difference in the speed of sound between day 1 and day 2 is due to the change in air temperature.

Explain whether the results obtained are sufficient for this statement to be made.

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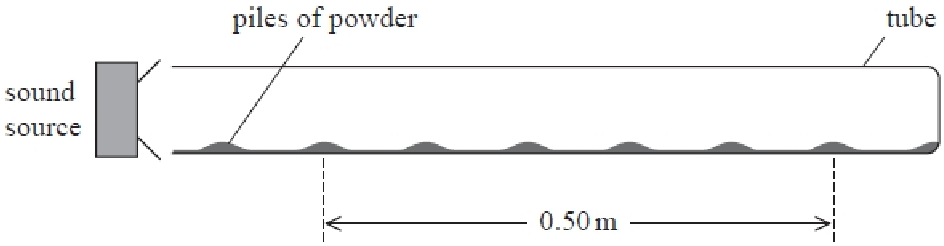
(Total for question = 9 marks)

Q3.

In an experiment to determine the speed of sound in air, a powder is sprinkled over the base of a horizontal glass tube. One end of the tube is closed. A sound source is placed at the open end of the tube, as shown.



Soundwaves travel along the tube and reflect from the closed end.

When the frequency of the source is 1.8 kHz the positions of six piles and the distance they cover is 0.50 m, as shown on the diagram.

Calculate a value for the speed of sound.

(3)

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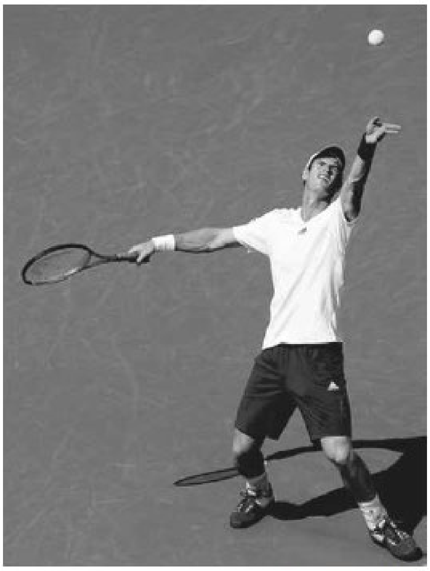
Speed = ...

(Total for question = 3 marks)

Q4.

A tennis player uses a racket to hit a ball over a net. When the racket strikes the ball the racket frame is set into oscillation.

The fundamental mode of oscillation is shown. Transverse waves travel along the length of the racket at a speed of 160 m s^{-1}.



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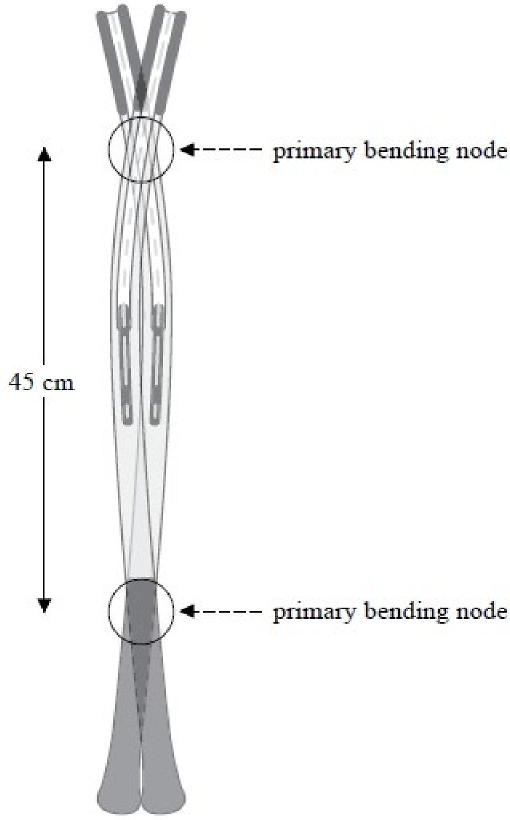

Calculate the frequency of oscillation of the frame.

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Frequency = ...

(Total for question = 3 marks)

Q5.

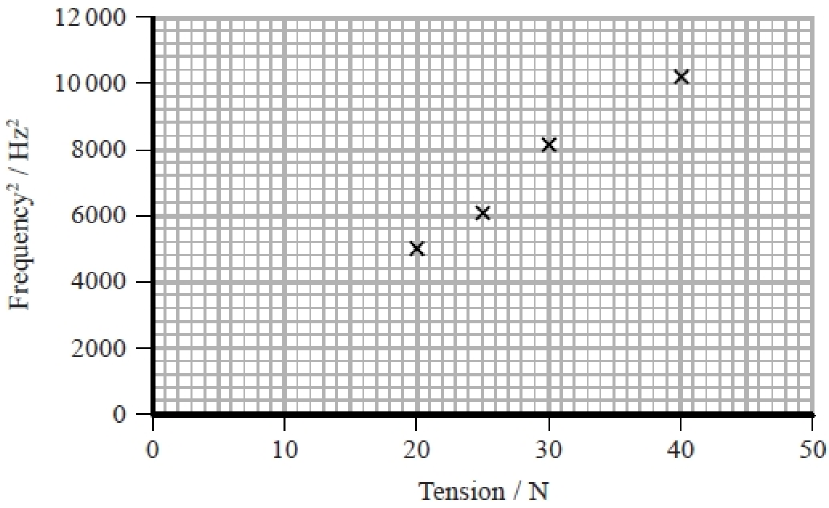
A student carries out an experiment using a guitar string. She investigates the effect of varying the tension in the guitar string on the frequency of sound produced when the string is plucked.

(a) The student records the following data and plots a graph.

Tension / N	20	25	30	35	40
Frequency / Hz	70	78	90	95	101
Frequency^2 / Hz^2	4900	6084	8100		10 201

Complete the table and graph.

(3)



(b) The student reads that guitar strings have a mass per unit length of between 0.4×10^{-3} kg m^{-1} and 7×10^{-3} kg m^{-1}.

Determine whether the guitar string used in this experiment lies within this range.
length of string vibrating = 0.40 m

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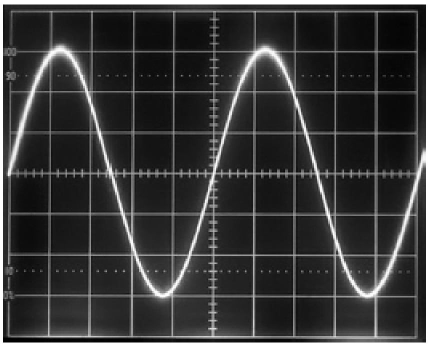
(Total for question = 8 marks)

Q6.

In an investigation to determine the speed of sound in air, a student sets up an oscilloscope to display the waveform of a sound wave as shown.



The timebase is set to 25 μs / division.

Determine the frequency of the sound wave.

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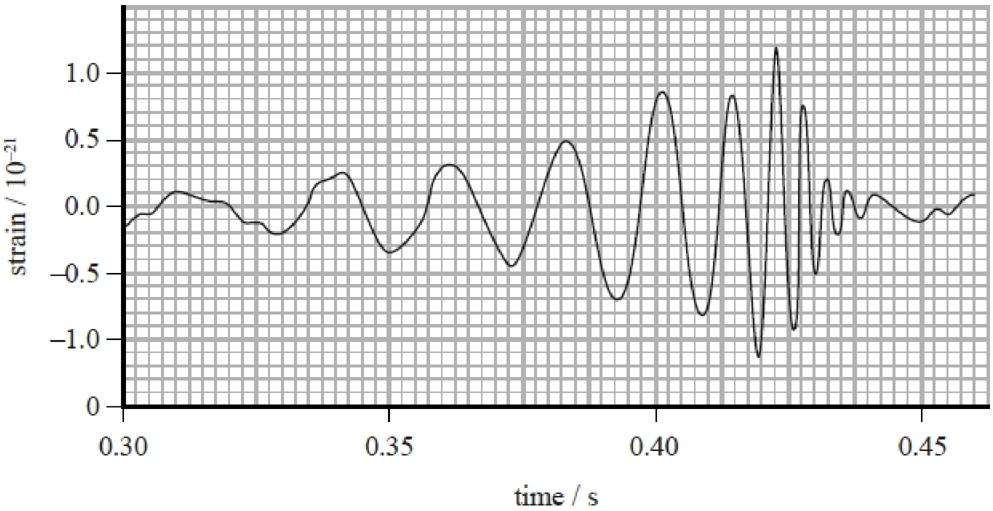
Frequency = ...

(Total for question = 2 marks)

Q7.

In 2016 scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that gravitational waves had been detected.

The signal they detected is shown on the graph.



Gravitational waves travel at the speed of light.

Determine the mean wavelength of the waves detected between 0.30 s and 0.35 s on the graph.

(3)

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Mean wavelength = ...

(Total for question = 3 marks)

Q8.

A string is held under tension. When it is plucked it vibrates with a frequency *f*.

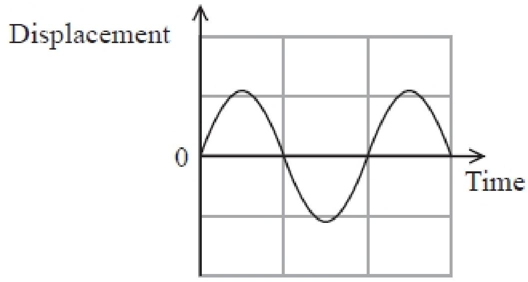
Which of the following would result in a lower value for *f* ?

- ☐ **A** decreasing the cross-sectional area of the string
- ☐ **B** decreasing the density of the material of the string
- ☐ **C** increasing the length of the string
- ☐ **D** increasing the tension

(Total for question = 1 mark)

Q9.

A displacement-time graph is shown for a particle in a transverse wave.



Which property of the wave **cannot** be determined directly from the displacement-time graph?

☐ **A** amplitude

☐ **B** frequency

☐ **C** time period

☐ **D** wavelength

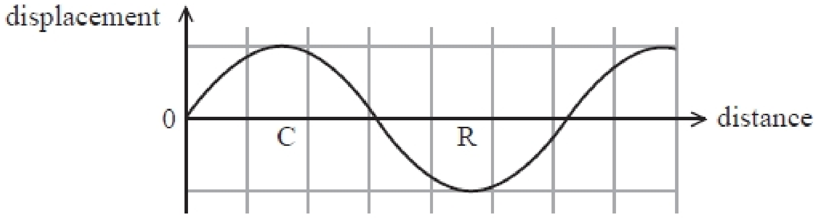
(Total for question = 1 mark)

Q10.

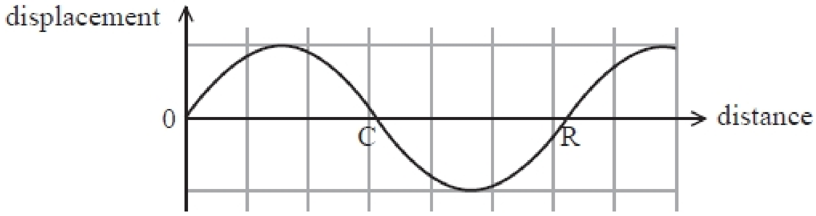
A longitudinal wave is represented on a displacement-distance graph. A positive displacement on the graph indicates a displacement to the right.

Which graph shows the correct labelling of possible positions of a compression, C, and a rarefaction, R?

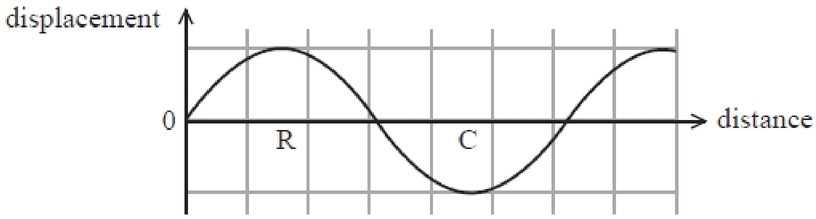
A



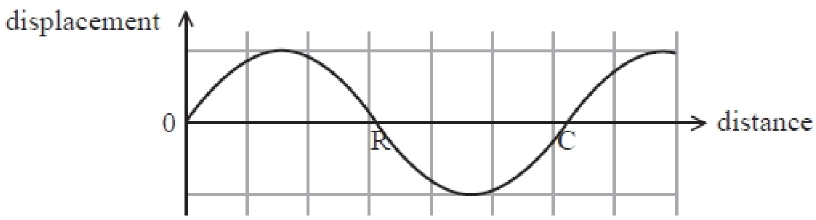
B



C



D



☐ **A**
☐ **B**
☐ **C**
☐ **D**

(Total for question = 1 mark)

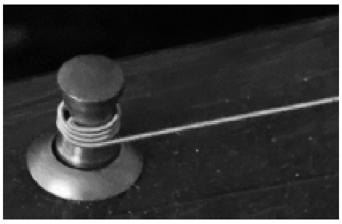
Q11.

The photograph shows a guitar.

When a guitar string is plucked, a standing wave is created.

One end of the guitar string is wrapped around a cylindrical tuning peg. Turning the peg changes the total length of the string and hence changes the tension in the string.

This changes the frequency of vibration of the string.



(i) The length of one string is 68 cm.

Calculate the extension required to produce a tension of 93.4 N in the string.

Young modulus of string material = 1.8×10^{9} N m^{-2}
cross-sectional area of string = 6.6×10^{-7} m^{2}

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Extension = ...

(ii) The vibrating length of string is unchanged by turning the tuning peg.

Explain the effect that tightening the string has on the frequency of the sound produced.

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(Total for question = 6 marks)

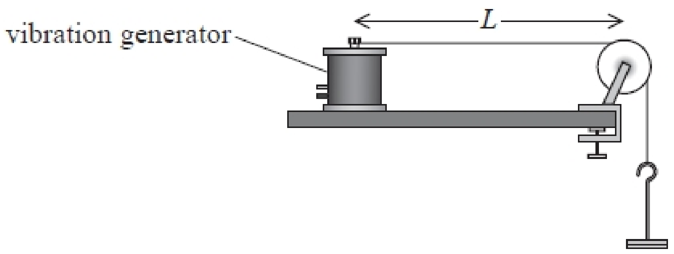
Q12.

The speed v of a transverse wave on a string is given by

$$v = \sqrt{\frac{T}{\mu}}$$

where μ is the mass per unit length of the string and T is the tension in the string.

A fixed length L of string is connected to a vibration generator and held under tension T as shown. The frequency of the vibration generator is varied until, at a frequency f, a standing wave with one antinode is observed. T is increased and the procedure is repeated.



Which of the following describes the variation in f as T increases?

☐ **A** decreases linearly

☐ **B** decreases non-linearly

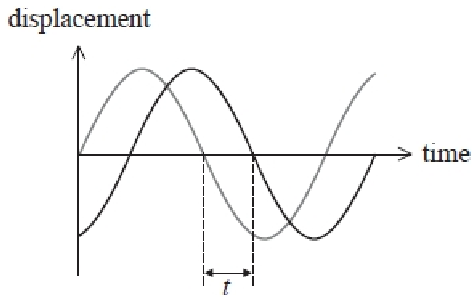
☐ **C** increases linearly

☐ **D** increases non-linearly

(Total for question = 1 mark)

Q13.

Displacement-time graphs are shown for two waves, each of frequency *f* and period *T*.



The phase difference in radians between the two waves is given by

(1)

☐ **A** $\frac{2\pi t}{T}$

☐ **B** $\frac{\pi t}{T}$

☐ **C** $\frac{2\pi t}{f}$

☐ **D** $\frac{\pi t}{f}$

(Total for question = 1 mark)

Q14.

A student carries out an experiment using a guitar string. She investigates the effect of varying the tension in the guitar string on the frequency of sound produced when the string is plucked.

Describe a method of varying and measuring the tension in the string.

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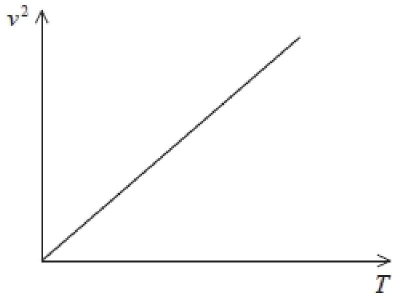
(Total for question = 2 marks)

Q15.

This question refers to an experiment to investigate stationary waves on a string.

Corresponding values of v^2 against T are plotted. A straight line graph is obtained, as shown.



Which of the following expressions for the mass per unit length μ of the string is correct?

☐ **A** $\mu = \text{gradient}$

☐ **B** $\mu = \sqrt{\text{gradient}}$

☐ **C** $\mu = \dfrac{1}{\text{gradient}}$

☐ **D** $\mu = \dfrac{1}{\sqrt{\text{gradient}}}$

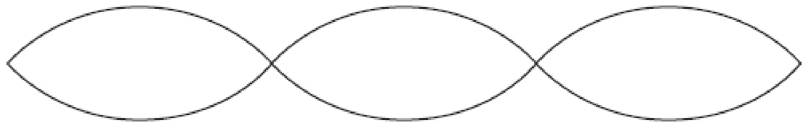
(Total for question = 1 mark)

Q16.

The photograph shows a guitar.

When a guitar string is plucked, a standing wave is created.

The diagram shows a standing wave on a guitar string.



The oscillating length of the guitar string is 66 cm.

(i) State the wavelength for this standing wave.

(1)

Wavelength = ...

(ii) Calculate the frequency of vibration for this standing wave.

tension in guitar string = 88.6 N
mass per unit length of guitar string = 4.47×10^{-3} kg m^{-1}

(3)

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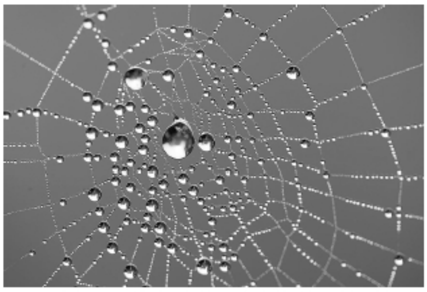
Frequency = ...

(Total for question = 4 marks)

Q17.

The photograph shows part of a spider's web where water droplets have collected at certain points. The web is made from spider silk which is made by the spider.



Spiders are almost completely dependent on vibrations transmitted through their web for receiving information about the location of trapped insects. When the threads are disturbed by the insects, progressive waves are transmitted along sections of the silk.

It has been suggested that the droplets of water collect at certain points on the web because stationary waves are formed.

* Explain how stationary waves can be setup on a thread of spider silk, and how this can account for the collection of water droplets at certain points on the thread.

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(Total for question = 6 marks)

Q18.

A beam of light from a torch with power *P* is shone onto a surface. The light is spread over a circular area with a radius *r*.

Which of the following gives the intensity of the light on the surface?

☐ **A** $P \times 4\pi r^2$

☐ **B** $\frac{P}{4\pi r^2}$

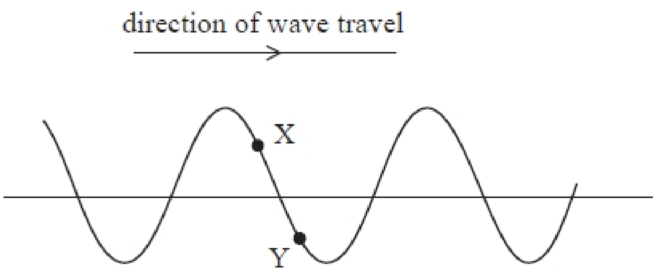
☐ **C** $P \times \pi r^2$

☐ **D** $\frac{P}{\pi r^2}$

(Total for question = 1 mark)

Q19.

The diagram shows the position of two particles, X and Y, on a transverse wave.
The wave is travelling from left to right.



Which of the following describes the directions in which the particles at X and Y are moving at the instant shown?

	Particle X	Particle Y
☐ **A**	down	down
☐ **B**	down	up
☐ **C**	up	down
☐ **D**	up	up

(Total for question = 1 mark)

Q20.

Light can be modelled as a wave.

Describe how light is transmitted as a transverse wave.

(2)

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(Total for question = 2 marks)

Q21.

Which of the following wave properties demonstrates that electromagnetic waves must be transverse?

- ☐ **A** diffraction
- ☐ **B** interference
- ☐ **C** polarisation
- ☐ **D** refraction

(Total for question = 1 mark)

Q22.

Which of the following statements about standing waves is **not** true?

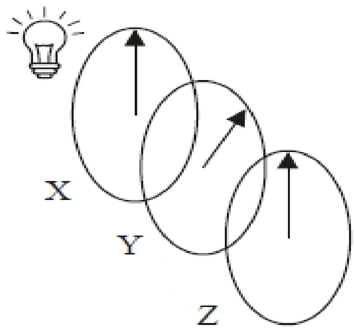
- ☐ **A** Particles between adjacent nodes oscillate with varying amplitudes.
- ☐ **B** Particles between adjacent nodes are moving in phase with each other.
- ☐ **C** Particles immediately either side of a node are moving in opposite directions.
- ☐ **D** Particles undergo no disturbance at an antinode.

(Total for question = 1 mark)

Q23.

Three polarising filters X, Y and Z, are placed in front of a source of unpolarised light. The planes of polarisation of the filters are initially parallel.

Filter Y is rotated by 45° as shown.



Filter Z is then rotated clockwise and the intensity of light emerging from Z is measured.

Which angle of rotation of Z will result in the lowest intensity of light?

☐ **A** 90°

☐ **B** 135°

☐ **C** 180°

☐ **D** 225°

(Total for question = 1 mark)

Q24.

The speed v of a transverse wave on a string is given by

$$v = \sqrt{\frac{T}{\mu}}$$

where μ is the mass per unit length of the string and T is the tension in the string.

μ can be calculated from measurements of the mass and length of the string.

The percentage uncertainty in the measurement of mass is 0.4%.
The percentage uncertainty in the measurement of length is 0.05%.

Which of the following is the percentage uncertainty in the calculated value for μ?

☐ **A** 0.4 + 0.05

☐ **B** 0.4 − 0.05

☐ **C** 0.4 × 0.05

☐ **D** 0.4 ÷ 0.05

(Total for question = 1 mark)

Q25.

A seiche is a standing wave that can form on the surface of a lake in strong winds, causing flooding and erosion.

Early in 2020, a single-node seiche was observed on Lake Erie in the USA. A node formed at the centre of the lake. Antinodes formed at the two ends of the lake.

The speed *v* of a seiche wave is given by

$$v = \sqrt{gh}$$

where *h* is the mean depth of the water.

Calculate the period of oscillation of the seiche.

length of Lake Erie = 400 km
mean depth of Lake Erie = 19 m

(3)

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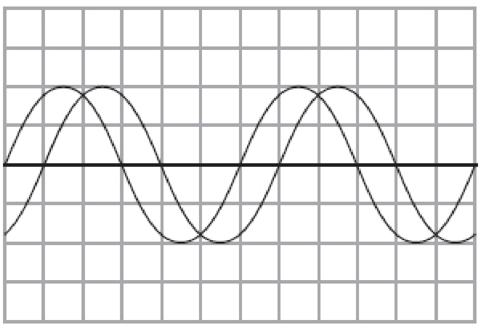
Period of oscillation = ...

(Total for question = 3 marks)

Q26.

A two-beam oscilloscope is used to display signals from two microphones as shown.



Which of the following could be the phase difference in radians between the traces?

☒ **A** $\frac{\pi}{6}$

☒ **B** $\frac{\pi}{4}$

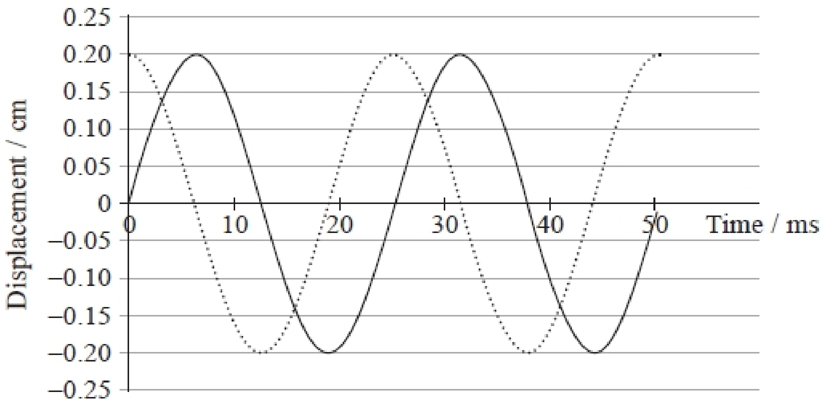
☒ **C** $\frac{\pi}{3}$

☒ **D** $\frac{\pi}{2}$

(Total for question = 1 mark)

Q27.

The graph shows the variation of displacement with time for two waves.



What is the phase difference between these two waves?

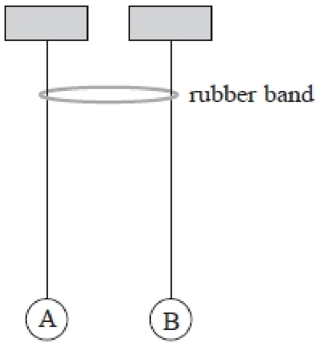
(1)

☒ **A** 6 ms
☒ **B** 0.20 cm
☒ **C** π radians
☒ **D** 90 degrees

(Total for question = 1 mark)

Q28.

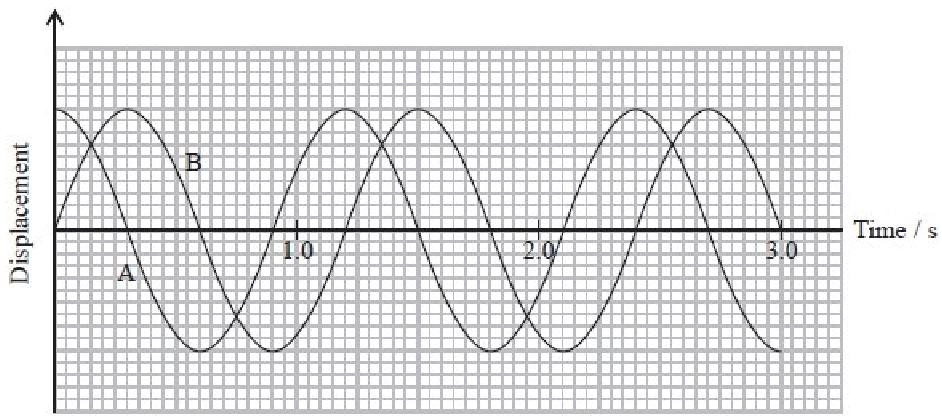
The diagram shows two identical pendulums, A and B, side by side with a rubber band placed over both strings.



Pendulum A is displaced and starts to oscillate. As pendulum A oscillates, pendulum B starts to oscillate with the same time period, its amplitude increasing as the amplitude of pendulum A decreases. At one stage pendulum A is no longer oscillating and pendulum B has its maximum amplitude. Then pendulum A starts to oscillate again with increasing amplitude, as the amplitude of pendulum B decreases.

The apparatus is adjusted so that the pendulums do not have the same length as each other. When the first pendulum is set into oscillation, the second pendulum starts to oscillate, but with very small amplitude; the first pendulum does not stop oscillating.

The graph shows how the displacement of each pendulum varies with time at one stage in the motion.



(i) State the phase relationship between the two pendulums.

(1)

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(ii) Determine the length of pendulums A and B.

(3)

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Length = ...

(Total for question = 4 marks)

Q29.

The lens in the eye of an octopus focuses light onto the retina at the back of the eye.

The octopus focuses on objects at different distances from the eye by changing the shape of the eye to move the lens closer or further from the retina.

An octopus can detect the orientation of polarised light.

State what is meant by polarised light.

(2)

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(Total for question = 2 marks)

Q30.

* A student views a laptop screen through a polarising filter. Initially the screen appears normal brightness. He rotates the filter to 90° and observes that the screen appears dark.

Explain what the student observes as he gradually rotates the filter to 180° and then to 270°.

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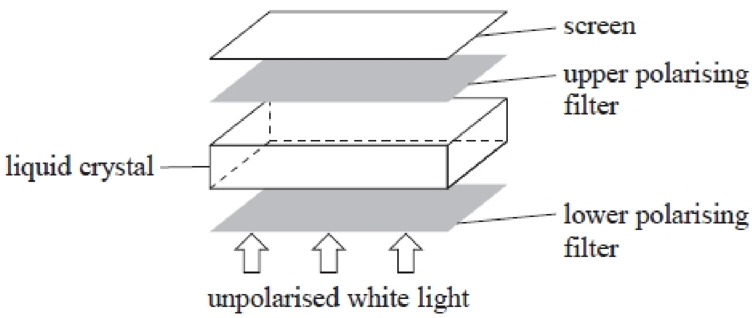
(Total for question = 6 marks)

Q31.

A liquid-crystal display uses a series of segments to form letters and numbers on a screen.

The construction of a display segment is shown.



- Unpolarised white light passes through the lower polarising filter and becomes plane polarised.
- When there is no potential difference (p.d.) across the liquid crystal, the molecules in the liquid crystal rotate the plane of polarisation by 90°.
- Light then passes through the upper polarising filter and appears on the screen.
- When a p.d. is applied across the liquid crystal, the molecules no longer rotate the plane of polarisation. The light will not pass through the upper polarising filter and the screen appears dark.

(i) Describe what is meant by plane polarised light.

(2)

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(ii) Explain the angle of polarisation of the upper polarising filter relative to the lower polarising filter.

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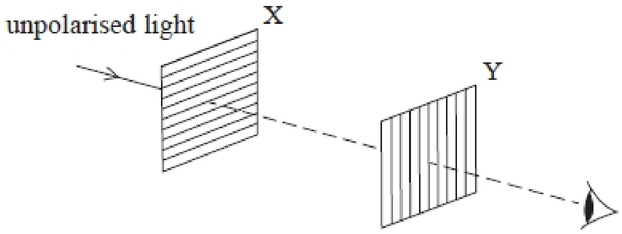
(Total for question = 4 marks)

Q32.

A source of unpolarised light is viewed through two crossed polarising filters X and Y.



Which row in the table correctly describes the light emerging from the two filters?

(1)

	Light emerging from filter X	Light emerging from filter Y
☒ **A**	oscillates in every direction	oscillates in one direction
☒ **B**	oscillates in every direction	no light
☒ **C**	oscillates in one direction	oscillates in one direction
☒ **D**	oscillates in one direction	no light

(Total for question = 1 mark)

Q33.

Vibrations of a car engine cause a sound wave in air.

Describe how the displacement of air molecules causes pressure variations in the air.

(3)

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(Total for question = 3 marks)

Q34.

Which of the following statements about waves is **not** correct?

- ☐ **A** An unpolarised wave may be polarised on reflection from a surface.
- ☐ **B** Longitudinal waves cannot be plane polarised.
- ☐ **C** The vibrations in an unpolarised wave are in many directions.
- ☐ **D** Transverse waves are always plane polarised.

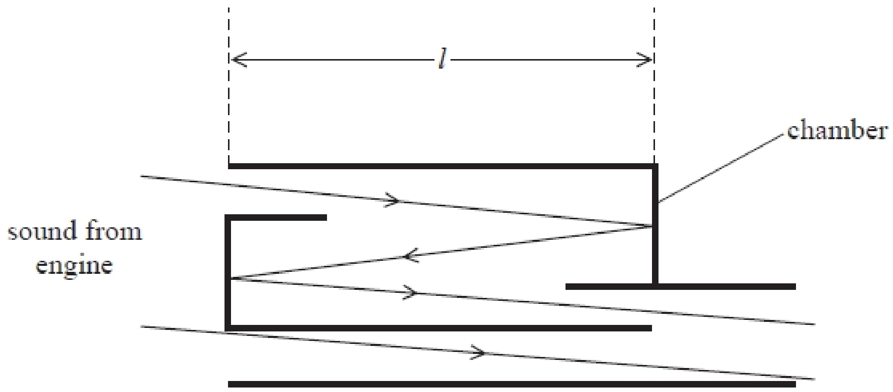
(Total for question = 1 mark)

Q35.

Vibrations of a car engine cause a sound wave in air.

A silencer is a device fitted to a car to reduce the sound from the engine.
Some sound passes through the silencer chamber and is reflected twice. Some sound passes straight through the chamber without being reflected.

The simplified diagram shows the paths of the sound as it travels through the chamber. Sound leaving the chamber is a combination of sound waves from the two paths. The sound waves are in phase as they enter the chamber.



An engine produces sound with a frequency of about 140 Hz.

Explain why, to reduce this sound, the length *l* of the chamber should be about 60 cm.

speed of sound in air = 340 m s^{-1}

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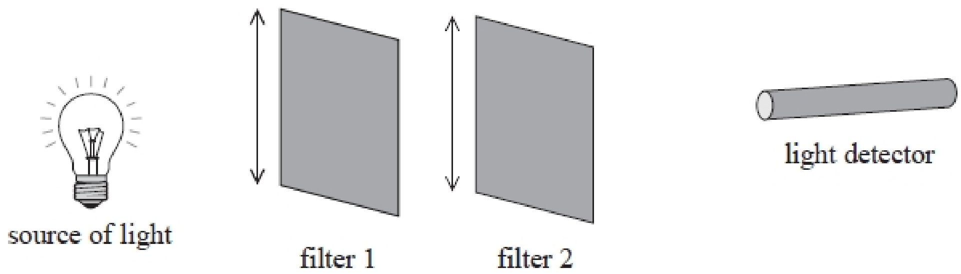
(Total for question = 4 marks)

Q36.

The diagram shows apparatus used to investigate polarising filters.

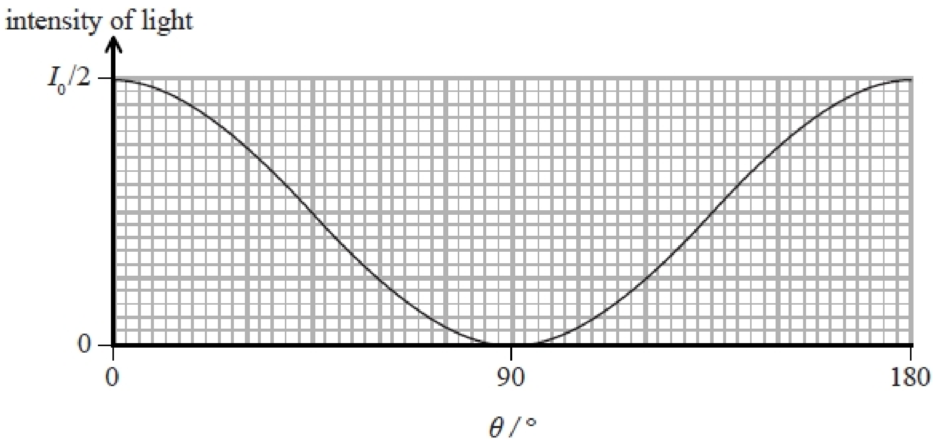


Light is incident on filter 1 and the intensity of the light is measured, using the light detector, when the filters are in the positions shown.

Filter 2 is then rotated and the intensity of light is measured for different angles of rotation θ.

The intensity of light measured with no filters present is I_0.

The results are shown on the graph.



Explain the effect of the filters on the intensity of light and why the intensity varies as shown.

(6)

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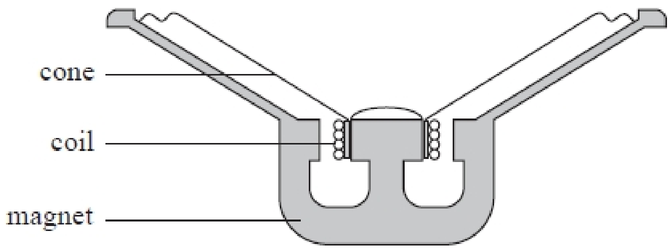
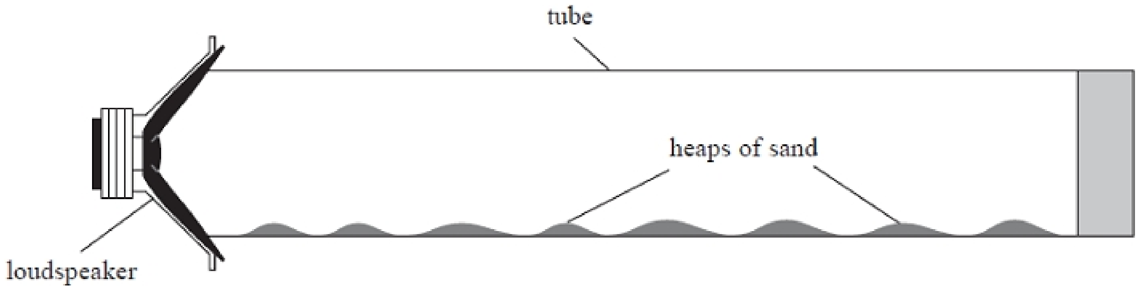
(Total for question = 6 marks)

Q37.

A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate. The loudspeaker is mounted in a wooden box. A cross-section through the loudspeaker is shown.



The student connected a signal generator to the loudspeaker, and placed the loudspeaker near to one end of a long tube containing sand. The student adjusted the signal generator until the sand collected in small heaps as shown.



(i) Explain why the sand collects in heaps.

(4)

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(ii) The student determined the distance *d* between the centres of adjacent heaps.

Describe the procedure she should follow to determine an accurate value for *d*.

(3)

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(iii) Assess whether the experimental data is consistent with a value for the speed of sound of 340 m s^{-1}.

signal generator frequency = 3.25 kHz.
d = 5.1 cm

(3)

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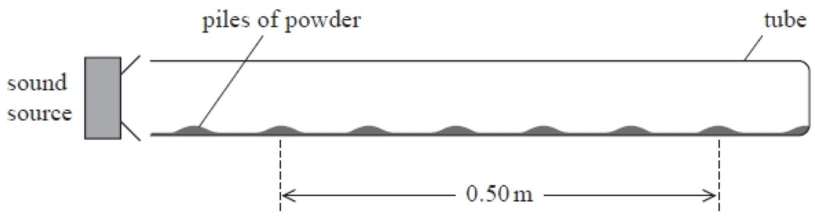
(Total for question = 10 marks)

Q38.

In an experiment to determine the speed of sound in air, a powder is sprinkled over the base of a horizontal glass tube. One end of the tube is closed. A sound source is placed at the open end of the tube, as shown.



Soundwaves travel along the tube and reflect from the closed end.

Explain why the powder forms into small piles at regular intervals along the length of the tube.

(5)

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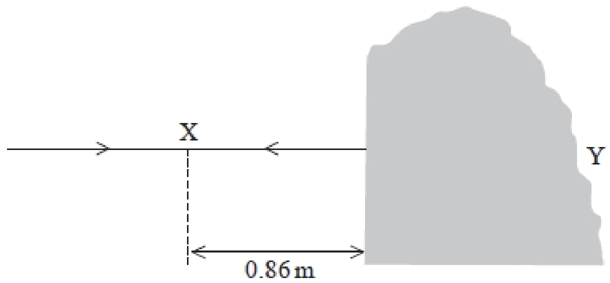
(Total for question = 5 marks)

Q39.

Lighthouses are located along coastlines to aid navigation. A lighthouse emits an intense beam of light. In clear weather the beam is visible for long distances, but in foggy weather the visibility of the beam is limited.

A lighthouse is also fitted with a foghorn to emit a loud sound in foggy weather.

A sound wave is incident normally on a large rock and is reflected. The reflected wave meets the incoming wave, creating a standing wave. The closest node to the rock is at point X, 0.86 m from the rock as shown.



(i) Calculate the speed of the sound wave.

frequency of sound wave = 200 Hz

(3)

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Speed of sound wave = ...

(ii) The rock is about 2 m wide and 2 m high.

Explain why sound would be heard at point Y behind the rock.

(2)

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(Total for question = 5 marks)

Q40.

This questions refers to an experiment to investigate stationary waves on a string.

A string of length *l*, fixed at both ends, is placed under tension *T* and plucked. The fundamental frequency *f* of the vibrating string is measured and the speed *v* of the wave on the string is calculated.

Which of the following gives the speed of the wave?

☐ **A** $v = 4fl$

☐ **B** $v = 2fl$

☐ **C** $v = fl$

☐ **D** $v = \frac{fl}{2}$

(Total for question = 1 mark)

Q41.

Two waves have the same amplitude and are travelling in the same medium.

The two waves can produce a standing wave if they

☐ **A** have different frequencies and travel in opposite directions.

☐ **B** have different frequencies and travel in the same direction.

☐ **C** have the same frequency and travel in opposite directions.

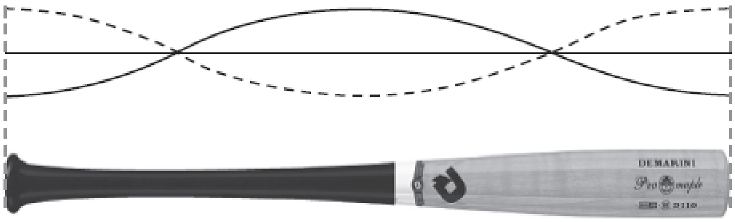
☐ **D** have the same frequency and travel in the same direction.

(Total for question = 1 mark)

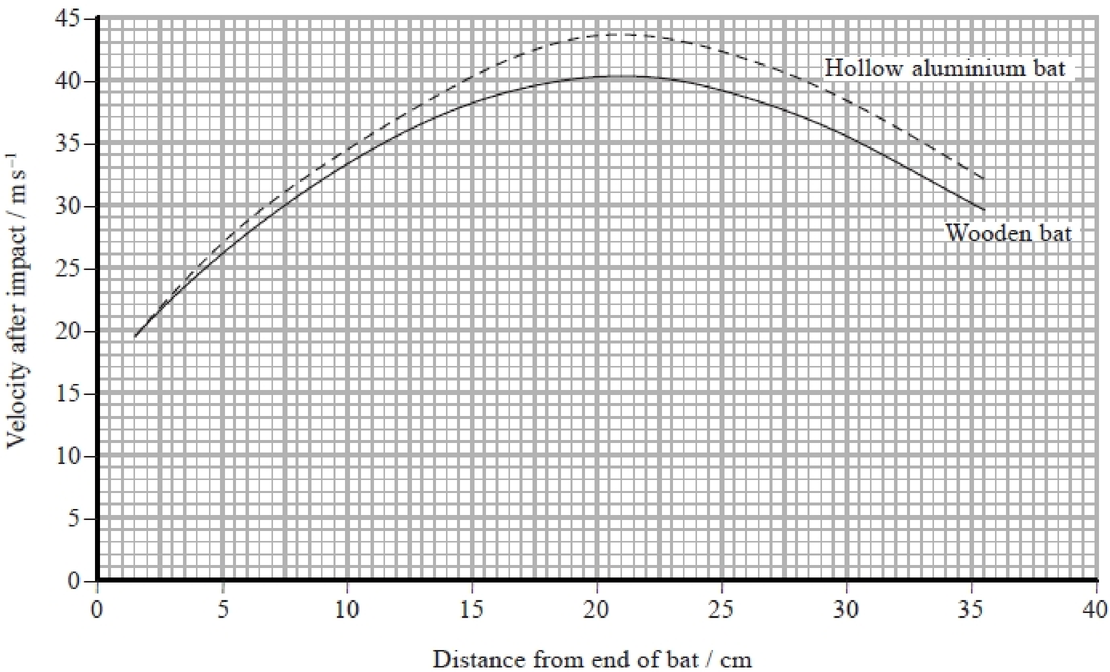
Q42.

As a baseball bat hits a ball, kinetic energy of the ball is transferred to the bat and a standing wave is set up along the length of the bat.

The diagram shows the standing wave that is set up.



The graph shows how the velocity of the ball after impact varies with the distance of impact from the free end of the bat for two bats made of different materials. Both bats have a length of 0.85m.



A baseball player states, "It is better to use a hollow aluminium bat, hitting the ball at a distance of about a quarter of the length from the free end of the bat."

Evaluate the baseball player's statement.

(5)

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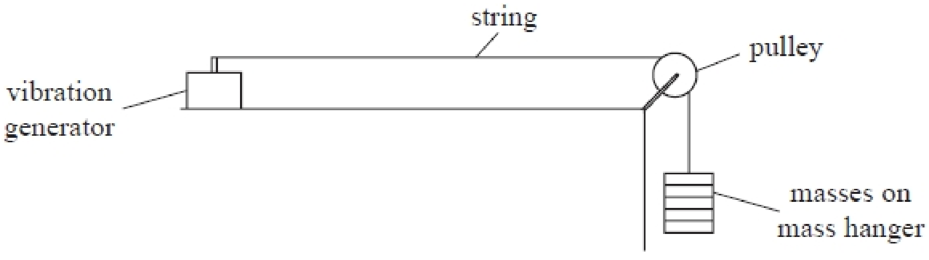
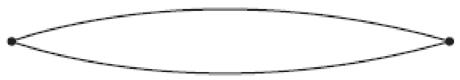
Q43.

The diagram represents an arrangement used to generate standing waves on a string.



A standing wave pattern with two nodes is obtained as shown.



Which of the following single changes could produce a standing wave pattern with three nodes?

- ☐ **A** decreasing the distance between the vibration generator and pulley
- ☐ **B** decreasing the frequency of the vibration generator
- ☐ **C** decreasing the mass on the mass hanger
- ☐ **D** decreasing the mass per unit length of the string

(Total for question = 1 mark)

Q44.

Which statement about sound is correct?

(1)

- ☐ **A** Sound can travel through a solid.
- ☐ **B** Sound can travel through a vacuum.
- ☐ **C** Sound waves can travel as polarised waves.
- ☐ **D** Sound waves travel in a direction perpendicular to the direction of the oscillations.

(Total for question = 1 mark)

Q45.

Which of the following is a correct statement about a stationary wave?

- ☐ **A** All points on the wave oscillate in phase.
- ☐ **B** A node is formed at a point of constructive interference.
- ☐ **C** Stationary waves can only be formed from transverse waves.
- ☐ **D** Two points $\frac{\lambda}{2}$ apart oscillate with the same amplitude.

(Total for question = 1 mark)

Q46.

The harp is a musical instrument with many strings, as shown.

(Source: © Peter Voronov/Shutterstock)

All the strings are under tension.

The strings on one type of harp are made from nylon of density 1070 kg m^{-3}. One string has a diameter of 1.14 mm.

(i) Show that the mass per unit length μ of the string is about 1.1×10^{-3} kg m^{-1}.

(2)

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(ii) When the middle of the string is plucked, a note of frequency 440 Hz is produced.

Calculate the tension in the string.
length of string = 41.0 cm

(4)

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Tension in string = ...

(Total for question = 6 marks)

Q47.

The photograph shows a guitar. The strings of the guitar are at the same tension.

When a string is plucked, a standing wave is set up on the string.

A thicker string produces a note with a lower fundamental frequency than a thinner string of the same material.

Justify this statement.

(5)

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(Total for question = 5 marks)

Q48.

Sound waves are produced by a vibrating guitar string.

Which row in the table correctly describes the waves produced?

(1)

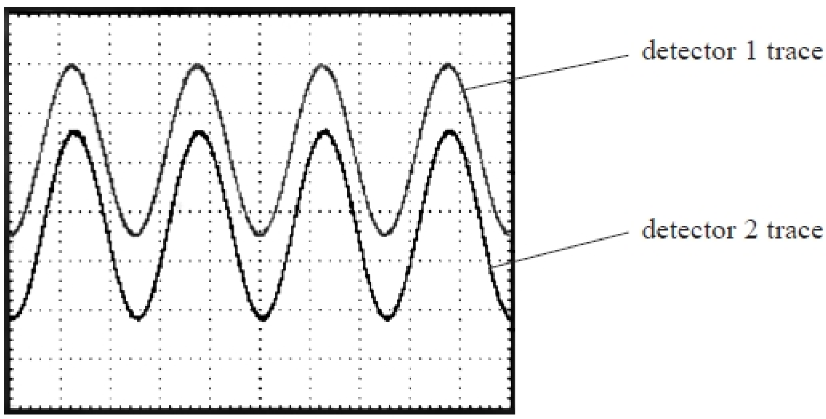
	Guitar string	Sound
☒ **A**	transverse	transverse
☒ **B**	longitudinal	longitudinal
☒ **C**	longitudinal	transverse
☒ **D**	transverse	longitudinal

(Total for question = 1 mark)

Q49.

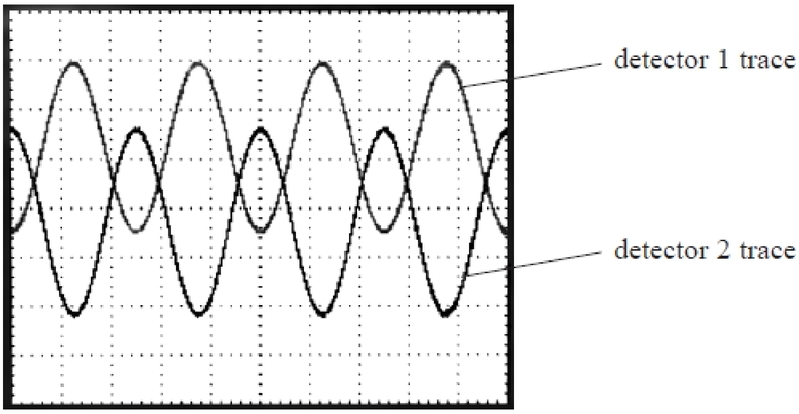
An ultrasound source and two ultrasound detectors are set up as shown.

The detectors are connected to an oscilloscope and photograph 1 shows the traces that are recorded.



photograph 1

Detector 2 is moved slightly further away from the source and photograph 2 shows the traces that are recorded.



photograph 2

(a) Explain the change in the traces between photograph 1 and photograph 2.

(3)

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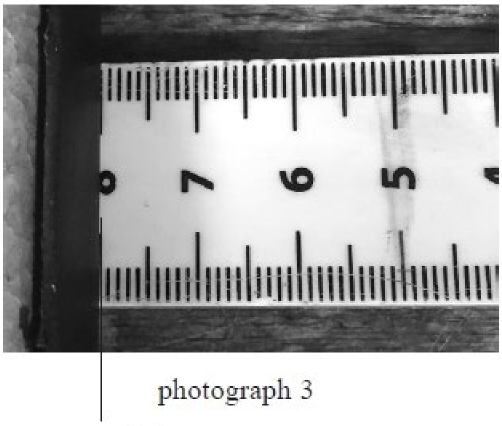
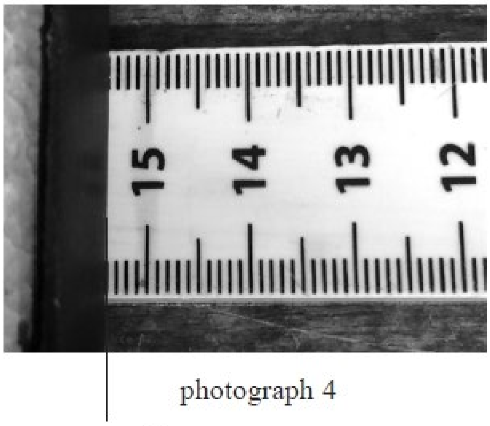
(b) Detector 2 is moved back to its original position, alongside detector 1. Detector 2 is then steadily moved away from the source. This produces the traces seen in photograph 2 then photograph 1 alternately, until nine such cycles have been seen.

The detector moves across a metre rule and the initial and final position of the detector are shown in photograph 3 and photograph 4.



photograph 3

position
of detector



photograph 4

position
of detector

Calculate, using the results of this experiment, the speed of sound in air.
frequency of ultrasound = 40.0 kHz

(4)

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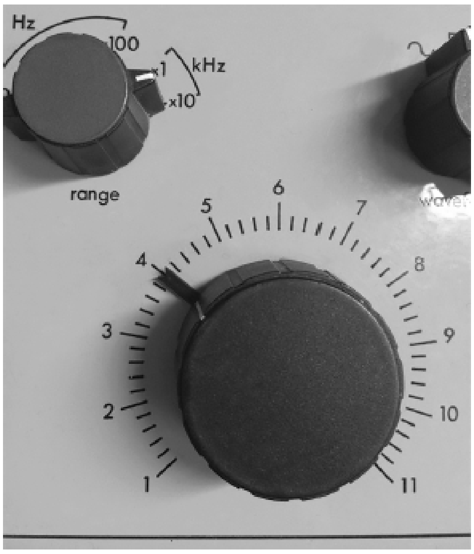
Speed of sound in air = ...

(c) The ultrasound was produced using a signal generator.

The frequency of the ultrasound was measured by reading from the dial of the signal generator as shown.



Explain one limitation of this method of determining the frequency.

(2)

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(Total for question = 9 marks)

Q50.

The light emitted from a laptop screen is plane polarised.

Explain how the plane of polarisation of the emitted light can be demonstrated using a polarising filter.

(3)

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(Total for question = 3 marks)

Mark Scheme - Wave properties and Stationary Waves

Q1.

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>*</td><td>This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table><tr><td>Number of indicative points seen in answer</td><td>Number of marks awarded for indicative points</td></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table>Indicative Content
Two waves travelling in opposite directions (1)
Superpose / interfere (1)
Constructive (interference) if waves in phase Or Constructive (interference) if path difference = nλ (1)
Destructive (interference) if waves in antiphase Or destructive (interference) if path difference = (n + ½)λ (1)
Nodes are formed from points of destructive (interference) or antinodes are formed from points of constructive (interference) (1)
Nodes are points with min amplitude and antinodes are points with max amplitude (1)</td><td></td><td>6</td></tr>
</table>

Q2.

Question Number	Acceptable Answers		Additional guidance	Mark
(a)	• Sound travels as a longitudinal wave **Or** in a series of compressions **and** rarefactions • With oscillations/vibrations of (air) particles/molecules parallel to the direction of energy transfer	(1) (1)	Accept: Direction of energy transfer **Or** propagation of the wave **Or** direction of wave travel/motion	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(i)	• the idea that there is a wide variation in the first two readings	(1)		1

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(ii)	• uses $\frac{\text{half the range of values}}{\text{mean value}}$ • percentage uncertainty = 8.5%	(1) (1)	Example of Calculation $\frac{0.5 \times (0.51\text{ s} - 0.43\text{ s})}{0.47\text{ s}} \times 100\% = 8.5\%$ Accept calculations based on $\frac{\text{range of values}}{\text{mean value}}$ (17%)	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(iii)	• attempt to calculate Δv • Δv = 7.4 m s^{-1} or 8.0 m s^{-1}	(1) (1)	Example of Calculation $\frac{160\text{ m}}{0.46\text{ s}} - \frac{160\text{ m}}{0.47\text{ s}} = 7.4\text{ m s}^{-1}$ Use of 80 m (Δv =3.7) scores MP1 only	2

Question Number	Acceptable Answers		Additional guidance	Mark
(b)(iv)	Max 2: • insufficient number of results • identifies one other variable to take into account • difference (in t or v) could be due to human reaction times • uncertainty in results may account for the difference	(1) (1) (1) (1)	Do not accept take readings over more days MP2 examples:wind speed/direction, humidity, air pressure MP3 do not credit human error	2

Q3.

Question Number	Acceptable Answers		Additional guidance	Mark
	• use of $v = f\lambda$ • identifies 0.5 m is 5 gaps • v = 360 m s^{-1}	(1) (1) (1)	Example of calculation $\frac{\lambda}{2} = \frac{0.50}{5}$ λ = 0.20 m v = 1800 Hz × 0.20 m = 360 m s^{-1}	3

Q4.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $L = \lambda/2$ **(1)** • Use of $v = f\lambda$ **(1)** • f = 180 Hz **(1)**	Example of calculation: $\lambda = 2 \times 0.45$ m = 0.90 m $f = v/\lambda$ = 160 m s^{-1}/0.9 m = 178 Hz	3

Q5.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Calculate missing $f^2 = 9025$ • Plot missing point • Draw line of best fit	(1) (1) (1)	Plot (35, 9025) or their calculated value of f^2	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Determines the gradient • Equates $v = f\lambda$ and $v = \sqrt{\frac{T}{\mu}}$ • Uses $\lambda = 0.8$ (m) • Mass per unit length μ = (6.0 to 6.2) x 10^{-3} (kg m^{-1}) • Conclusion consistent with their value	(1) (1) (1) (1) (1)	e.g. gradient= $\frac{(10200-0)}{(40-0)}$ =255 accept $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ $\mu = \frac{1}{255 Hz^2 N^{-1} \times 0.8^2 m^2}$ =6.1 x 10^{-3} (kg m^{-1})	5

Q6.

Question Number	Answer		Additional Guidance	Mark
	• Use of $f = \frac{1}{T}$ with T = 125 μs • 8000 Hz	(1) (1)	Example of calculation $f = \frac{1}{1.25\times10^{-8}\text{ s}}$ = 8000 Hz	2

Q7.

Question Number	Acceptable answers		Additional guidance	Mark
	• use of $f = 1/T$ • use of $v = f\lambda$ • wavelength = 7.5×10^6 m	(1) (1) (1)	MP3: accept variations e.g. 1.75 waves or two wavelengths averaged with correct calculation Example of calculation 2 waves $2T$ = 0.05 s T = 0.025 s f = 1/0.025 s = 40 Hz $\lambda = 3.00 \times 10^8$ m s^{-1} ÷ 40 Hz = 7.5×10^6 m	3

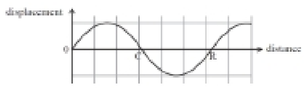
Q8.

Question Number	Answer	Mark
	C increasing the length of the string	1
	Incorrect Answers: A results in a higher value for f B results in a higher value for f D results in a higher value for f	

Q9.

Question Number	Answer	Mark
	D wavelength	**1**
	Incorrect Answers: **A** – determined from the maximum displacement on y-axis **B** – determined from 1/time for one cycle **C** – determined from the time for one cycle on x-axis	

Q10.

Question Number	Answer	Mark
	B 	1
	Incorrect Answers: A compression and rarefaction both occur at regions of 0 displacement C compression and rarefaction both occur at regions of 0 displacement D compression and rarefaction are labelled the wrong way round with respect to the direction of the positive displacement	

Q11.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of stress = F/A (1) • Use of Young modulus = stress / strain (1) • Use of strain = $\Delta x/x$ (1) • Extension = 0.053 m (1)	<u>Example of calculation</u> stress = 93.4 N / 6.6 ×10^{-7} m^2 = 1.42 ×10^8 N m^{-2} strain = 1.42 ×10^8 N m^{-2} / 1.8 ×10^9 N m^{-2} = 0.0786 extension = 0.0786 × 0.68 m = 0.053 m	4
(ii)	• Increase tension so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$ **Or** decrease μ so increase wavespeed since $v = \sqrt{\frac{T}{\mu}}$ (1) • Since $v = f\lambda$ and wavelength unchanged, this increases frequency (1)		2

Q12.

Question Number	Answer	Mark
	D – increases non-linearly	1
	Incorrect Answers: A – incorrect as $f \propto \sqrt{T}$ B – incorrect as $f \propto \sqrt{T}$ C – incorrect as $f \propto \sqrt{T}$	

Q13.

Question Number	Answer	Mark
	A $\frac{2\pi t}{T}$	1
	Incorrect Answers: B – no factor of 2 C – incorrect substitution of f D – incorrect substitution of f and no factor of 2	

Q14.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use a pulley and set of masses/weights hung on string (1) • Tension = weight (of set of masses) **Or** $T=mg$ (1)		2

Q15.

Question Number	Answer	Mark
	C - $\mu = \frac{1}{\text{gradient}}$	1
	Incorrect Answers: A – incorrect use of $v = \sqrt{\frac{T}{\mu}}$ B – incorrect use of $v = \sqrt{\frac{T}{\mu}}$ D - incorrect use of $v = \sqrt{\frac{T}{\mu}}$	

Q16.

Question Number	Acceptable answers		Additional guidance	Mark
(i)	• Wavelength = 44 cm	(1)		1
(ii)	• Use of $v = \sqrt{\frac{T}{\mu}}$ • Use of $v = f\lambda$ (ecf from (i)) • f = 320 Hz	(1) (1) (1)	Example of calculation $v = \sqrt{\frac{88.6\ \text{N}}{4.47 \times 10^{-3}\ \text{kg m}^{-1}}}$ = 141 m s^{-1} f = 141 m s^{-1} / 0.44 m = 320 Hz	3

Q17.

<table>
<tr><th>Question Number</th><th>Acceptable answer</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(a)*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

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<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
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<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td><td>Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td></td></tr>
</table>

	The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>		(6)
	Indicative content • the progressive waves are reflected and two waves travelling in opposite directions meet • superposition/interference takes place • where the waves are in phase, it is constructive, forming antinodes • where the waves are in antiphase, it is destructive, forming nodes • antinodes are points of maximum <u>amplitude</u>, so water will not remain at antinodes • nodes are points of zero displacement, so water can stay at these points		

Q18.

Question Number	Answer	Mark
	D – $\frac{P}{\pi r^2}$ Incorrect Answers: A – Incorrect equations B – Incorrect equation for area of a circle C – Incorrect equation	**1**

Q19.

Question Number	Answer	Mark
	D – both are moving up	**1**
	Incorrect Answers: A – incorrect answer B – incorrect answer C – incorrect answer	

Q20.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Light is an electromagnetic wave **Or** Light is oscillations of electric and magnetic fields (1) • Oscillations are perpendicular to the direction of energy transfer (1)	Accept direction of wave travel	2

Q21.

Question Number	Answer	Additional guidance	Mark
	C	(polarisation)	**(1)**

Q22.

Question Number	Answers	Additional Guidance	Mark
	D	particles undergo no disturbance at an antinode	**(1)**

Q23.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is B: light leaving Y is polarised in its plane of polarisation and 135° is perpendicular to the plane of Y, so there will be maximum absorption by filter Z A is not correct because Z is not perpendicular to the plane of Y so some light is transmitted C is not correct because Z is not perpendicular to the plane of Y so some light is transmitted D is not correct because Z is not perpendicular to the plane of Y so some light is transmitted	1

Q24.

Question Number	Answer	Mark
	A 0.4 + 0.05	1
	Incorrect Answers: B – compound uncertainties by addition C – compound uncertainties by addition D – compound uncertainties by addition	

Q25.

Question Number	Answer	Additional Guidance	Mark
	• Recognises $\lambda = 2L$ (1) • Equates $v=f\lambda$ and $v=\sqrt{gh}$ (1) • $T = 5.9 \times 10^4$ s (1)	<u>Example of calculation</u> $T = \frac{L}{\sqrt{gh}} = \frac{2 \times 4.0 \times 10^5 \text{ m}}{\sqrt{9.81 \text{ m s}^{-1} \times 19 \text{ m}}} =$ 5.9×10^4 s = 16.4 h	3

Q26.

Question Number	Answer	Mark
	C $\frac{\pi}{3}$	1
	Incorrect Answers: **A** – incorrect **B** – incorrect **D** – incorrect	

Q27.

Question Number	Acceptable answers	Additional guidance	Mark
	D 90 degrees		1

Q28.

Question Number	Acceptable Answers		Additional Guidance	Mark
(i)	• Pendulum A is $\pi/2$ ahead of pendulum B	(1)		1
(ii)	• $T = 1.2$ s from graph • Use of $T = 2\pi\sqrt{(l/g)}$ • $l = 0.36$ m	(1) (1) (1)	$T = 3.0$ s / 2.5 oscillations 1.2 s $= 2\pi\sqrt{(l/9.81 \text{ N kg}^{-1})}$ $l = 0.36$ m	3

Q29.

Question Number	Acceptable answers		Additional guidance	Mark
	Either • Polarised light is light where the oscillations are in a single plane • Which includes the direction of propagation **Or** • Polarised light is light where the oscillations are in a single direction • Which is perpendicular to the direction of propagation	 (1) (1) (1) (1)		2

Q30.

Question Number	Acceptable Answers
*	This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. **Indicative content** • At 180° the screen is normal/bright • When oscillations/vibrations are parallel to the filter all the light is transmitted **or** When oscillations/vibrations are parallel to the filter no light is absorbed • At 270° the screen is dark/darkest/black • When oscillations/vibrations are perpendicular to the filter all the light is absorbed **or** When oscillations/vibrations are perpendicular to the filter no light is transmitted • The idea of a gradual change as the filter is rotated • (as) Light from the screen is (partially) polarised

Number of indicative points seen in answer	Number of marks awarded for indicative points
6	4
5-4	3
3-2	2
1	1
0	0

Question Number	Additional guidance	Mark
*	The following table shows how the marks should be awarded for structure and lines of reasoning	6

	Number of marks awarded for structure and lines of reasoning
Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkage between points and is unstructured	0

Q31.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Oscillations/vibrations (of the light) are in one plane only (1) • Plane includes the direction of energy transfer **Or** Plane includes the direction of travel/propagation (1)	Accept: • Oscillations/vibrations (of the light) are in one direction only • perpendicular to the direction of propagation/travel **Or** perpendicular to the direction of energy transfer Allow labelled diagrams for each marking point	2
(ii)	• The (angle of polarisation of the) filters are 90° to one another (1) **Either** • If plane of polarisation of light is rotated (by 90°) when it passes through the crystal (with no p.d. across it), it can still pass through the upper filter (1) **Or** • If plane of polarisation of light is not rotated (by 90°) when it passes through the crystal (with a p.d. across it), it cannot pass through the upper filter (1)	MP2: it must be clear as to whether the candidate is describing a light screen or a dark screen	2

Q32.

Question Number	Acceptable answers	Additional guidance	Mark
	D oscillates in one direction, no light		1

Q33.

Question Number	Answer	Additional Guidance	Mark
	• Longitudinal wave **Or** Oscillations of air molecules are parallel to the direction of the energy transfer (1) • Creating compressions **and** rarefactions **Or** Creating regions where the molecules are close together **and** regions where they are further apart (1) • Molecules close together create higher pressure **Or** molecules further apart create lower pressure **Or** compressions are areas of high pressure **Or** rarefactions are areas of low pressure (1)		3

Q34.

Question Number	Answer	Mark
	D Transverse waves are always plane polarised.	1
	Incorrect Answers: A – An unpolarised wave may be polarised on reflection from a surface. B – Longitudinal waves cannot be plane polarised. C – The vibrations in an unpolarised wave are in many directions.	

Q35.

Question Number	Answer	Additional Guidance	Mark
	• use of $v = f\lambda$ (1) • Path difference needs to be = $\left(n + \frac{1}{2}\right)\lambda$ **Or** Path difference needs to be $\frac{\lambda}{2}$ **Or** Length of chamber needs to be $\frac{\lambda}{4}$ (1) **Or** See $\frac{2.4\text{ m}}{4}$ • (so) waves meet in antiphase (1) • destructive interference (1)	<u>Example of calculation</u> $\lambda = \frac{340\text{ m s}^{-1}}{140\text{ s}^{-1}} = 2.43\text{ m}$ path difference = $2l = \frac{2.43\text{ m}}{2}$ $l = \frac{2.43\text{ m}}{4} = 0.61\text{ m}$	**4**

Q36.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td></td><td>This question assesses a student's ability to show a coherent and logical structured answer with linkage and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.

Number of indicative points seen in answer → Number of marks awarded for indicative points:
6 → 4
5-4 → 3
3-2 → 2
1 → 1
0 → 0

Indicative content
• Light from the source is unpolarised Or light from source has oscillations in all planes.
• Intensity is reduced to ½ by filter 1
• By absorbing the perpendicular components Or by transmitting the parallel components.
• At 0° / 180° filter 2 aligned with filter 1 so all light through filter 1 passes through filter 2
• As filter 2 is rotated only the <u>component</u> of the light from filter 1 in the plane of filter 2 is allowed through, so the intensity reduces.
• At 90°, all light is absorbed because their planes (of polarisation) are at right angles.</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning

Number of marks awarded for structure and lines of reasoning:
Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout → 2
Answer is partially structured with some linkages and lines of reasoning → 1
Answer has no linkage between points and is unstructured → 0

Number of IC points awarded → Possible linkage marks:
0,1 → 0
2, 3 → 1
4, 5, 6 → 2

IC3,6 allow, no light passes through, blocked by, stopped by</td><td>6</td></tr>
</table>

Indicative content marks:

Number of indicative points seen in answer	Number of marks awarded for indicative points
6	4
5-4	3
3-2	2
1	1
0	0

Structure and lines of reasoning marks:

	Number of marks awarded for structure and lines of reasoning
Answer shows a coherent and logical structure with linkage and fully sustained lines of reasoning demonstrated throughout	2
Answer is partially structured with some linkages and lines of reasoning	1
Answer has no linkage between points and is unstructured	0

Number of IC points awarded	**Possible linkage marks**
0,1	0
2, 3	1
4, 5, 6	2

Q37.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• A standing wave is set up in the tube **Or** interference (of sound waves) takes place in the tube (1) • Where constructive interference occurs the amplitude is a maximum **Or** at antinodes the amplitude is a maximum (1) • Where destructive interference occurs the amplitude is a minimum **Or** at nodes the amplitude is zero/minimum (1) • Sand is displaced from points of max amplitude to points of min amplitude **Or** sand is displaced from antinodes to nodes (1)		4
(ii)	• Measure over at least 3 heaps (1) • Divide by the number of gaps between the heaps (1) • Repeat measurement and calculate average (1)	i.e at least 2 gaps	3
(iii)	• Use of $d = \frac{\lambda}{2}$ (1) • Use of $v = f\lambda$ (1) • v = 330 (m s^{-1}) and a comment on consistency with 340 m s^{-1} (1)	<u>Example of calculation:</u> $\lambda = 2d = 2 \times 5.1 \times 10^{-2}$ m $= 0.102$ m $v = 3.25 \times 10^{3}$ Hz $\times 0.102$ m $= 332$ m s^{-1}	3

Q38.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Interference of soundwaves occurs in the tube (1) • (and a) stationary wave is formed **Or** nodes **and** antinodes are formed (1) • (where) constructive interference occurs the amplitude is maximum **Or** at antinodes the amplitude is maximum (1) • (where) destructive interference occurs the amplitude is zero/minimum **Or** at nodes the amplitude is zero/minimum (1) • Powder is displaced from points of max amplitude to min amplitude points **Or** Powder is displaced from antinode to nodes (1)		5

Q39.

Question Number	Acceptable Answers	Additional guidance	Mark
(i)	• Use of node to node distance = $\frac{\lambda}{2}$ (1) • Use of $v=f\lambda$ (1) • v = 340 m s^{-1} (1)	Example of Calculation λ = 2 x 0.86 m = 1.72 m v = 200 s^{-1} x 1.72 m = 344 m s^{-1}	3
(ii)	• Wavelength is 1.7 m which is the same order of magnitude as 2 m (1) • Diffraction will take place so sound will be heard at Y (1)	Example of Calculation λ = 2 x 0.86 (m) = 1.7 m	2

Q40.

Question Number	Answer	Mark
	B - $v = 2fl$	1
	Incorrect Answers: A – wavelength is $2l$ C - wavelength is $2l$ D - wavelength is $2l$	

Q41.

Question Number	Acceptable Answers	Additional Guidance	Mark
	C		1

Q42.

Question Number	Acceptable Answer		Additional Guidance	Mark
	Comparison of graphs • maximum velocity of aluminium bat greater than wood	(1)		
	• (this is because) aluminium will store and then release more of the incident energy **Or** (this is because) aluminium is more elastic compared to wood	(1)		
	Discussion of the position of the maximum velocity **Max 2** • maximum velocity occurs at a node / $\frac{\lambda}{4}$	(1)		
	• this produces no / minimal vibrations along the bat	(1)		
	• no / less energy transfer to bat to set up extra vibrations so maximum kinetic energy returned to ball	(1)		**(5)**
	Conclusion • a statement that makes reference to baseball player being correct	(1)	Conclusion mark is dependent on at least one graph mark and one postion mark	

Q43.

Question Number	Answer	Mark
	The only correct answer is C because decreasing the mass on the hanger decreases the tension in the string and, since $v = \sqrt{\frac{T}{\mu}}$, decreases the speed of waves on the string. $\lambda = v/f$ so the wavelength is shorter and a whole wavelength could fit in the original length A the wavelength at the original frequency is unchanged, so decreasing the length will not allow a whole wavelength B decreasing the frequency will increase the wavelength, since wave speed is unchanged, so this will not allow a whole wavelength D since $v = \sqrt{\frac{T}{\mu}}$, decreasing the mass per unit length will increase the wave speed, increasing the wavelength at the original frequency, so this will not allow a whole wavelength	1

Q44.

Question Number	Acceptable answers	Additional guidance	Mark
	A Sound can travel through a solid.		1

Q45.

Question Number	Answer	Mark
	D – Two points $\frac{\lambda}{2}$ apart oscillate with the same amplitude	1
	Incorrect Answers: A – Points on a wave do not all oscillate in phase B – A node is formed from destructive interference C – Stationary waves may also be formed from longitudinal waves	

Q46.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• Use of $\rho = \frac{m}{V}$ with $V = \pi r^2 L$ (1) • $\mu = 1.09 \times 10^{-3}$ (kg m^{-1}) (to at least 3 sf) (1)	For MP1, accept use of ρA Example of calculation: $\mu = \frac{m}{L} = \frac{V\rho}{L} = \frac{\pi r^2 L\rho}{L} = \pi r^2 \rho$ $\therefore \mu = \pi\left(\frac{1.14 \times 10^{-3}\ \text{m}}{2}\right)^2 \times 1070\ \text{kg m}^{-3}$ $\mu = 1.09 \times 10^{-3}\ \text{kg m}^{-1}$	2

Question Number	Acceptable answers	Additional guidance	Mark
(ii)	• Use of $L = \frac{\lambda}{2}$ (1) • Use of $v = f\lambda$ (1) • Use of $v = \sqrt{\frac{T}{\mu}}$ (1) • T = 140 N (ecf from (a)(i)) (1)	Example of calculation: $\lambda = 2 \times 0.41\ \text{m} = 0.82\ \text{m}$ $v = 440\ \text{Hz} \times 0.82\ \text{m} = 361\ \text{m s}^{-1}$ $361\ \text{m s}^{-1} = \sqrt{\frac{T}{1.09 \times 10^{-3}\ \text{kg m}^{-1}}}$ $\therefore T = (361\ \text{m s}^{-1})^2 \times 1.09 \times 10^{-3}\ \text{kg m}^{-3}$ T = 142 N	4

Q47.

Question Number	Acceptable Answers	Additional guidance	Mark
	• the thicker string has a greater mass per unit length (1) • wavelength is the same in each string (1) • Valid assumption stated (1) **Either** • Equate $v = \sqrt{\frac{T}{\mu}}$ and $v=f\lambda$ (1) • Leading to $f \propto \frac{1}{\sqrt{\mu}}$ **or** $f = \frac{1}{\lambda}\sqrt{\frac{T}{\mu}}$ so f is lower (1) **Or** • $v = \sqrt{\frac{T}{\mu}}$ so v is lower (as T constant) (1) • $v=f\lambda$ so f is lower (1)	A thicker string has a greater mass **Or** length of strings is the same	5

Q48.

Question Number	Acceptable answers	Additional guidance	Mark
	D transverse, longitudinal		1

Q49.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• initially the waves are in phase (1) • as one detector moves there is a path difference (1) • they are in antiphase at the point shown because the detector has moved half a wavelength (or an odd multiple) (1)		**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	• calculates distance moved by detector = 7.4 cm (1) • use of wavelength = distance / 9 (= 0.822 cm) (1) • use of $v = f\lambda$ (1) • v = 329 m s^{-1} to 2 or 3 sf (1)	Example of calculation Distance moved = 15.4 cm - 8.0 cm = 7.4 cm Wavelength = 7.4 cm / 9 waves = 0.822 cm v = 40 000 Hz × 0.00822 m = 329 m s^{-1}	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)	• the pointer on the dial is about as thick as the interval between the scale markings (1) • this will cause a large uncertainty in measurements (1) OR • there is a gap between pointer on the dial and the scale so there can be a parallax error (1) (1) • this will introduce uncertainty in measurements (1) OR • the frequency on the dial may differ from the output (1) • so there could be a systematic error		(2)

Q50.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Rotate filter or laptop (1) • brightness of the screen goes bright-dark every 90° (1) • When screen goes dark plane of emitted / polarised light is perpendicular to the plane of polarisation of the filter **OR** When screen is brightest plane of emitted / polarised light is parallel to the plane of polarisation of the filter (1)		3