PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 5: WAVES AND PARTICLE NATURE OF LIGHT

WAVE PROPERTIES AND STATIONARY WAVES

SCORE	PERCENTAGE
/680	%

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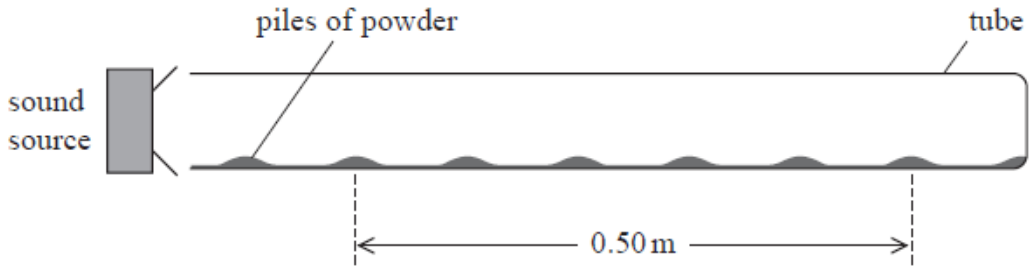
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Q1.

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.

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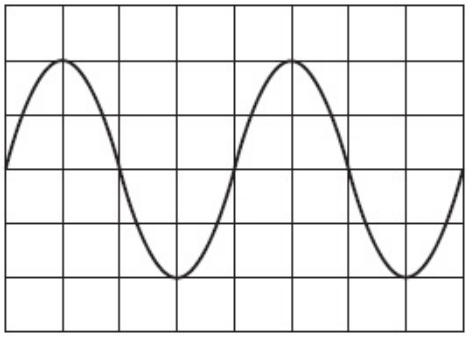
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Speed = ...

(Total for question = 3 marks)

Q2.

A particular sound is investigated by connecting a microphone to an oscilloscope. The diagram shows the trace of a sound wave on the oscilloscope. The screen of the oscilloscope has a grid on it. On the x-axis 1 division represents 5 ms.



The frequency of the sound wave is

☒ **A** 0.05 Hz

☒ **B** 0.1 Hz

☒ **C** 50 Hz

☒ **D** 100 Hz

(Total for question = 1 marks)

Q3.

The length of the string is 4 m.
What is the wavelength of the stationary wave?

☒ **A** 1 m

☒ **B** 2 m

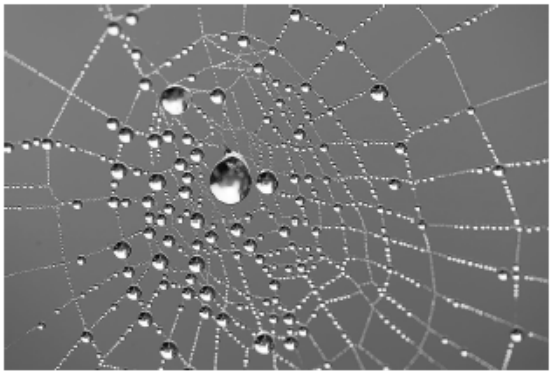
☒ **C** 4 m

☒ **D** 8 m

(Total for question = 1 mark)

Q4.

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.

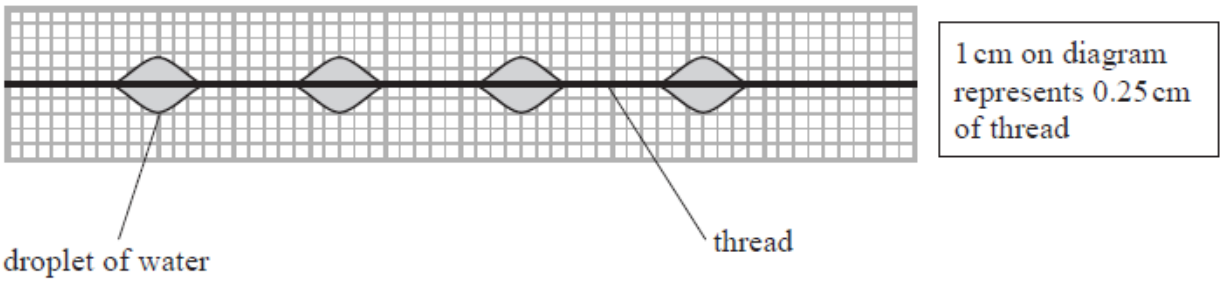


Spiders are almost completely dependent on vibrations transmitted through their web for receiving information about the location of trapped insects. When the threads are disturbed by the insects, progressive waves are transmitted along sections of the silk.

It has been suggested that the droplets of water collect at certain points on the web because

stationary waves are formed.

The diagram shows water droplets on a single thread of spider silk when the frequency of waves is 7.9 Hz.



Further measurements are taken to test whether the observations are consistent with the presence of stationary waves in the threads.

diameter of the thread = 3.6×10^{-6} m

mass per unit length of the thread = 1.32×10^{-8} kg m^{-1}

Young modulus of spider silk = 1.2×10^{9} N m^{-2}

strain in the thread = 9.7×10^{-9}

Determine, by considering wave speed, whether the measurements are consistent with this suggestion.

(7)

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Q5.

When electromagnetic radiation is incident on a metal plate, electrons may be emitted.

(a) State what is meant by threshold frequency.

(1)

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(b) Calculate the threshold frequency for a metal with a work function of 2.28 eV.

(3)

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Threshold frequency = ...

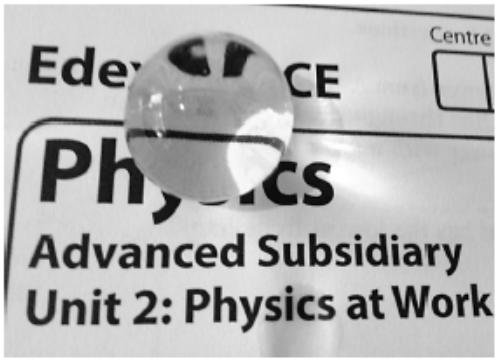
(Total for question = 4 marks)

Q6.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photograph below shows some writing seen through one of these gel balls. The writing is distorted because the gel ball refracts light.



(a) Explain what is meant by refraction.

(2)

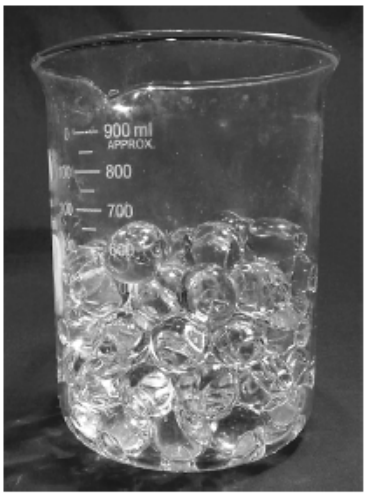
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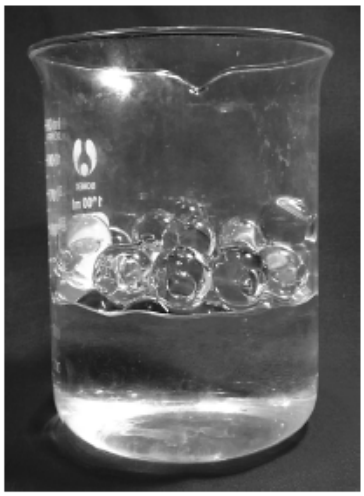
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(b) The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.





Explain how this shows that the gel has the same refractive index as water.

(2)

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Q7.

The distance travelled by a wave during one oscillation may be described as

☒ **A** frequency.

☒ **B** period.

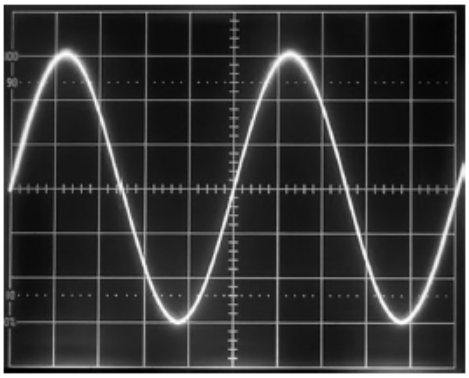
☒ **C** wavelength.

☒ **D** wave speed.

(Total for question = 1 mark)

Q8.

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.

(2)

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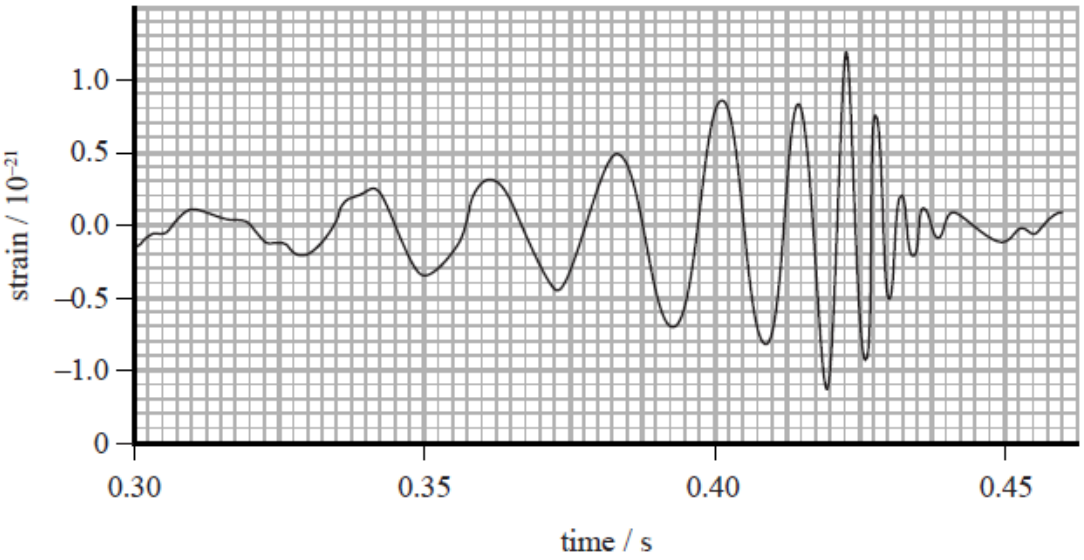
Frequency = ...

(Total for question = 2 marks)

Q9.

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)

Q10. Which term may be defined as the number of waves passing a point in one second?

☒ **A** wave speed

☒ **B** wavelength

☒ **C** period

☒ **D** frequency

(Total for Question = 1 mark)

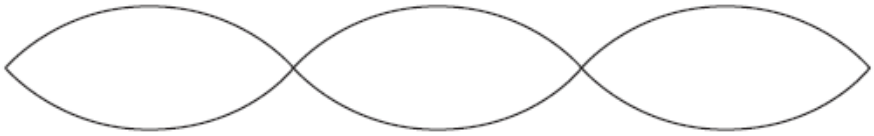
Q11.

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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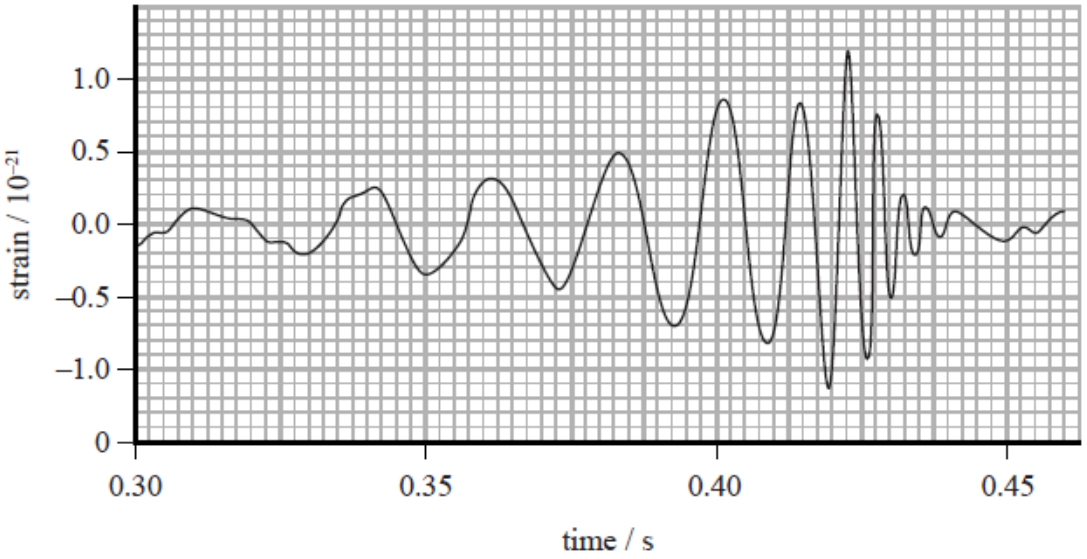
Frequency = ...

(Total for question = 4 marks)

Q12.

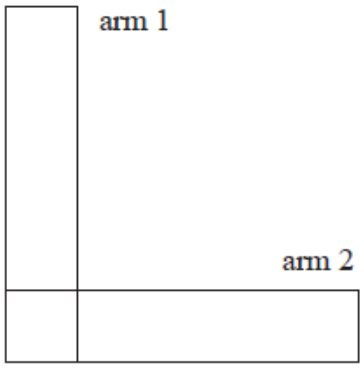
In 2016 scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that gravitational waves had been detected.

The signal they detected is shown on the graph.



Gravitational waves alternately compress and stretch matter by very small amounts as they pass through.

The LIGO detector has two arms, at 90° to each other, each 4 km long. As a gravitational wave passes the detector, the arms change length. The detector continuously compares the lengths of the two arms.



(i) An article states that 'the maximum change in the 4 km length of the arm is about 0.001 times the diameter of a proton'.

Determine whether this statement applies to the gravitational wave shown in the graph.

diameter of proton = 8.8×10^{-16} m

(3)

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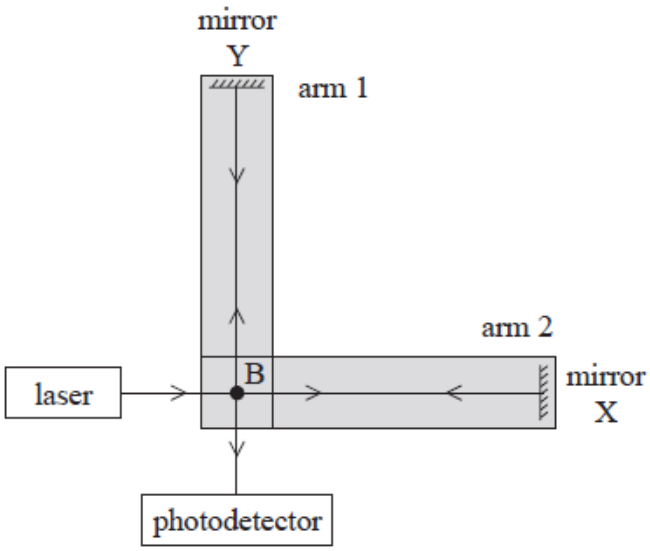
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(ii) In the LIGO detector, any change in the lengths of the arms is detected using a laser beam and photodetector.



The laser beam is split into two at B, one beam travelling to one mirror and the other beam travelling to the other mirror. After reflection at the mirrors, the beams are recombined at B and reach the photodetector. The photodetector measures the intensity of the incident light.

The system is arranged so that when no gravitational waves are present, the beams have a path difference of half a wavelength at the photodetector.

Explain how the photodetector detects very small changes in the length of one arm, when the other arm stays the same length.

(4)

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(iii) The system could be arranged so that when no gravitational waves are present, the beams have zero path difference at the photodetector.

Explain whether using an initial path difference of half a wavelength is a more sensitive way of detecting changes in length than having an initial path difference of zero.

(2)

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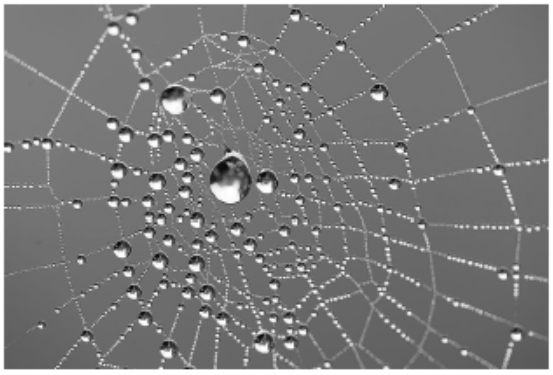
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(Total for question = 9 marks)

Q13.

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.

(6)

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Q14.

The photograph shows an ultrasonic mouse repeller used in a house.



The mouse repeller produces ultrasound that repels mice but cannot be heard by humans.
The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

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

A student makes the following suggestion.

"If the ultrasound reflects off a wall directly opposite the mouse repeller a standing wave is formed, so there will be areas in the room where the mice will not hear the ultrasound."

Evaluate this suggestion.

(6)

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(Total for question = 6 marks)

Q15.

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)

Q16.

An ultrasonic distance estimator can be used to measure the length of a room.



The estimator is held against one wall. It emits pulses of ultrasound and detects them when they return after reflection by the opposite wall.

(a) Explain why the ultrasound must be emitted in pulses.

(1)

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(b) The shortest distance the estimator can measure is 40 cm.
Calculate the longest pulse duration that would allow this distance to be measured.

speed of ultrasound in air = 330 m s^{-1}

(3)

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Pulse duration = ...

(c) When the estimator is pointed at a sloping wall, as shown in the photograph, it is unable to measure this distance.



Suggest why the estimator is unable to measure the distance to the sloping wall.

(1)

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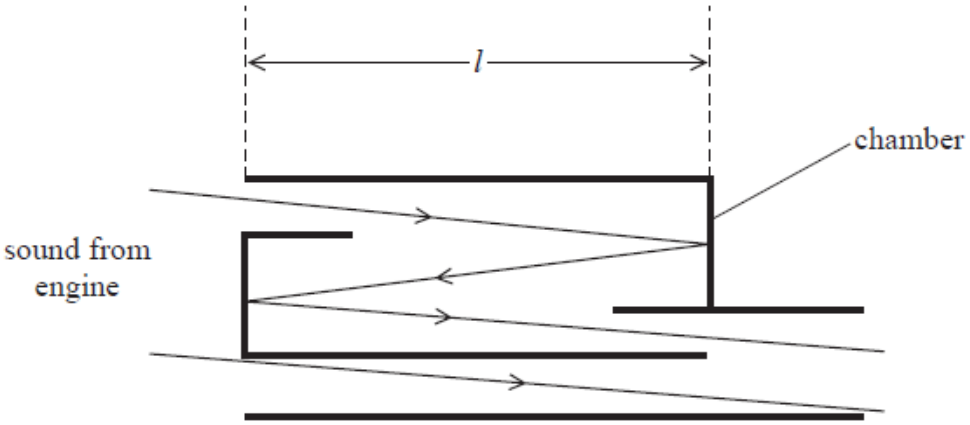
(Total for question = 5 marks)

Q17.

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}

(4)

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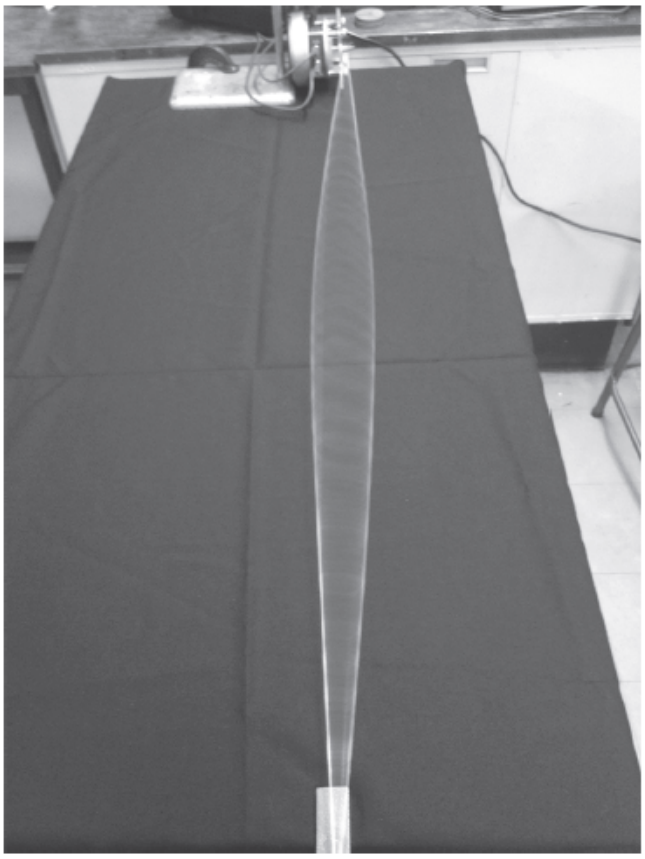
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(Total for question = 4 marks)

Q18.

A student investigates the effect of changing the frequency of waves on a string held in tension.

The string is fixed at one end and has a vibration generator attached to the other end. When the vibration generator is switched on a wave is produced on the string as shown in the photograph.



(a) Name the type of wave produced on the string and explain how it has been formed.

(4)

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(b) The length of string between the vibration generator and the fixed end is 1.8 m. The string is vibrating with a frequency of 330 Hz.

Calculate the speed of the waves on the string.

(3)

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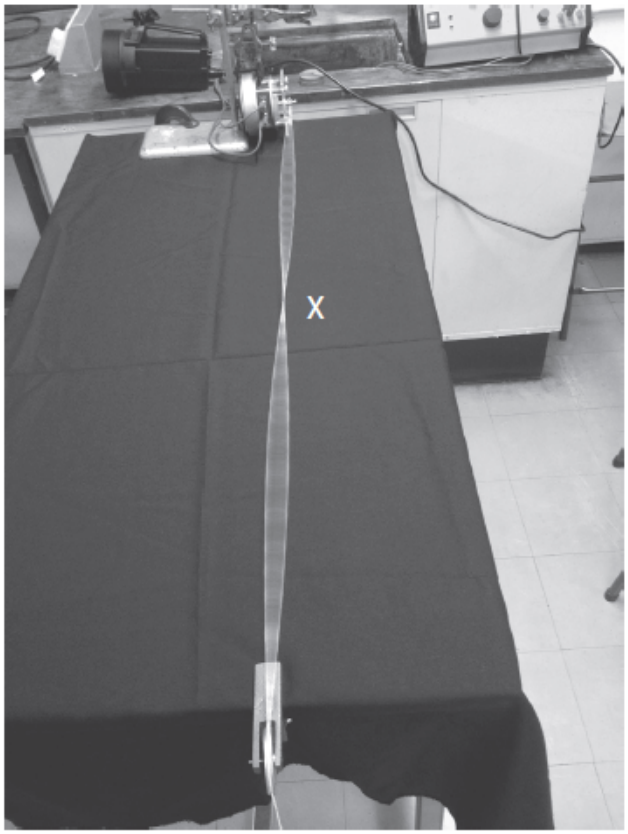
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Speed of the waves = ...

(c) The frequency of the vibration generator is changed from 330 Hz. The new wave produced on the string is shown in the photograph below.



(i) The student is able to touch the string at point X without disturbing the pattern.

Explain why.

(2)

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(ii) Calculate the new frequency of the vibration generator.

(1)

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Frequency = ...

(iii) The vibrating string is now illuminated using a strobe lamp without adjusting the frequency of the vibration generator. The lamp flashes on and off many times a second at a frequency which may be varied by the student. The picture below shows a section of the string that now

appears to be two separate strands.



Calculate the maximum possible frequency of the strobe lamp which will cause the appearance of two separate strands and explain why this is a maximum frequency.

(2)

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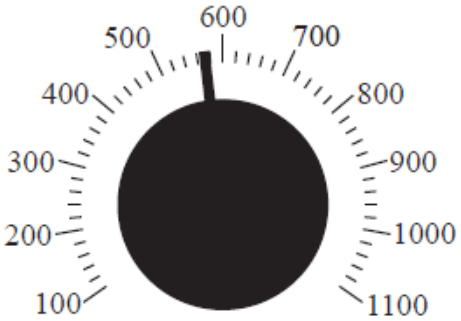
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(d) The frequency of the vibration generator is adjusted by turning the dial shown below. The student measures the frequency of vibration by reading from the scale shown on the dial.



Explain a disadvantage of this method of measuring the frequency.

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(Total for question = 14 marks)

Q19.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

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.

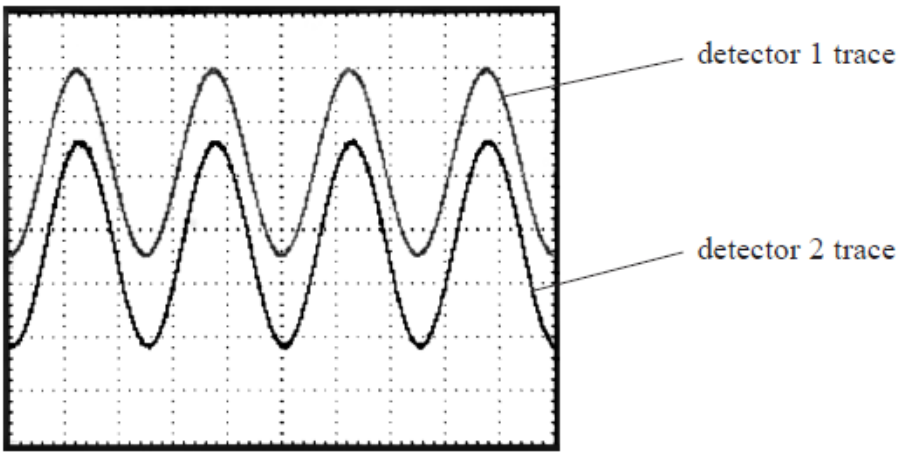
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Q20.

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

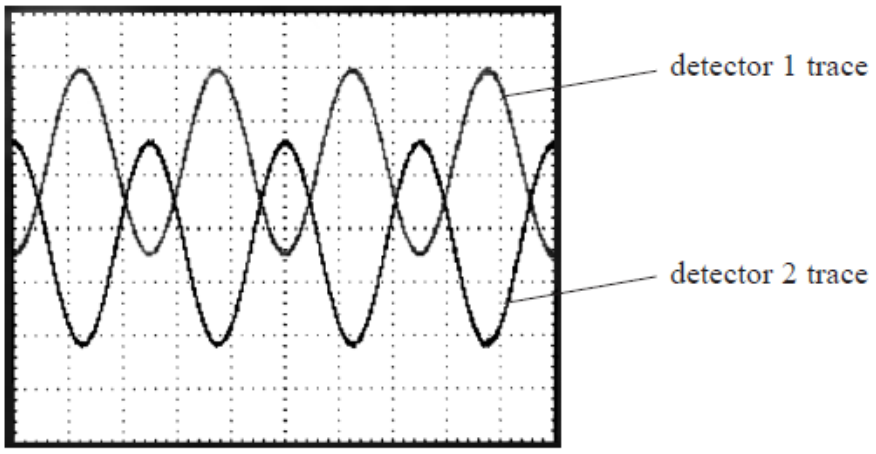


The detectors are connected to an oscilloscope and photograph 1 shows the traces that are recorded.



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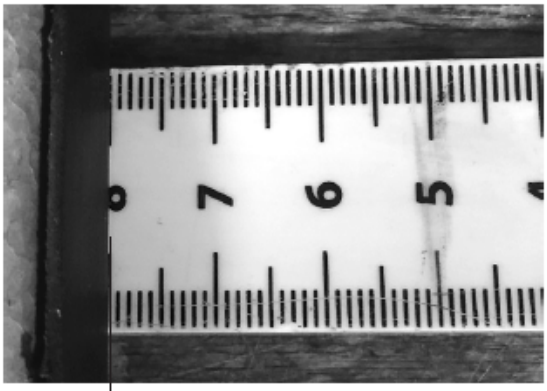
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(b) Detector 2 is moved back to its original position, alongside detector 1. Detector 2 is then steadily moved away from the source. This produces the traces seen in photograph 2 then

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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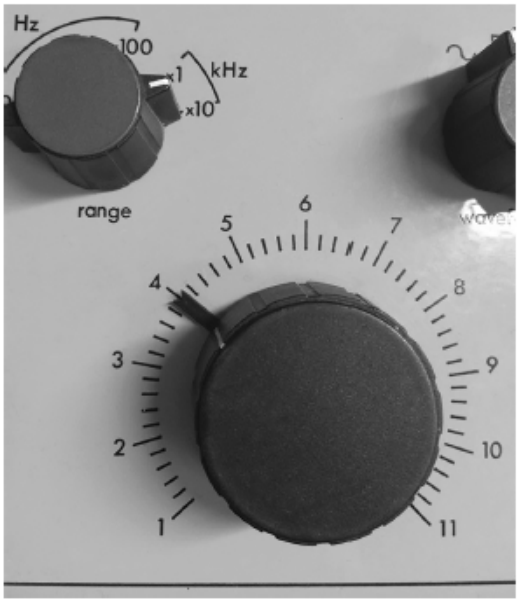
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Speed of sound in air = ...

(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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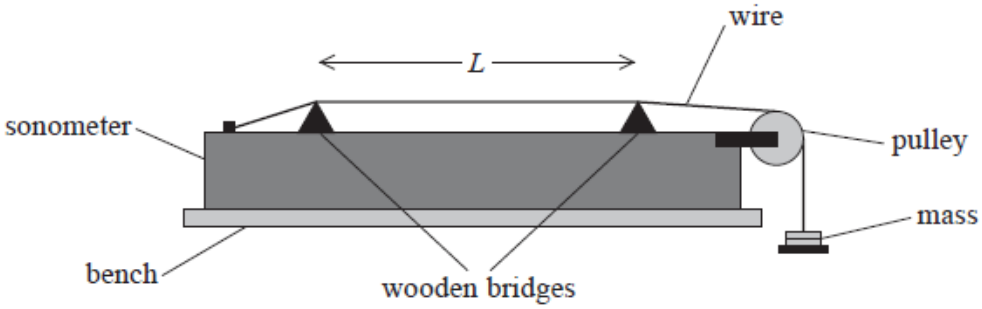
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(Total for question = 9 marks)

Q1.

A student used a sonometer to investigate the properties of a stretched wire. The sonometer is a long hollow wooden box.

A steel wire is attached to one end of the box and rests on two wooden bridges. The wire is placed under tension T by hanging a mass from the end of the wire, as shown.



The student placed the base of a vibrating tuning fork in contact with the wire, at one of the bridges. This set the wire into oscillation. He adjusted the position of the other bridge until a single-loop standing wave was produced on the wire between the bridges.

The student repeated this for a series of tuning forks with different frequencies f. For each fork he measured the distance L between the bridges.

The steel wire, of mass per unit length μ, was placed under tension T by hanging a mass of 2.10 kg from the end of the wire.

(i) State one safety precaution that should be taken when carrying out the investigation.

(1)

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(ii) The student plotted a graph of L^2 against $1/f^2$.

Show that the gradient of this graph is equal to $\frac{T}{4\mu}$

(3)

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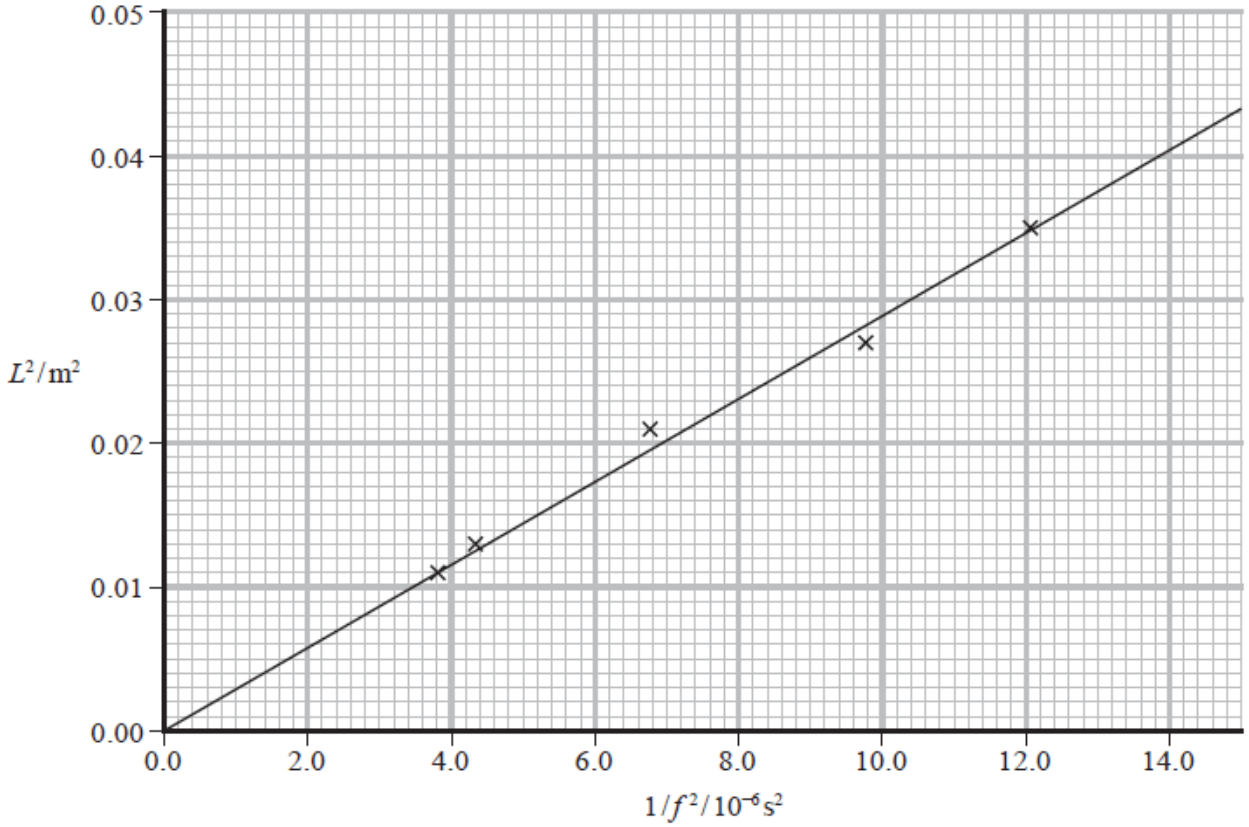
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(iii) The student's graph is shown below.



The value of μ for different standard wire gauge (SWG) steel wire is shown in the table.

SWG	μ / g m^{-1}
22	3.15
24	1.95
26	1.31

Deduce which wire the student used in the investigation.

(4)

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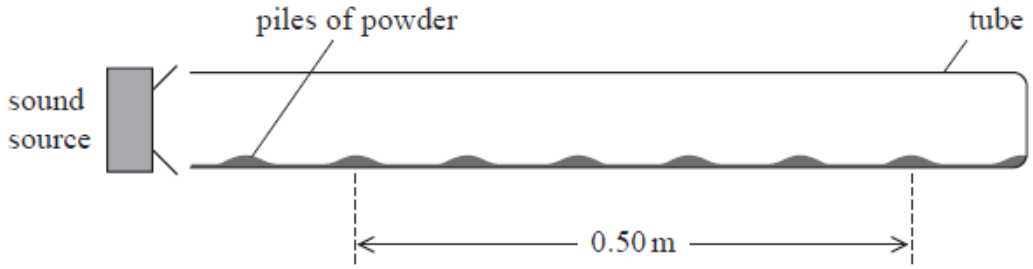
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(Total for question = 8 marks)

Q2.

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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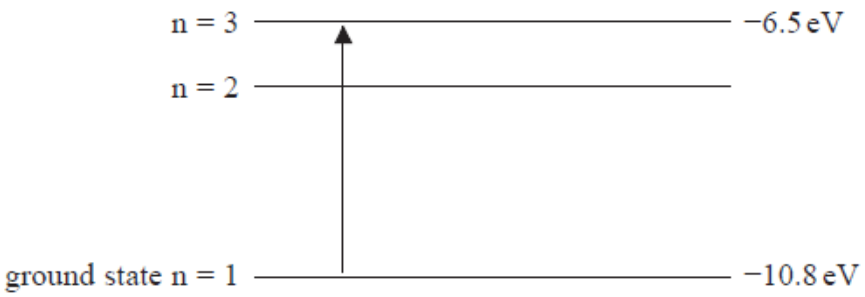
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Speed = ...

(Total for question = 3 marks)

Q3.

An electron in its ground state absorbs electromagnetic radiation of wavelength λ.
The energy level diagram represents the resulting energy transition of the electron.



Calculate the wavelength of radiation absorbed by the electron.

(3)

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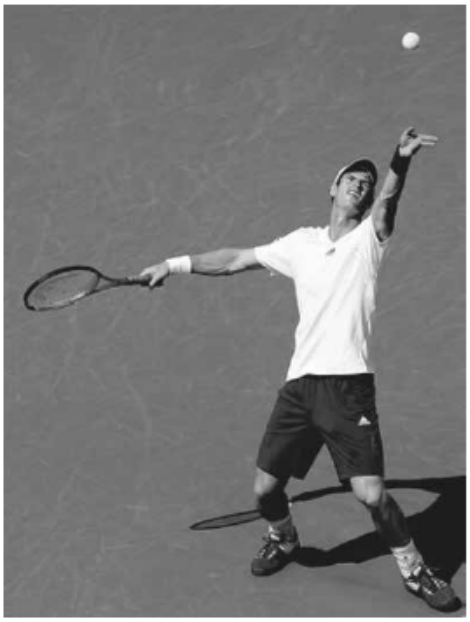
Wavelength = ...

(Total for question = 3 marks)

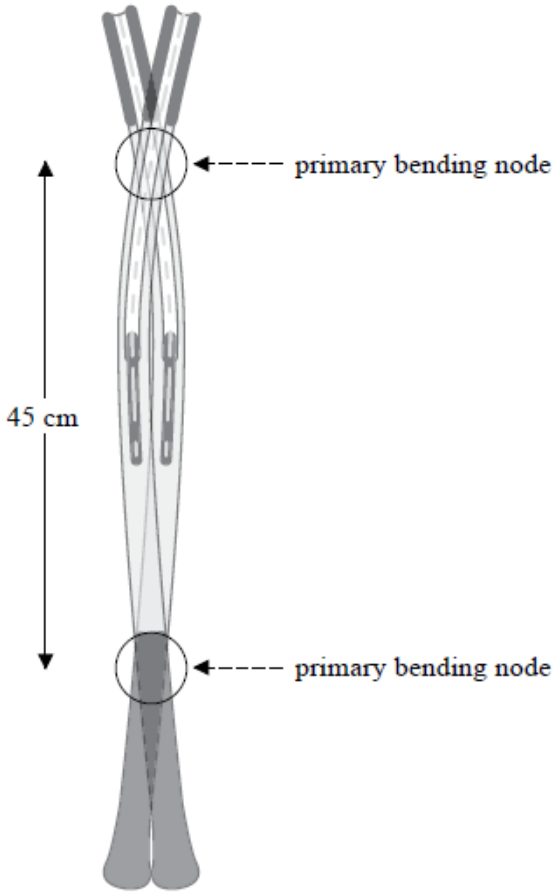
Q4.

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}.



© Getty images



Calculate the frequency of oscillation of the frame.

(3)

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Frequency = ...

(Total for question = 3 marks)

Q5.

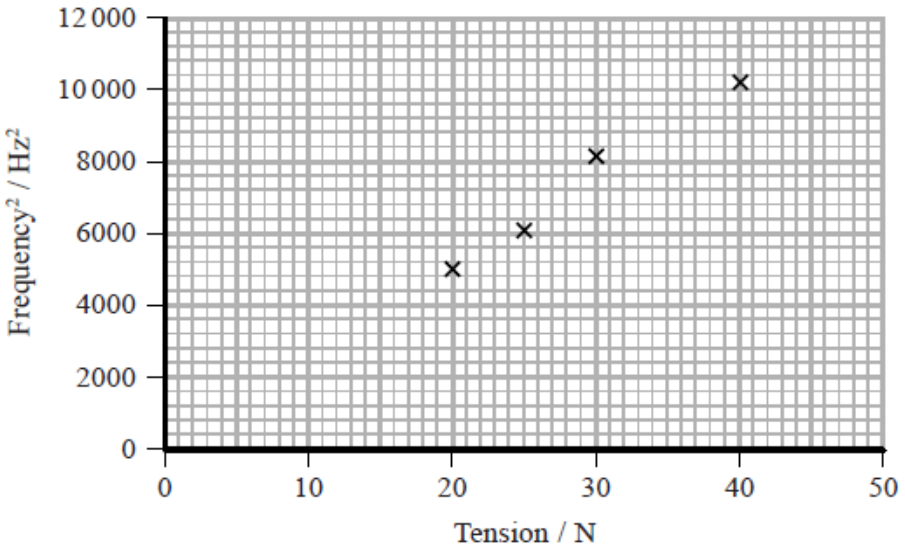
A student carries out an experiment using a guitar string. She investigates the effect of varying the tension in the guitar string on the frequency of sound produced when the string is plucked.

(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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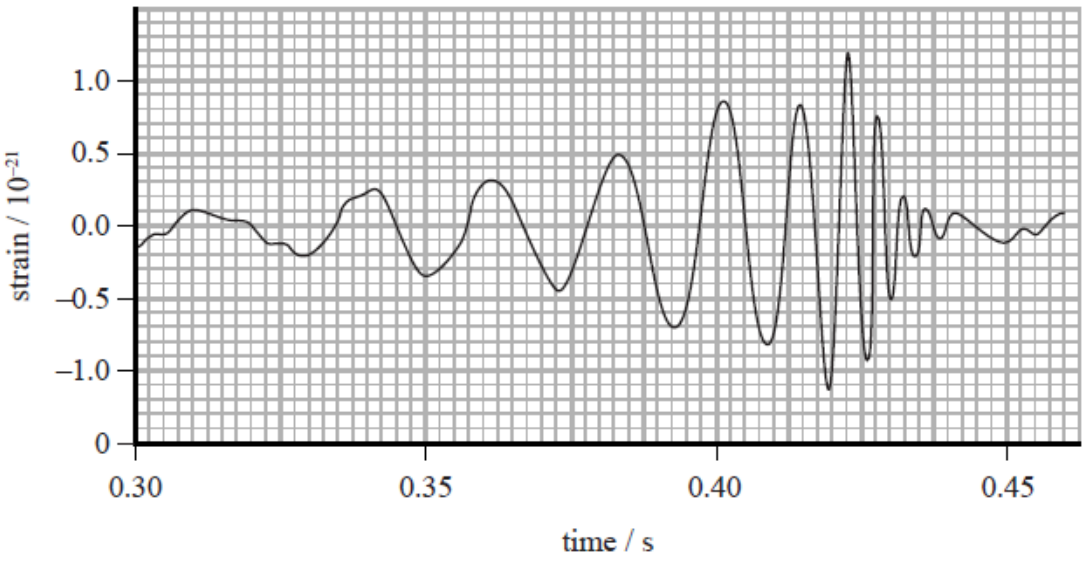
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(Total for question = 8 marks)

Q6.

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)

Q7.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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)

Q8. The diagrams show the motions of a source of sound, S, and an observer, O.

Which line of the table correctly shows the effect this relative motion has on the frequency of the sound heard by the observer.

	Motions of S and O	Frequency
☒ A	S ← ● O stationary	increased
☒ B	S → ● ← O	decreased
☒ C	S ← ● O →	decreased
☒ D	S stationary ● O →	increased

(Total for Question = 1 mark)

Q9.

Light passes between medium X and medium Y.

Speed of light in X = 2.00×10^8 m s^{-1}

Speed of light in Y = 2.25×10^8 m s^{-1}

Which line of the table correctly shows what happens to the frequency and wavelength of the light as it passes from medium X to medium Y?

	Frequency	Wavelength
☒ A	decreases	increases
☒ B	increases	decreases
☒ C	unchanged	increases
☒ D	unchanged	decreases

(Total for question = 1 mark)

Q10.

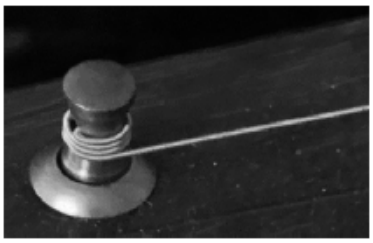
The photograph shows a guitar.



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 = $1.8 \times 10^{9}\,\text{N}\,\text{m}^{-2}$

cross-sectional area of string = $6.6 \times 10^{-7}\,\text{m}^{2}$

(4)

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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.

(2)

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(Total for question = 6 marks)

Q11.

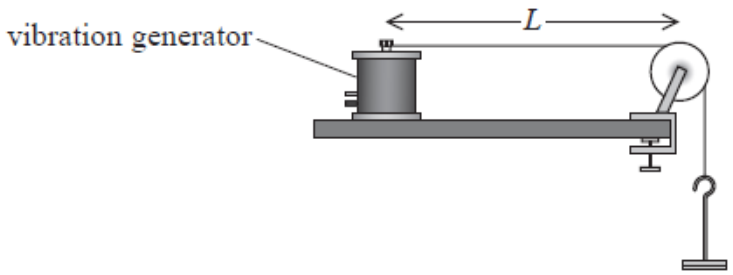
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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)

Q12. Which type of electromagnetic radiation is used for communicating with satellites?

☒ **A** infrared

☒ **B** microwave

☒ **C** ultraviolet

☒ **D** visible light

(Total for Question = 1 mark)

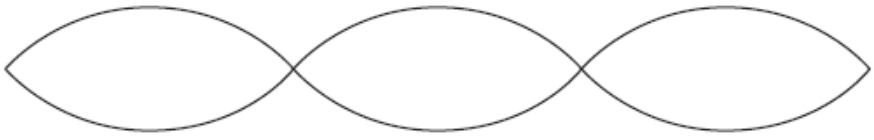
Q13.

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)

Q14. Dolphins use ultrasound when hunting prey. They emit short pulses of ultrasound, known as clicks, and detect the ultrasound reflected from their prey.

(a) Describe how ultrasound travels through water.

(2)

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(b) Suggest why the dolphins emit a series of clicks rather than a continuous sound.

(1)

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(c) When searching for prey the dolphins emit 16 clicks per second.

(i) Show that the time between clicks when searching for prey is about 0.06 s.

(1)

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(ii) Calculate the maximum distance that can be determined by the dolphin when searching for prey.

speed of sound in seawater = 1530 m s^{-1}

(3)

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Maximum distance = ...

(iii) The dolphin increases the number of clicks per second to 125 when near to capturing its prey.

Suggest why.

(1)

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(d) Bats use ultrasound in air when hunting prey. The ultrasound frequency and the duration of the click is the same for both bats and dolphins.

Explain whether bats or dolphins would be able to locate their prey more precisely.

speed of sound in air = 330 m s^{-1}

(3)

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(Total for Question = 11 marks)

Q15.

A wave of wavelength λ and frequency f is travelling in a medium with wave speed v_1.
The wave passes into another medium with wave speed v_2.

The wavelength of the wave in the second medium is

☒ **A** $\frac{v_1}{f}$

☒ **B** $\frac{v_2}{f}$

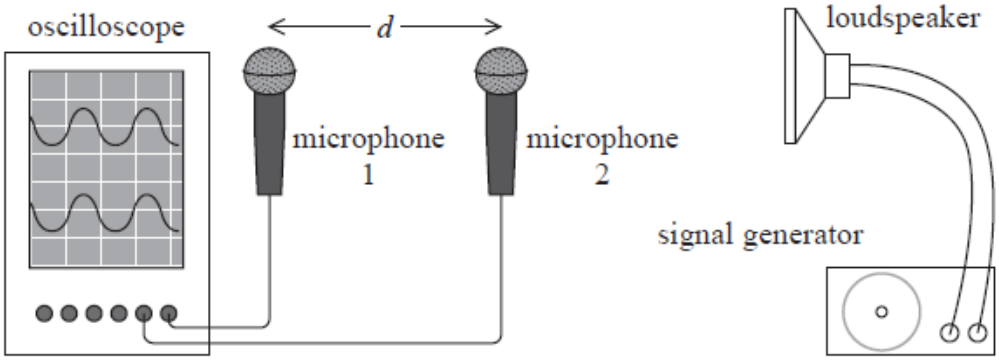
☒ **C** $\frac{v_1}{v_2 f}$

☒ **D** $\frac{v_2 f}{v_1}$

(Total for question = 1 mark)

Q16.

In an experiment to determine the speed of sound in air a student connected two microphones to an oscilloscope, as shown.

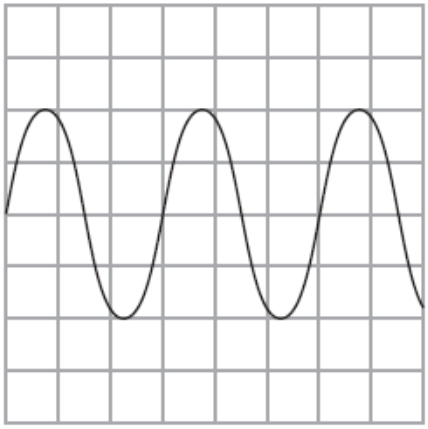


The microphones detect sound from the loudspeaker, converting it to an electrical signal. The signal is displayed on the oscilloscope screen.

Both microphones were initially positioned the same distance from the loudspeaker. The two signals were in phase on the oscilloscope screen. The student slowly moved microphone 2 towards the loudspeaker, until the two signals on the oscilloscope were in phase again. He then measured the distance *d* between the microphones to determine the wavelength λ of the sound waves.

d = 20.5cm

The oscilloscope trace for the signal from microphone 1 is shown below.



The time base of the oscilloscope was set to 0.20 ms div^{-1}.

Determine a value for the speed of sound in air.

(5)

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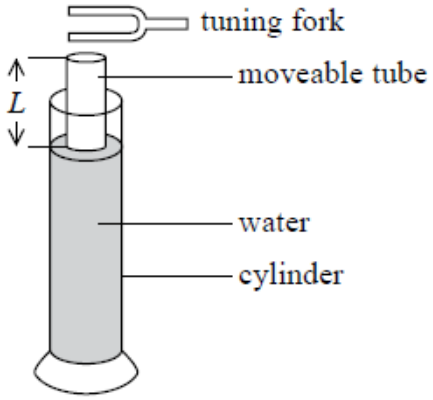
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Speed of sound = ...

(Total for question = 5 marks)

Q17.

A set of tuning forks is used to find a value for the speed of sound in air.
A tuning fork is struck and then held near to the end of an air column formed by a moveable tube. The moveable tube is used to adjust the length, *L*, of the air column until a standing wave is set up in the tube and the loudest sound is heard. The experiment is repeated for a number of different tuning forks.



The following results are obtained by a student.

Fork frequency/Hz	Length, *L*/cm	Speed of sound/m s^{-1}
256	31.9	327
320	25.6	328
512	16.1	330

Student A says "These results show that the speed of sound increases as the frequency of the sound increases".

Student B says "The speed of sound should be the same for each frequency".

By estimating the uncertainties in these results, conclude which of these statements is valid.

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(Total for question = 4 marks)

Q18.

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)

Q19.

A book entitled *Interesting Projects with a Microwave Oven* suggests using chocolate to measure the speed of light. The chocolate is placed on a non-metallic tray in the oven.
The oven is switched on and a pattern is observed in the melting chocolate.



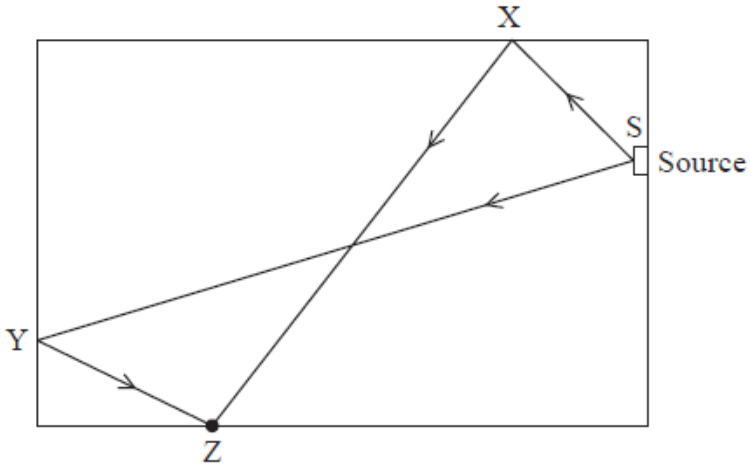
The photograph shows some lighter areas where the chocolate is melting and some darker areas where the chocolate remains hard.

The book states that microwaves are emitted from the source in the oven. The microwaves reflect off the metal walls so that the microwaves reaching any point arrive from different directions. The microwaves produce a standing wave pattern causing hot and cold areas in the oven.

The wavelength was determined to be 12 cm by measuring the distance between adjacent hot and cold areas.

(a) The diagram shows two different paths by which microwaves can reach the point Z.

Not to scale



SX = 9 cm, XZ = 23 cm, SY = 36 cm, YZ = 8 cm

Calculate the phase difference between microwaves from the source at S reaching point Z by the two different paths.

(2)

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Phase difference = ...

(b) Explain how a pattern of hot and cold areas is produced in the chocolate. You should assume that each point of the chocolate is reached by microwaves following two different paths only.

(4)

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(c) Explain why the microwaves reaching a point in the chocolate must be coherent for this effect to occur.

(2)

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(d) The microwave frequency is stated on the oven as 2450 MHz.

Evaluate the success of this experiment at determining the speed of light.

(3)

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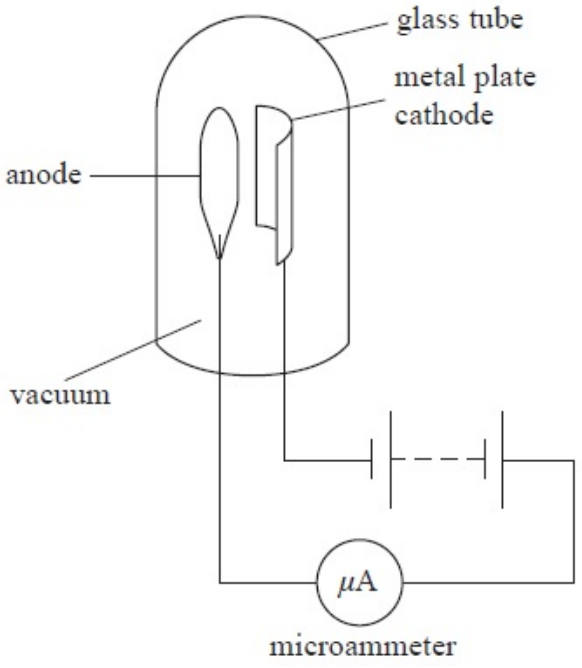
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(Total for question = 11 marks)

Q20. Phototubes are devices which make use of the photoelectric effect to detect light above a specific frequency.



(a) Explain why

- no current flows when the phototube is in darkness
- current flows in the circuit when the phototube is illuminated by light above a specific frequency.

(5)

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(b) Make an appropriate calculation to explain why caesium is used as the cathode for visible light but zinc is not.

work function of zinc = 3.63 eV

work function of caesium = 2.14 eV

(4)

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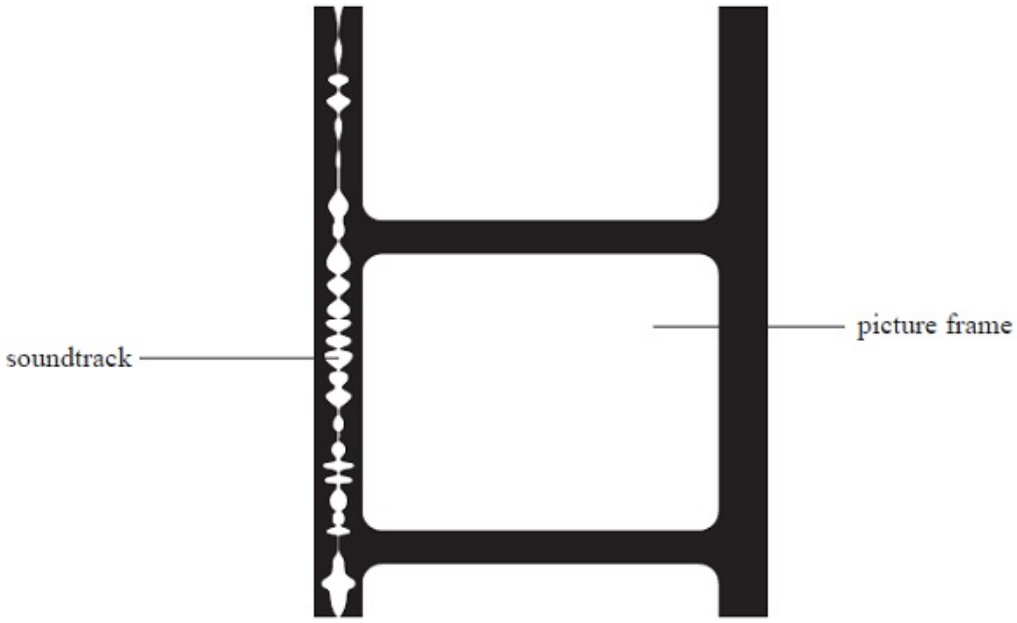
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(c) Before digital technology was used, the films used at the cinema had an optical soundtrack

next to the picture frames.



The film, including the soundtrack as shown, moves through a projector past a source of light. Light is detected by a phototube on the other side of the soundtrack. The changing current produced by the phototube circuit is converted to a sound signal with the same variation in amplitude and frequency as the original sound.

(i) State what is meant by amplitude.

(1)

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(ii) Explain how the changing pattern of the soundtrack produces a changing current in the phototube circuit.

(3)

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(Total for Question = 13 marks)

Q21.

(a) Solar sails are a form of propulsion for spacecraft. The sail is made of a thin sheet of reflective material. When photons of light from the Sun reflect from the material a force is exerted on the sail. The photons reflect with a momentum equal to their initial momentum but in the opposite direction.

(i) Show that a single photon of frequency 1.5×10^{15} Hz has a momentum of about 3×10^{-27} N s.

(2)

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(ii) Hence determine the momentum transferred to the solar sail by this photon.

(1)

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Momentum transferred = ...

(b) An alternative method of producing a momentum change is being investigated. Researchers have suggested that 'larger changes in momentum could be produced by directing laser light at graphene oxide'. Electrons are emitted from the graphene oxide surface, resulting in a force being exerted on the graphene oxide in the opposite direction.

A researcher has suggested that one possible mechanism for the emission of the electrons is the photoelectric effect.

(i) Show that the maximum velocity for a photoelectron emitted after absorption of a photon of light of frequency 1.5×10^{15} Hz is about 8×10^{5} m s^{-1}.

work function of graphene oxide = 6.7×10^{-19} J

(3)

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(ii) Hence calculate the momentum of the photoelectron.

(2)

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Momentum of photoelectron = ...

(c) Explain whether the suggestion in (b) that 'larger changes in momentum could be produced by directing laser light at graphene oxide' is true.

(2)

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(Total for question = 10 marks)

Q22. When the photoelectric effect was first observed in the nineteenth century, scientists could not explain it using the wave theory of light.

In 1905 Albert Einstein published a paper, for which he won a Nobel Prize, explaining the photoelectric effect by using a photon model of light, rather than a wave model.

(a) Explain what is meant by a photon.

(2)

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*(b) Explain why the following observations may be understood by using a photon model of light, rather than a wave model.

- Light above a certain frequency causes the emission of electrons from the surface of a metal. This emission occurs instantaneously.
- Light below a certain frequency will not result in the emission of electrons however long it illuminates the surface.

(5)

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(c) Zinc has a work function of 4.3 eV.

(i) Calculate the threshold frequency for zinc.

(3)

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Threshold frequency = ...

(ii) State the part of the electromagnetic spectrum to which radiation of this frequency belongs.

(1)

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(Total for Question = 11 marks)

Q23.

In 1925 Franck and Hertz were awarded the Nobel Prize in Physics "for their discovery of the laws governing the impact of an electron upon an atom".
In one of their experiments, a beam of high-speed electrons is fired through mercury vapour.

An electron in the beam collides with a mercury atom, which becomes excited. The atom returns to its initial state by emitting electromagnetic radiation of a single frequency.

An electron travelling with a speed of 2.5×10^6 m s^{-1} collides with a stationary mercury atom and continues at a speed of 2.1×10^6 m s^{-1}.

The table gives a range of wavelengths for ultraviolet, visible and infrared radiation.

Type of radiation	Typical range of wavelengths / m
ultraviolet	2.0×10^{-7} to 4.0×10^{-7}
visible	4.0×10^{-7} to 7.8×10^{-7}
infrared	7.8×10^{-7} to 1.0×10^{-3}

Deduce the type of radiation that is emitted by the stationary mercury atom.

(4)

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Type of radiation .....

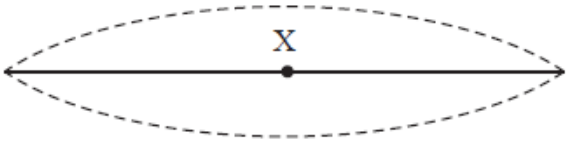
(Total for question = 4 marks)

Q24.

Guitar strings can oscillate with simple harmonic motion.



Shortly after the string is plucked, a standing wave exists on the string. The simplified diagram below shows a string in three positions of the standing wave.



(a) State what is meant by simple harmonic motion.

(2)

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(b) (i) Describe the acceleration of point X on the string as it moves between the extreme positions of its motion.

(2)

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(ii) Comment on the energy changes in the string as it moves between the extreme positions of its motion.

(3)

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(c) The oscillating string has a length of 0.53 m. Calculate the frequency of the sound emitted when the string oscillates as shown previously.

speed of the wave on the string = 270 m s^{-1}

(3)

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Frequency = ...

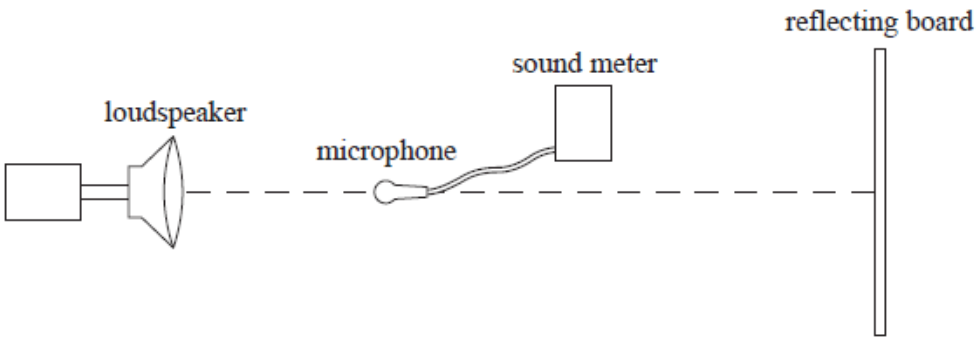
(Total for question = 10 marks)

Q25.

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.

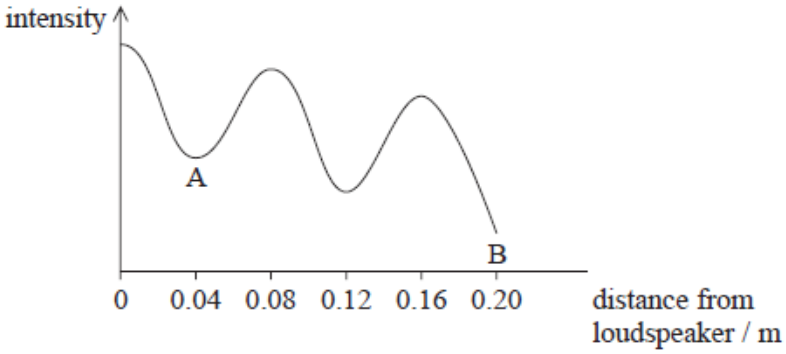
A method to determine a value for the speed of sound is shown in the diagram.



A loudspeaker is placed at a distance from a vertical reflecting board. Sound waves reflect off the board and set up a standing wave between the loudspeaker and the board. A microphone

connected to a sound meter is moved in a straight line from the loudspeaker to the board. As the microphone is moved, the sound meter records the varying intensity of the standing wave.

The sketch graph shows how the intensity varies with distance from the loudspeaker.



(i) Explain why the intensity at point B is less than the intensity at point A.

(3)

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(ii) Use the graph to determine a value for the speed of sound.

frequency of sound wave = 2.0 kHz

(3)

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Speed of sound = ...

(Total for question = 6 marks)

Q26.

If certain crystals are subjected to a mechanical stress, a potential difference is generated across them. This is called the piezoelectric effect. These crystals can be produced as very thin films.

Below is a photograph of a T-shirt with a built-in phone charger, which is being tested at a music festival. The white rectangle is a piezoelectric film.



(a) By considering how a sound wave travels through the air, explain how sound can cause a piezoelectric film to generate a potential difference.

(4)

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(b) Explain why the crystals used in the T-shirt need to be in the form of a large, thin film.

(3)

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(c) When the T-shirt is used at a music festival the sound levels are sufficient to generate about 20 kJ over ten hours. This is enough to charge one phone.

Calculate the electrical power output.

(3)

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Power output = ...

(d) Give **one** advantage and **one** disadvantage of this charger compared with a conventional charger.

(2)

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(Total for question = 12 marks)

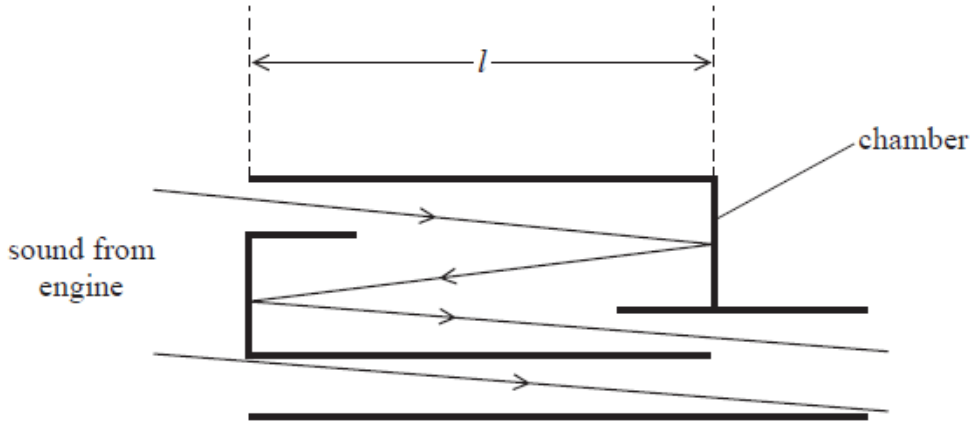
Q27.

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}

(4)

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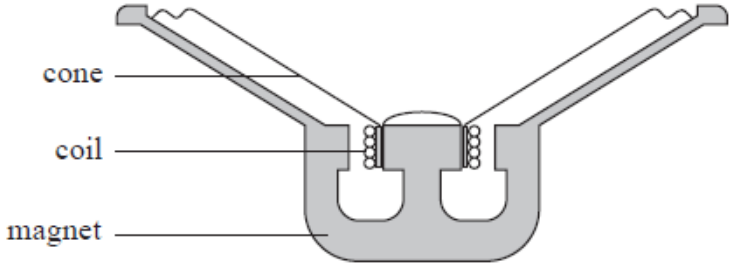
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(Total for question = 4 marks)

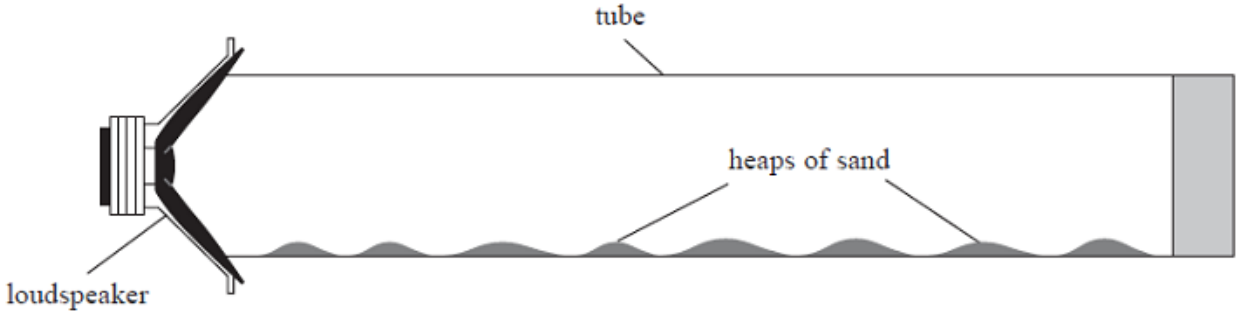
Q28.

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 $340\,\text{m}\,\text{s}^{-1}$.

signal generator frequency = 3.25 kHz.

d = 5.1 cm

(3)

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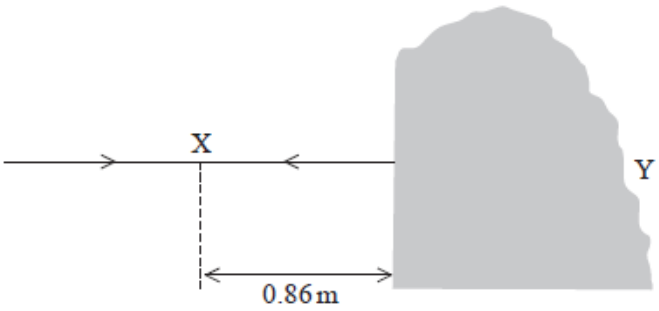
(Total for question = 10 marks)

Q29.

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)

Q30.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

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)

Q1.

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.

(1)

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

(2)

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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.

(2)

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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.

(2)

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(Total for question = 9 marks)

Q2.

When tidying a prep room, a teacher discovers a tray of resistance wires that have lost their labels. She decides to ask her students to carry out experiments to determine the material that each wire is made of by measuring the resistivity of the wires.

(a) Explain why the teacher asks the students to measure the resistivity and not the resistance of the wires.

(2)

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*(b) You are to describe a method to determine accurately the resistivity of one of the metal wires.

Your description should include:

- the circuit diagram you would use
- the quantities you would measure
- the graph you would plot
- how you would determine the resistivity

(9)

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(Total for question = 11 marks)

Q3.

In February 2013 the largest known meteor for a century exploded over the Ural region of Russia.

The explosion was detected by stations monitoring infrasound, a type of sound with a frequency too low for humans to hear.

Describe how infrasound travels through the air.

(3)

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(Total for question = 3 marks)

Q4.

Which of the following does **not** apply to longitudinal waves?

☒ **A** coherence

☒ **B** polarisation

☒ **C** superposition

☒ **D** transmission

(Total for question = 1 mark)

Q5. Ultrasonic testing can be used for detecting corrosion inside metal pipes.

(a) Describe how the ultrasound travels through a metal.

(3)

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(b) A steel pipe was manufactured with a wall thickness of 4.0 cm.

After several years of use this pipe is tested for corrosion. A pulse of ultrasound is sent into the steel from the outer surface and the reflection from the inner surface is detected after a time of 5.1×10^{-6} s.

Determine whether the steel is corroded at this point.

speed of sound in steel = 5900 m s^{-1}

(4)

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(c) In this technique the ultrasound is emitted as pulses.

Explain why pulses are used rather than a continuous wave and how the duration of the pulse affects the thickness of the pipe wall that can be accurately measured.

(3)

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(Total for Question = 10 marks)

Q6.

Which of the following phenomena does **not** occur with sound waves?

☒ **A** diffraction

☒ **B** interference

☒ **C** polarisation

☒ **D** refraction

(Total for question = 1 mark)

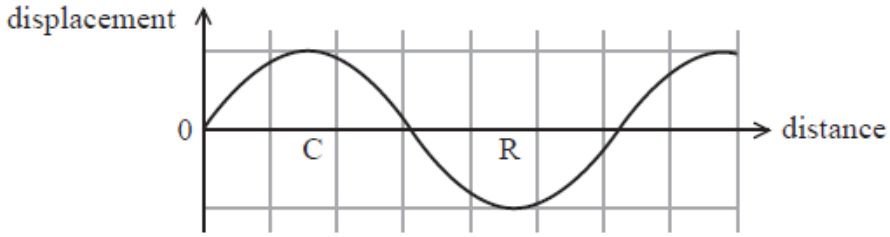
Q7.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

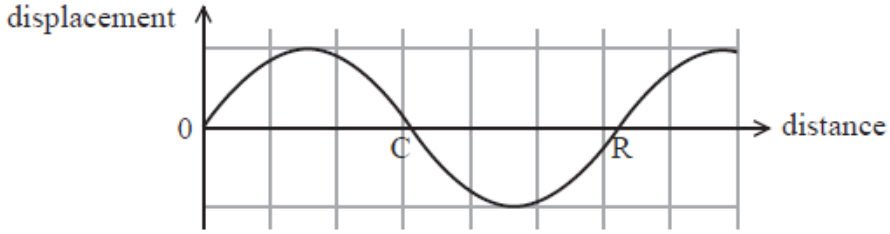
A longitudinal wave is represented on a displacement-distance graph. A positive displacement on the graph indicates a displacement to the right.

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

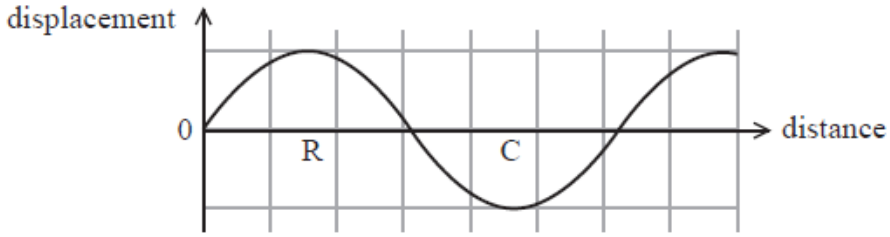
A



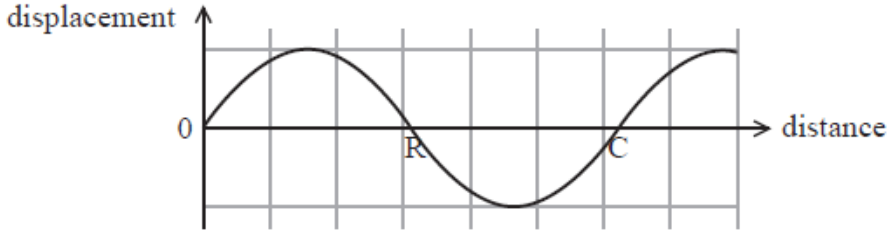
B



C



D



☒ **A**

☒ **B**

☒ **C**

☒ **D**

(Total for question = 1 mark)

Q8.

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)

Q9.

A glass tube, closed at one end, has a loudspeaker placed at the other end. This is used to create a vibrating column of air, producing sound.

The wave in the tube is best described as

☒ **A** longitudinal and progressive.

☒ **B** longitudinal and standing.

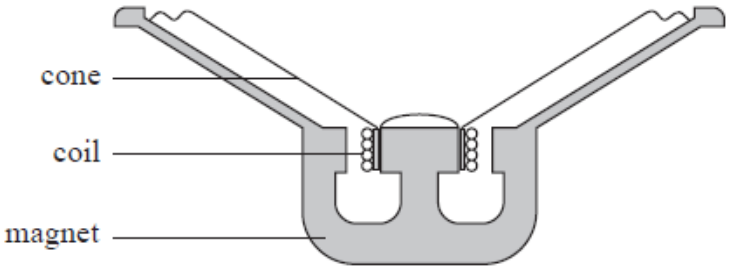
☒ **C** transverse and progressive.

☒ **D** transverse and standing.

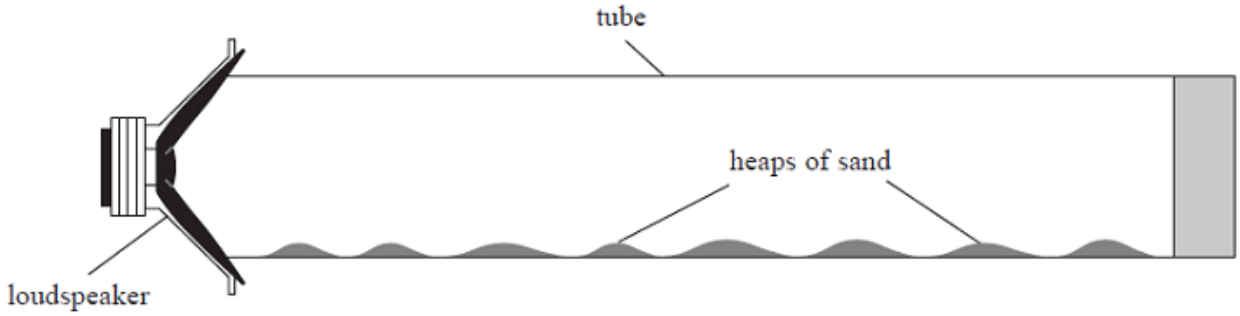
(Total for question = 1 mark)

Q10.

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 $340\,\text{m}\,\text{s}^{-1}$.

signal generator frequency = 3.25 kHz.

d = 5.1 cm

(3)

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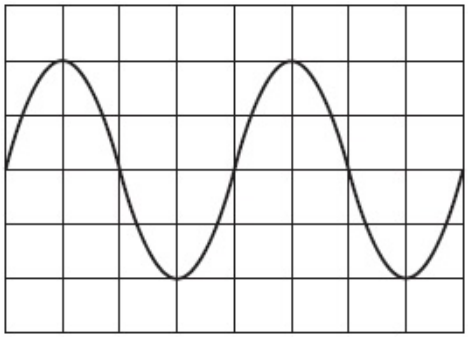
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(Total for question = 10 marks)

Q1.

A particular sound is investigated by connecting a microphone to an oscilloscope. The diagram shows the trace of a sound wave on the oscilloscope. The screen of the oscilloscope has a grid on it. On the x-axis 1 division represents 5 ms.



The frequency of the sound wave is

- ☒ **A** 0.05 Hz
- ☒ **B** 0.1 Hz
- ☒ **C** 50 Hz
- ☒ **D** 100 Hz

(Total for question = 1 marks)

Q2.

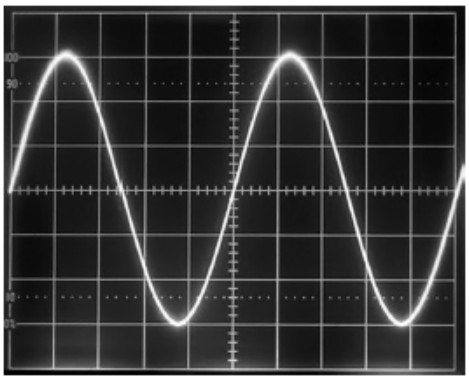
The length of the string is 4 m.
What is the wavelength of the stationary wave?

- ☒ **A** 1 m
- ☒ **B** 2 m
- ☒ **C** 4 m
- ☒ **D** 8 m

(Total for question = 1 mark)

Q3.

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.

(2)

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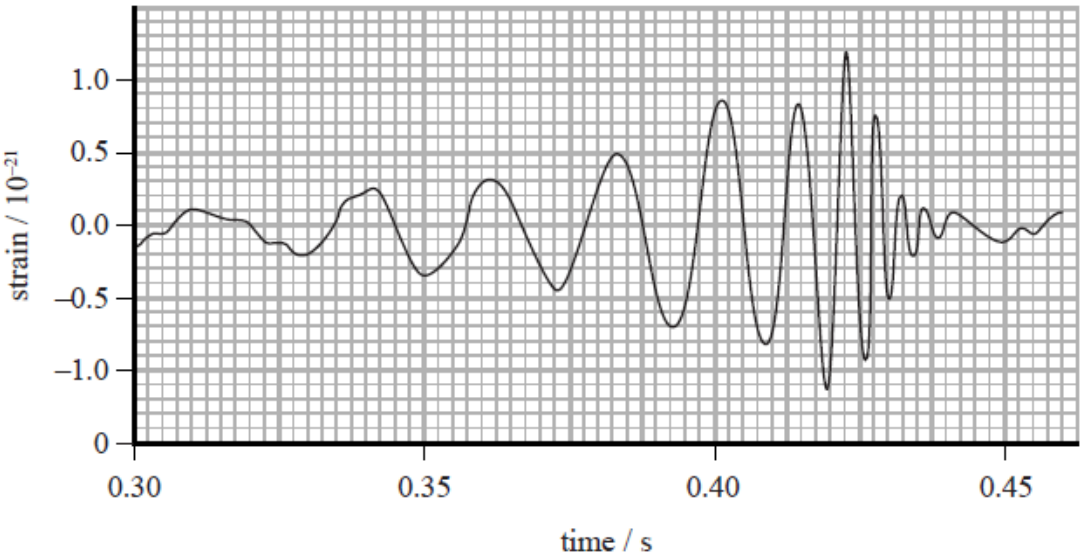
Frequency = ...

(Total for question = 2 marks)

Q4.

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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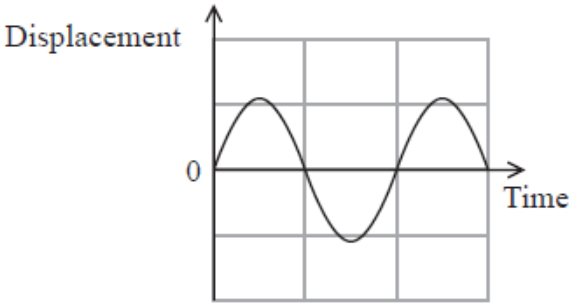
Mean wavelength = ...

(Total for question = 3 marks)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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



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

☒ **A** amplitude

☒ **B** frequency

☒ **C** time period

☒ **D** wavelength

(Total for question = 1 mark)

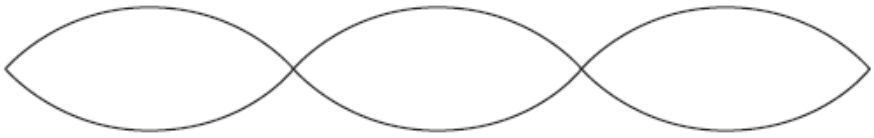
Q6.

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)

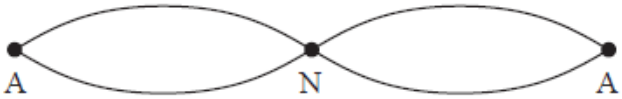
Q7.

The diagram represents a stationary wave on a string.

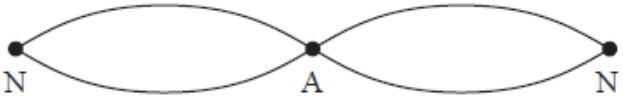


Which diagram correctly shows the position of nodes N and/or antinodes A?

☒ **A**



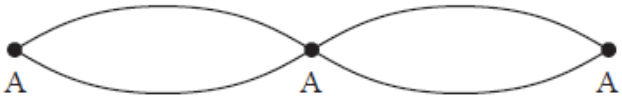
☒ **B**



☒ **C**



☒ **D**

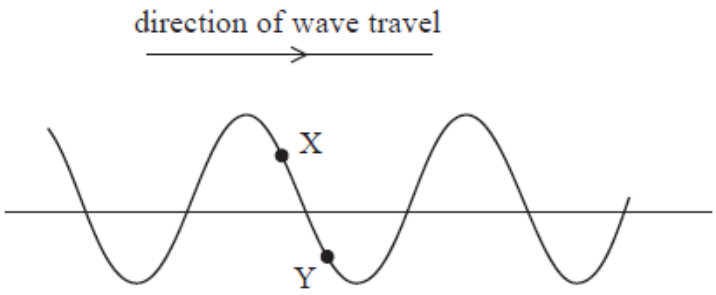


(Total for question = 1 mark)

Q8.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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

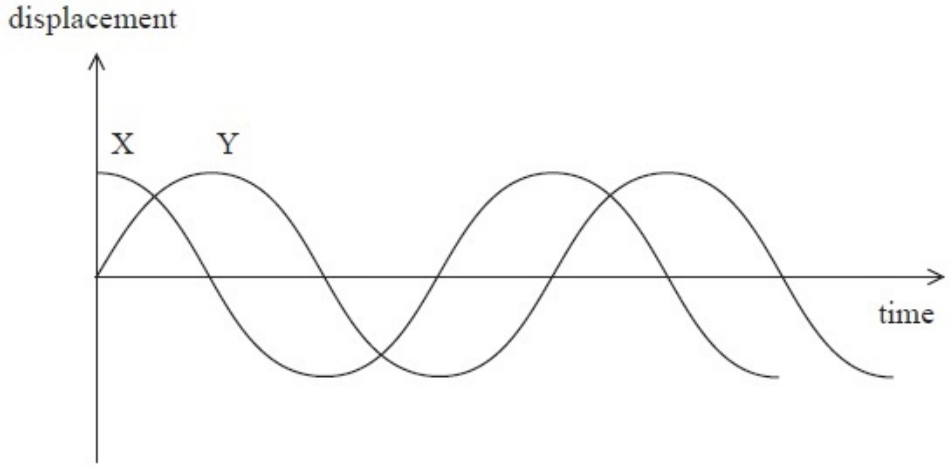


Which of the following describes the directions in which the particles at X and Y are moving at the instant shown?

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

(Total for question = 1 mark)

Q9. The diagram shows displacement-time graphs for two oscillations, X and Y.



Which of the following statements correctly describes their phase relationship?

☒ **A** X and Y are in antiphase

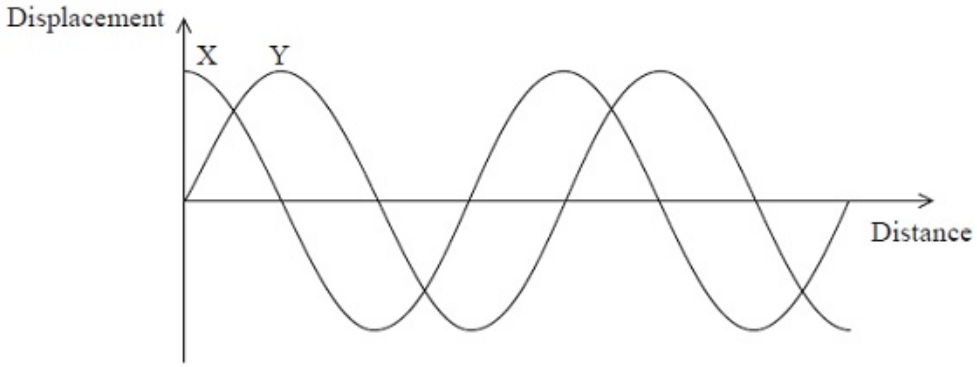
☒ **B** X and Y are in phase

☒ **C** X is π/2 radians ahead of Y

☒ **D** Y is π/2 radians ahead of X

(Total for Question = 1 mark)

Q10. The diagram shows a displacement-distance graph at an instant for two waves, X and Y, travelling to the right.



Which of the following statements correctly describes the phase relationship between the two waves?

☒ **A** X and Y are in antiphase

☒ **B** X and Y are in phase

☒ **C** X is π/2 radians ahead of Y

☒ **D** Y is π/2 radians ahead of X

(Total for Question = 1 mark)

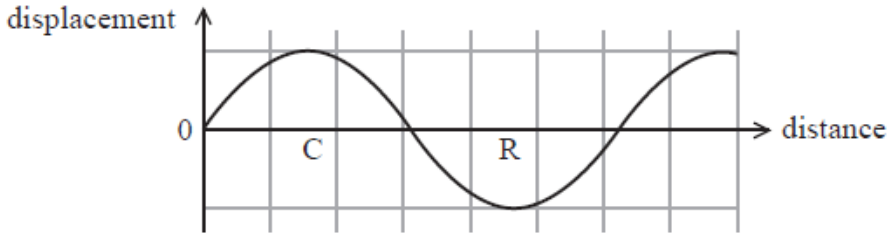
Q11.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

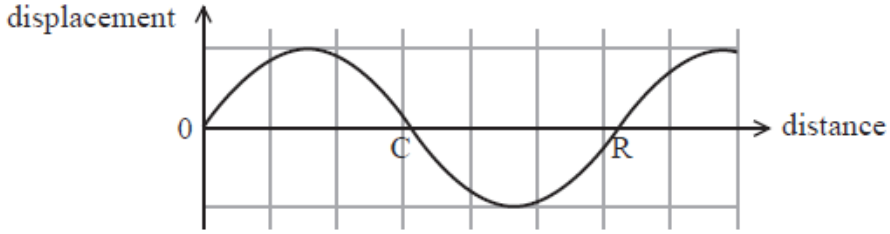
A longitudinal wave is represented on a displacement-distance graph. A positive displacement on the graph indicates a displacement to the right.

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

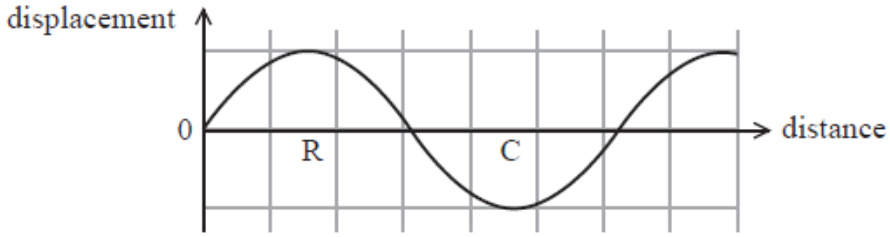
A



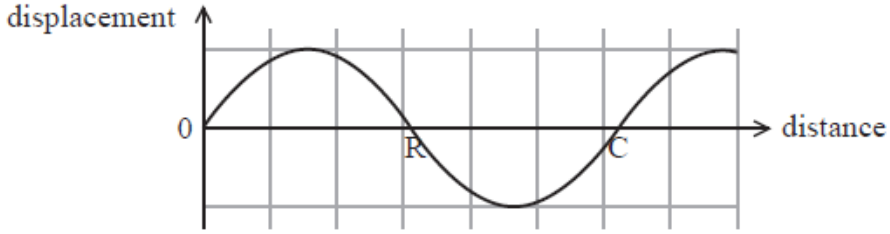
B



C



D



☒ **A**

☒ **B**

☒ **C**

☒ **D**

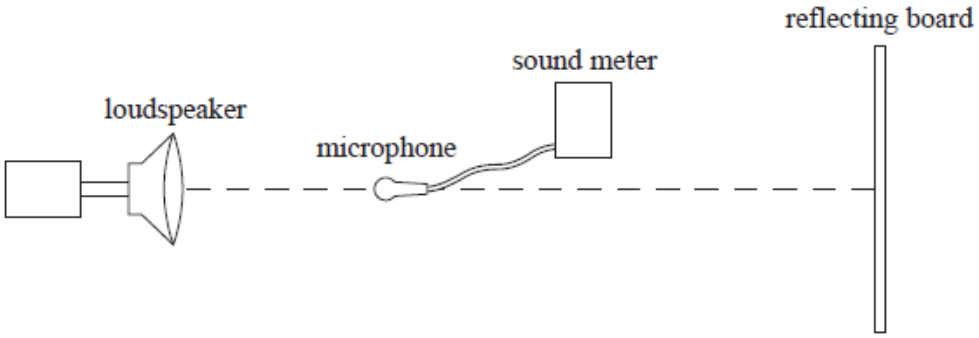
(Total for question = 1 mark)

Q12.

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

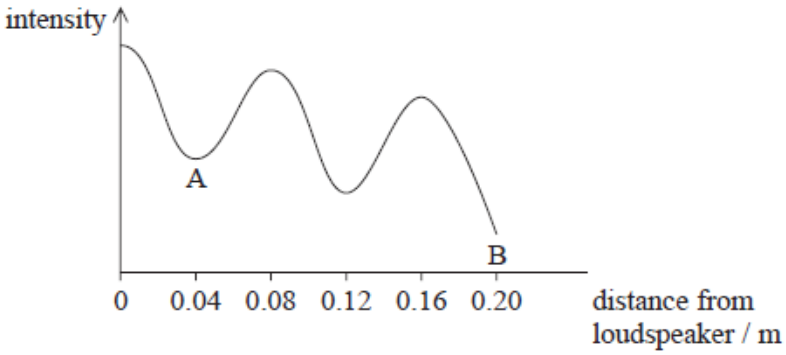
They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval *t* between the two pieces of wood being hit and the echo being heard. The procedure is repeated.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

A method to determine a value for the speed of sound is shown in the diagram.



A loudspeaker is placed at a distance from a vertical reflecting board. Sound waves reflect off the board and set up a standing wave between the loudspeaker and the board. A microphone connected to a sound meter is moved in a straight line from the loudspeaker to the board. As the microphone is moved, the sound meter records the varying intensity of the standing wave.

The sketch graph shows how the intensity varies with distance from the loudspeaker.



(i) Explain why the intensity at point B is less than the intensity at point A.

(3)

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(ii) Use the graph to determine a value for the speed of sound.

frequency of sound wave = 2.0 kHz

(3)

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Speed of sound = ...

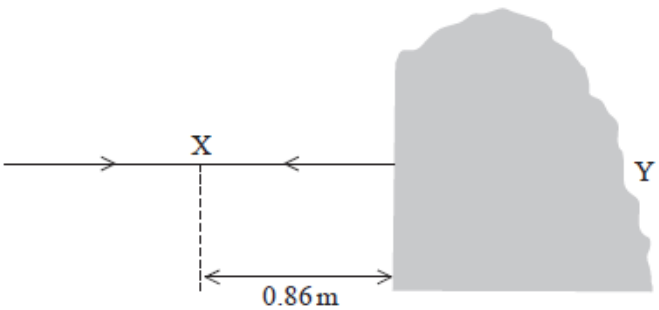
(Total for question = 6 marks)

Q13.

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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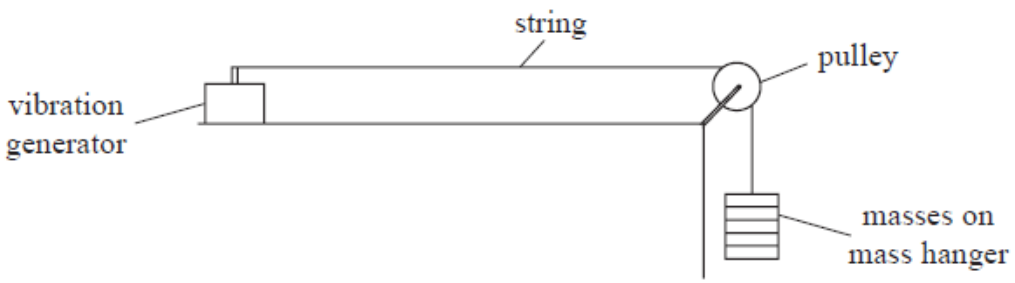
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(Total for question = 5 marks)

Q14.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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

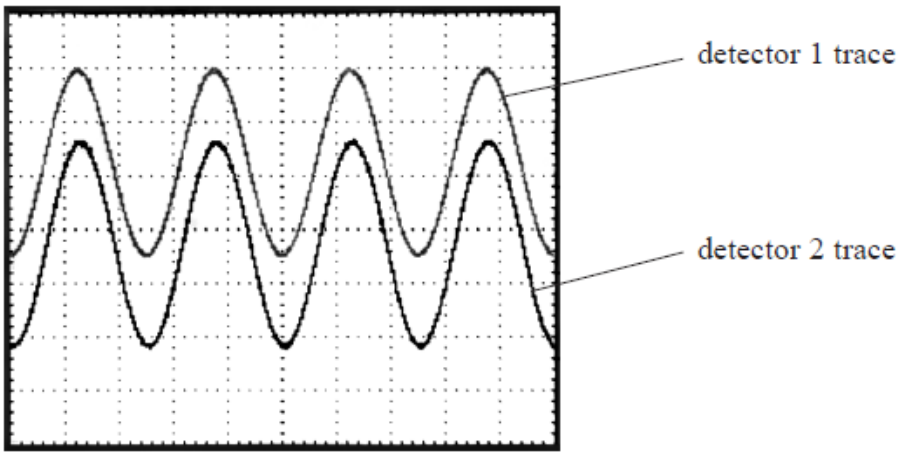
(Total for question = 1 mark)

Q15.

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

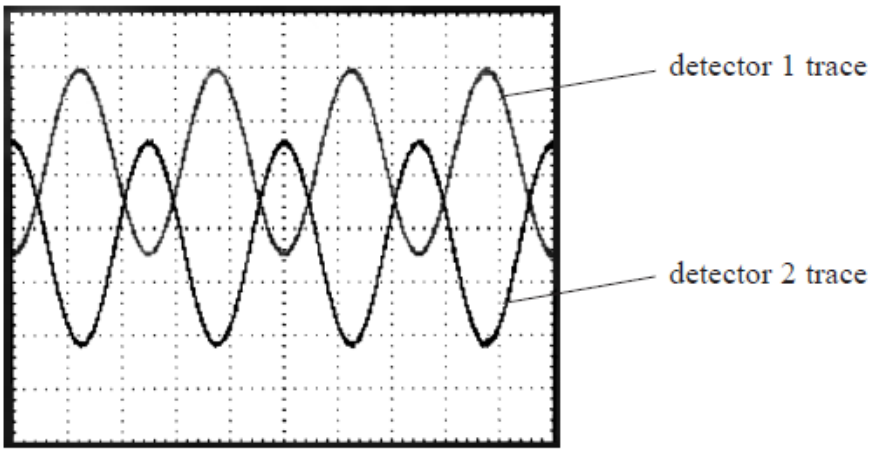


The detectors are connected to an oscilloscope and photograph 1 shows the traces that are recorded.



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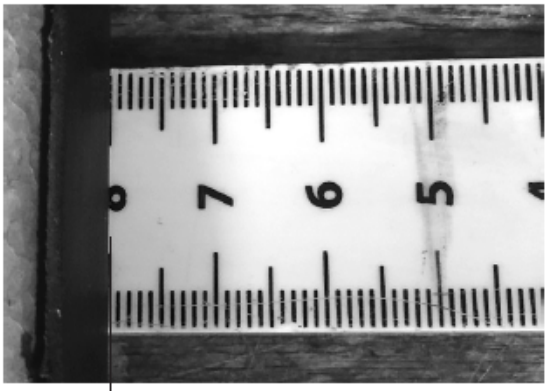
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(b) Detector 2 is moved back to its original position, alongside detector 1. Detector 2 is then steadily moved away from the source. This produces the traces seen in photograph 2 then photograph 1 alternately, until nine such cycles have been seen.

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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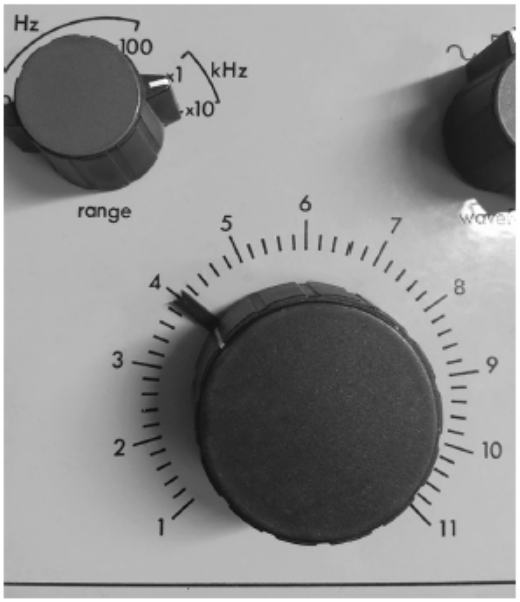
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Speed of sound in air = ...

(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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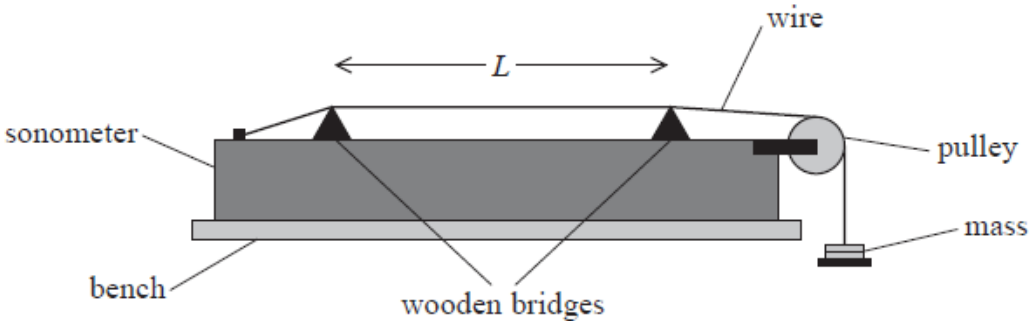
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(Total for question = 9 marks)

Q1.

A student used a sonometer to investigate the properties of a stretched wire. The sonometer is a long hollow wooden box.

A steel wire is attached to one end of the box and rests on two wooden bridges. The wire is placed under tension *T* by hanging a mass from the end of the wire, as shown.



The student placed the base of a vibrating tuning fork in contact with the wire, at one of the bridges. This set the wire into oscillation. He adjusted the position of the other bridge until a single-loop standing wave was produced on the wire between the bridges.

Explain how an antinode is produced at the mid-point of the wire between the bridges.

(3)

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(Total for question = 3 marks)

Q2.

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.

(6)

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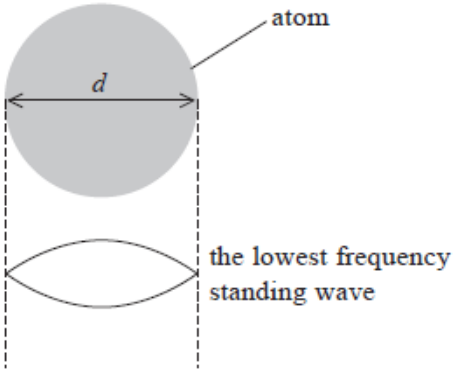
(Total for question = 6 marks)

Q3.

The Planck constant is an important universal constant used in the study of wave–particle duality.

Atomic electrons are confined within the atom. One model of atomic electrons suggests that the wave associated with an atomic electron forms a standing wave that fits exactly into the diameter *d* of the atom.

(i) The diagram shows the lowest frequency standing wave that fits into the diameter of the atom.



Calculate the momentum of the electron.

$d = 2.00 \times 10^{-10}$m

(3)

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Momentum = ...

(ii) Electrons in an atom can only exist at discrete energy levels.

Explain how this standing wave model can account for this.

(2)

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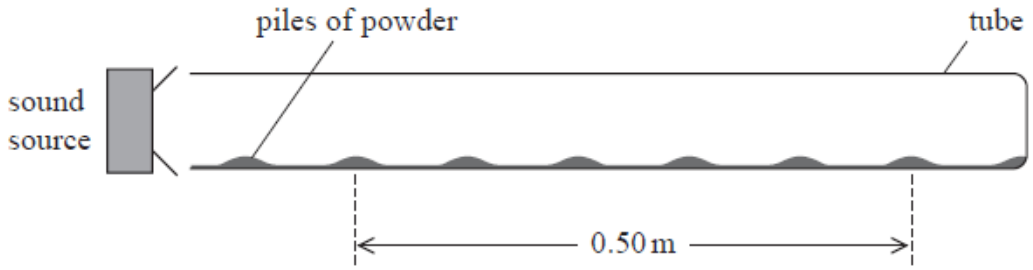
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(Total for question = 5 marks)

Q4.

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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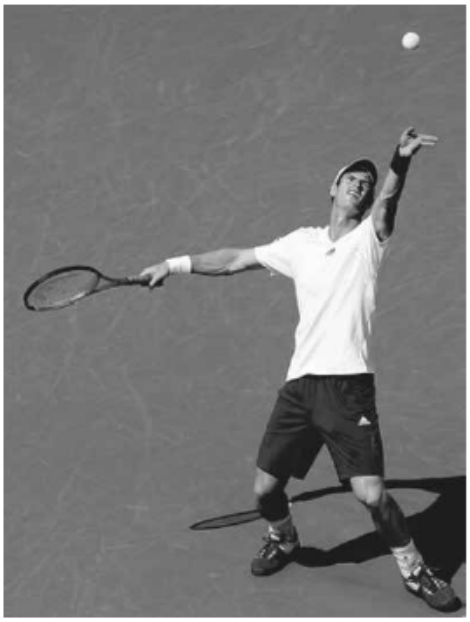
Speed = ...

(Total for question = 3 marks)

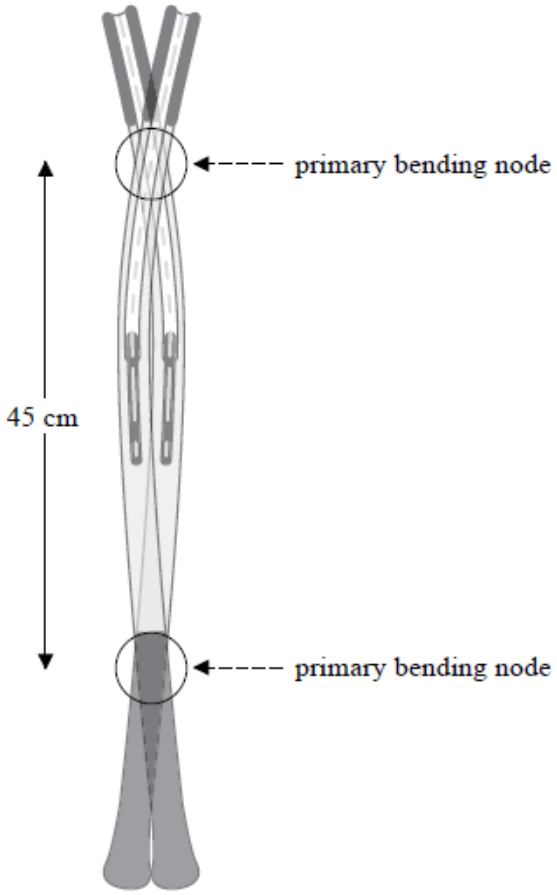
Q5.

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}.



© Getty images



Calculate the frequency of oscillation of the frame.

(3)

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Frequency = ...

(Total for question = 3 marks)

Q6.

The length of the string is 4 m.
What is the wavelength of the stationary wave?

☒ **A** 1 m

☒ **B** 2 m

☒ **C** 4 m

☒ **D** 8 m

(Total for question = 1 mark)

Q7.

The diagram represents a stationary wave on a string.

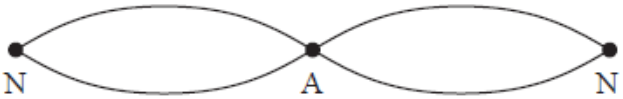


Which diagram correctly shows the position of nodes N and/or antinodes A?

☒ **A**



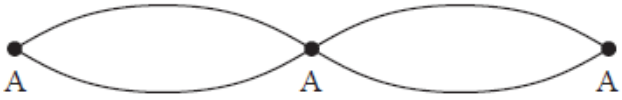
☒ **B**



☒ **C**



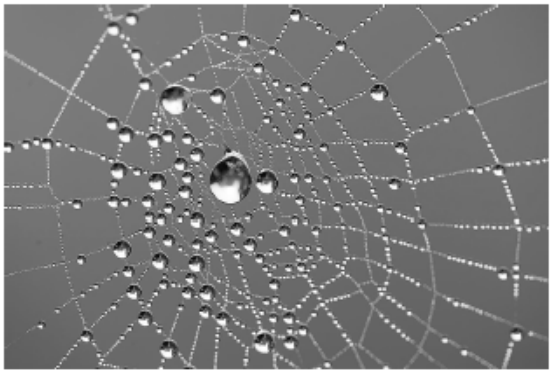
☒ **D**



(Total for question = 1 mark)

Q8.

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.

(6)

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Q9.

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)

Q10.

The photograph shows an ultrasonic mouse repeller used in a house.



The mouse repeller produces ultrasound that repels mice but cannot be heard by humans. The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

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

A student makes the following suggestion.

"If the ultrasound reflects off a wall directly opposite the mouse repeller a standing wave is formed, so there will be areas in the room where the mice will not hear the ultrasound."

Evaluate this suggestion.

(6)

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(Total for question = 6 marks)

Q11.

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)

Q12.

A book entitled *Interesting Projects with a Microwave Oven* suggests using chocolate to measure the speed of light. The chocolate is placed on a non-metallic tray in the oven.
The oven is switched on and a pattern is observed in the melting chocolate.



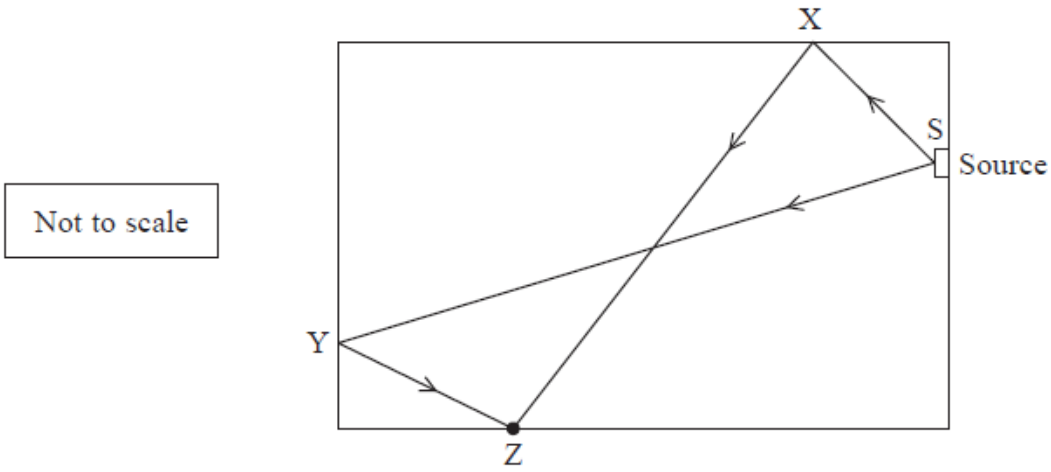
The photograph shows some lighter areas where the chocolate is melting and some darker areas where the chocolate remains hard.

The book states that microwaves are emitted from the source in the oven. The microwaves

reflect off the metal walls so that the microwaves reaching any point arrive from different directions. The microwaves produce a standing wave pattern causing hot and cold areas in the oven.

The wavelength was determined to be 12 cm by measuring the distance between adjacent hot and cold areas.

(a) The diagram shows two different paths by which microwaves can reach the point Z.



SX = 9 cm, XZ = 23 cm, SY = 36 cm, YZ = 8 cm

Calculate the phase difference between microwaves from the source at S reaching point Z by the two different paths.

(2)

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Phase difference = ...

(b) Explain how a pattern of hot and cold areas is produced in the chocolate. You should assume that each point of the chocolate is reached by microwaves following two different paths only.

(4)

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(c) Explain why the microwaves reaching a point in the chocolate must be coherent for this effect to occur.

(2)

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(d) The microwave frequency is stated on the oven as 2450 MHz.

Evaluate the success of this experiment at determining the speed of light.

(3)

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(Total for question = 11 marks)

Q13.

* The photograph shows a pipe organ in a concert hall.



(Source: www.yucatanliving.com/article-photos/news/01042010/pipe-organ.jpg)

When the organ is played, sound travels through the air to a person in the audience as a wave. It is found that there are some positions in the concert hall where particular frequencies are quieter than others.

Explain why this might be the case and give an action that could be taken to eliminate this problem.

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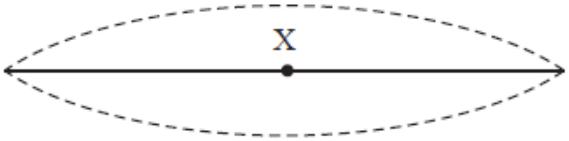
(Total for question = 6 marks)

Q14.

Guitar strings can oscillate with simple harmonic motion.



Shortly after the string is plucked, a standing wave exists on the string. The simplified diagram below shows a string in three positions of the standing wave.



(a) State what is meant by simple harmonic motion.

(2)

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(b) (i) Describe the acceleration of point X on the string as it moves between the extreme positions of its motion.

(2)

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(ii) Comment on the energy changes in the string as it moves between the extreme positions of its motion.

(3)

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(c) The oscillating string has a length of 0.53 m. Calculate the frequency of the sound emitted when the string oscillates as shown previously.

speed of the wave on the string = 270 m s^{-1}

(3)

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Frequency = ...

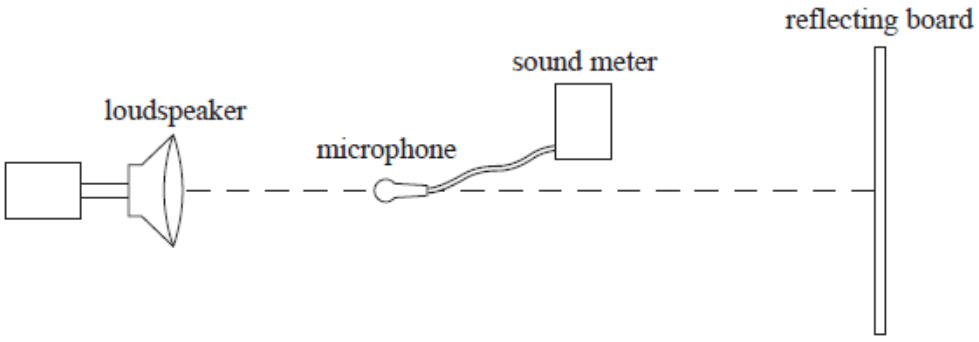
(Total for question = 10 marks)

Q15.

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

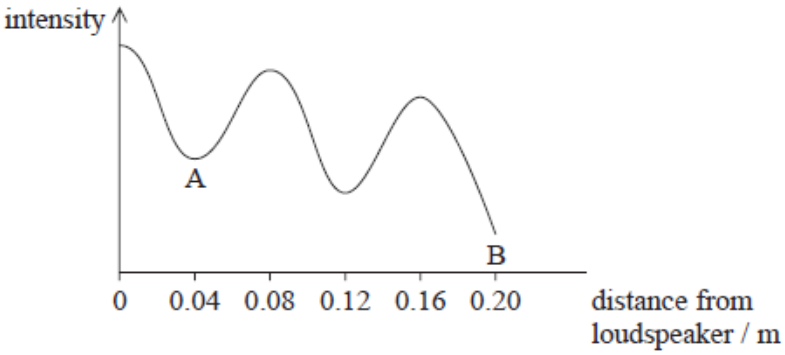
They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval *t* between the two pieces of wood being hit and the echo being heard. The procedure is repeated.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

A method to determine a value for the speed of sound is shown in the diagram.



A loudspeaker is placed at a distance from a vertical reflecting board. Sound waves reflect off the board and set up a standing wave between the loudspeaker and the board. A microphone connected to a sound meter is moved in a straight line from the loudspeaker to the board. As the microphone is moved, the sound meter records the varying intensity of the standing wave.

The sketch graph shows how the intensity varies with distance from the loudspeaker.



(i) Explain why the intensity at point B is less than the intensity at point A.

(3)

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(ii) Use the graph to determine a value for the speed of sound.

frequency of sound wave = 2.0 kHz

(3)

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Speed of sound = ...

(Total for question = 6 marks)

Q16.

A glass tube, closed at one end, has a loudspeaker placed at the other end. This is used to create a vibrating column of air, producing sound.

The wave in the tube is best described as

☒ **A** longitudinal and progressive.

☒ **B** longitudinal and standing.

☒ **C** transverse and progressive.

☒ **D** transverse and standing.

(Total for question = 1 mark)

Q17.

If certain crystals are subjected to a mechanical stress, a potential difference is generated across them. This is called the piezoelectric effect. These crystals can be produced as very thin films.

Below is a photograph of a T-shirt with a built-in phone charger, which is being tested at a music festival. The white rectangle is a piezoelectric film.



(a) By considering how a sound wave travels through the air, explain how sound can cause a

piezoelectric film to generate a potential difference.

(4)

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(b) Explain why the crystals used in the T-shirt need to be in the form of a large, thin film.

(3)

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(c) When the T-shirt is used at a music festival the sound levels are sufficient to generate about 20 kJ over ten hours. This is enough to charge one phone.

Calculate the electrical power output.

(3)

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Power output = ...

(d) Give **one** advantage and **one** disadvantage of this charger compared with a conventional charger.

(2)

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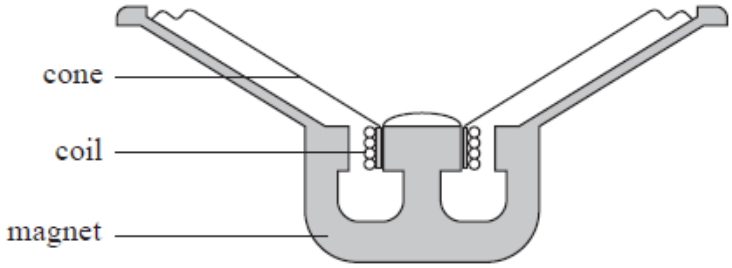
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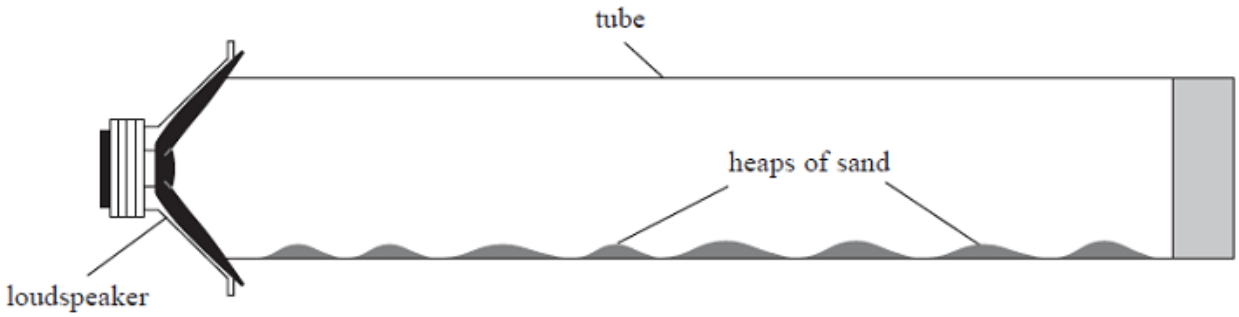
(Total for question = 12 marks)

Q18.

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 $340\,\text{m}\,\text{s}^{-1}$.

signal generator frequency = 3.25 kHz.

d = 5.1 cm

(3)

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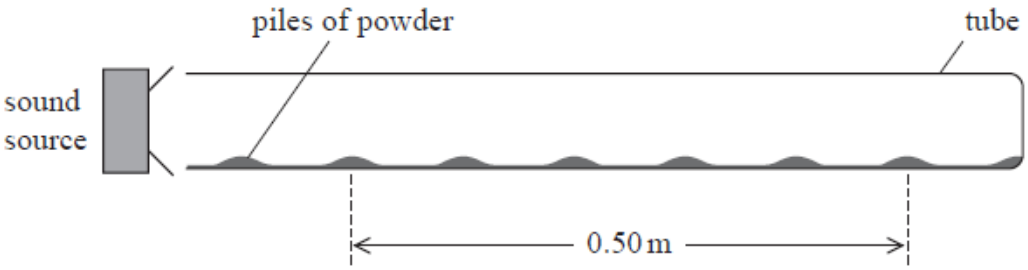
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(Total for question = 10 marks)

Q19.

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)

Q20.

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)

Q21. Which of the following is a standing wave?

☒ **A** light emitted as a line spectrum

☒ **B** ripples on water from a stone thrown into a pond

☒ **C** sound from an opera singer in a theatre

☒ **D** vibrations on a violin string as it is played

(Total for Question = 1 mark)

Q22. A standing wave is created on a string stretched between two supports.

Which statement is always true?

☒ **A** There is a node at each end.

☒ **B** There is a node in the centre.

☒ **C** There is an antinode at each end.

☒ **D** There is an antinode in the centre.

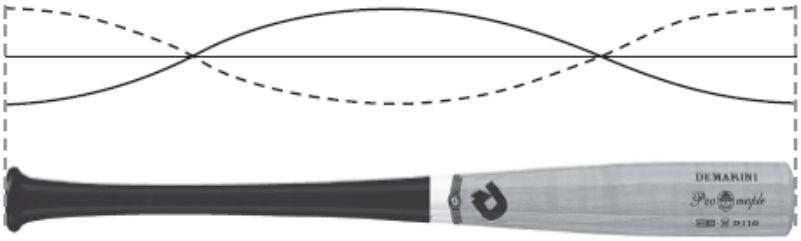
(Total for Question = 1 mark)

Q23.

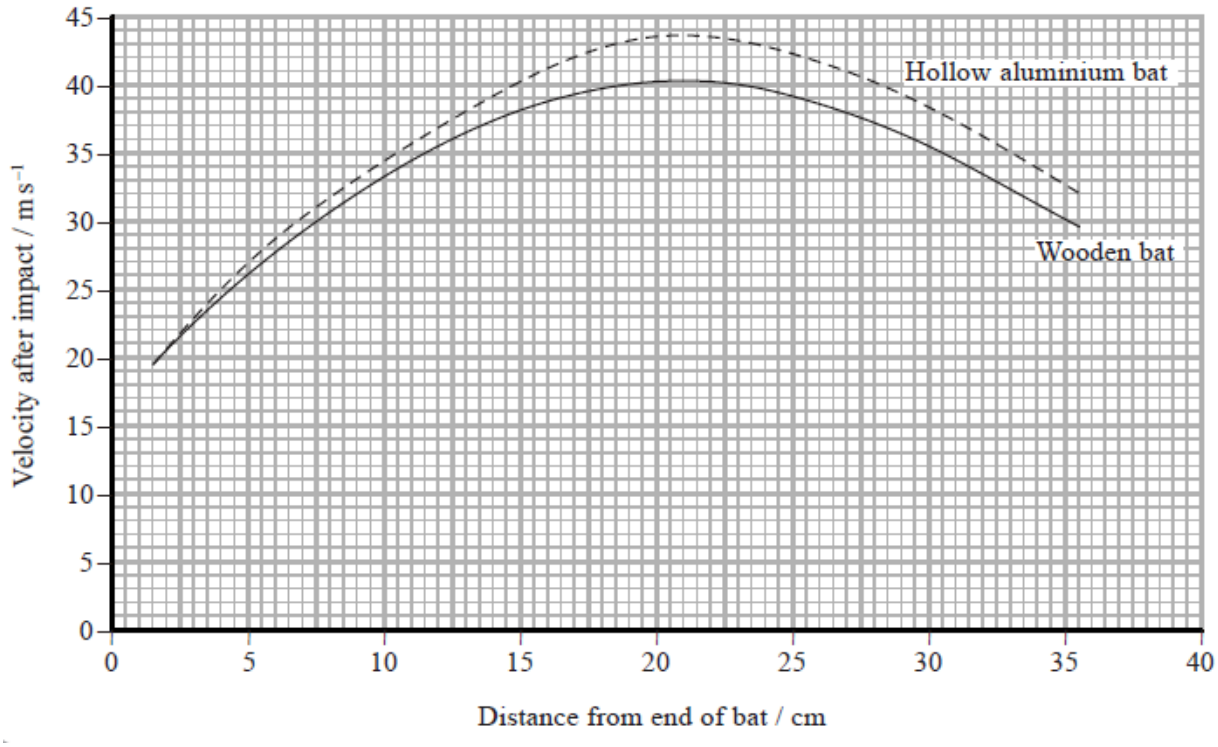
As a baseball bat hits a ball, kinetic energy of the ball is transferred to the bat and a standing wave is set up along the length of the bat.



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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Q24.

The photograph shows a guitar.



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

Explain how a standing wave is created on the string.

(3)

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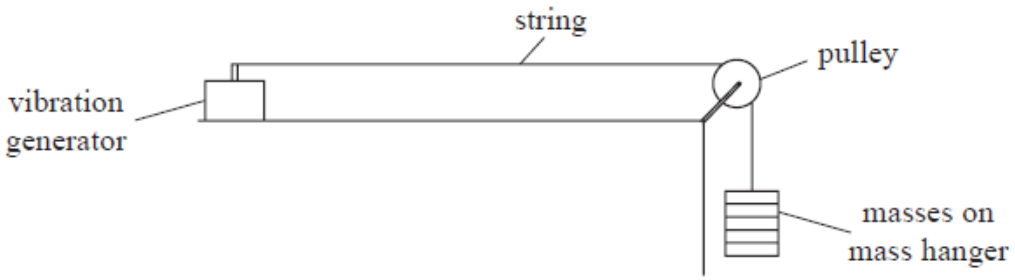
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(Total for question = 3 marks)

Q25.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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

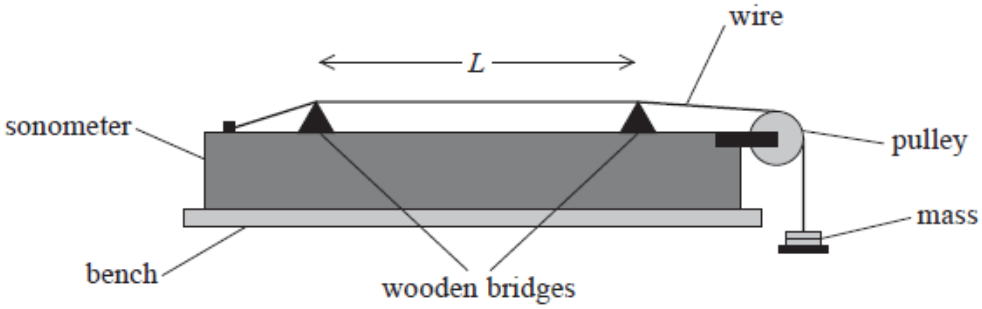
☒ **D** decreasing the mass per unit length of the string

(Total for question = 1 mark)

Q1.

A student used a sonometer to investigate the properties of a stretched wire. The sonometer is a long hollow wooden box.

A steel wire is attached to one end of the box and rests on two wooden bridges. The wire is placed under tension T by hanging a mass from the end of the wire, as shown.



The student placed the base of a vibrating tuning fork in contact with the wire, at one of the bridges. This set the wire into oscillation. He adjusted the position of the other bridge until a single-loop standing wave was produced on the wire between the bridges.

The student repeated this for a series of tuning forks with different frequencies f. For each fork he measured the distance L between the bridges.

The steel wire, of mass per unit length μ, was placed under tension T by hanging a mass of 2.10 kg from the end of the wire.

(i) State one safety precaution that should be taken when carrying out the investigation.

(1)

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(ii) The student plotted a graph of L^2 against $1/f^2$.

Show that the gradient of this graph is equal to $\frac{T}{4\mu}$

(3)

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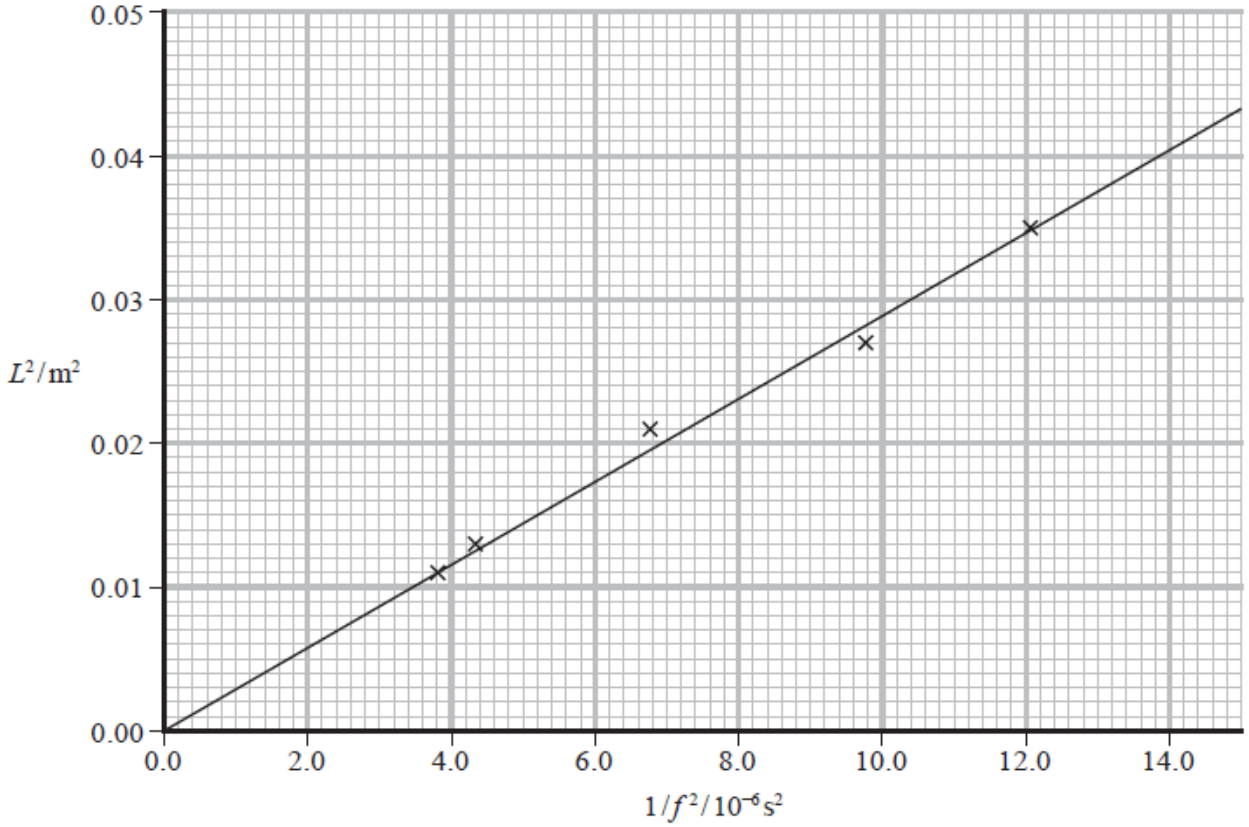
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(iii) The student's graph is shown below.



The value of μ for different standard wire gauge (SWG) steel wire is shown in the table.

SWG	μ / g m^{-1}
22	3.15
24	1.95
26	1.31

Deduce which wire the student used in the investigation.

(4)

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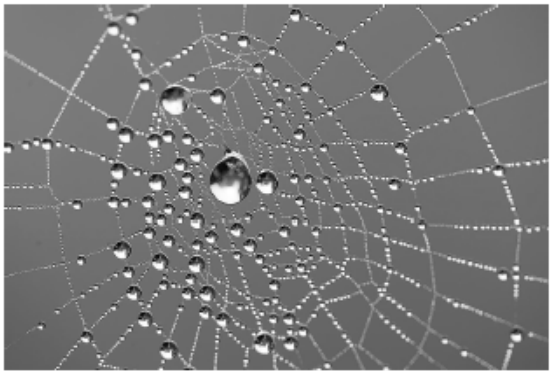
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(Total for question = 8 marks)

Q2.

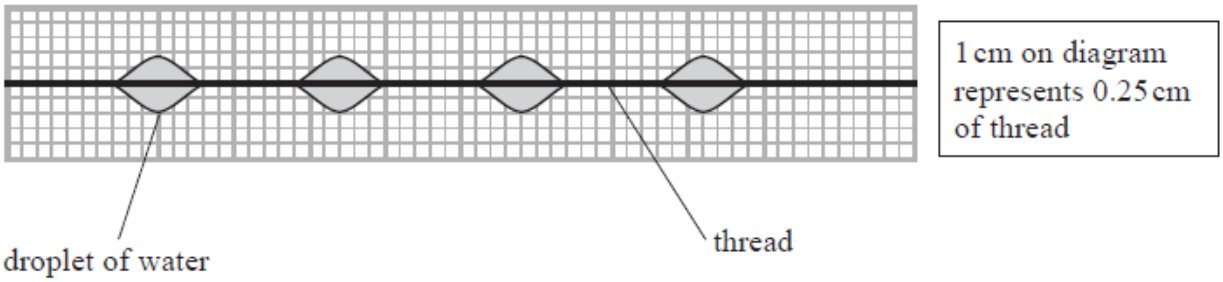
The photograph shows part of a spider's web where water droplets have collected at certain points. The web is made from spider silk which is made by the spider.



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.

The diagram shows water droplets on a single thread of spider silk when the frequency of waves is 7.9 Hz.



Further measurements are taken to test whether the observations are consistent with the presence of stationary waves in the threads.

diameter of the thread = 3.6×10^{-6} m

mass per unit length of the thread = 1.32×10^{-8} kg m^{-1}

Young modulus of spider silk = 1.2×10^{9} N m^{-2}

strain in the thread = 9.7×10^{-9}

Determine, by considering wave speed, whether the measurements are consistent with this suggestion.

(7)

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Q3.

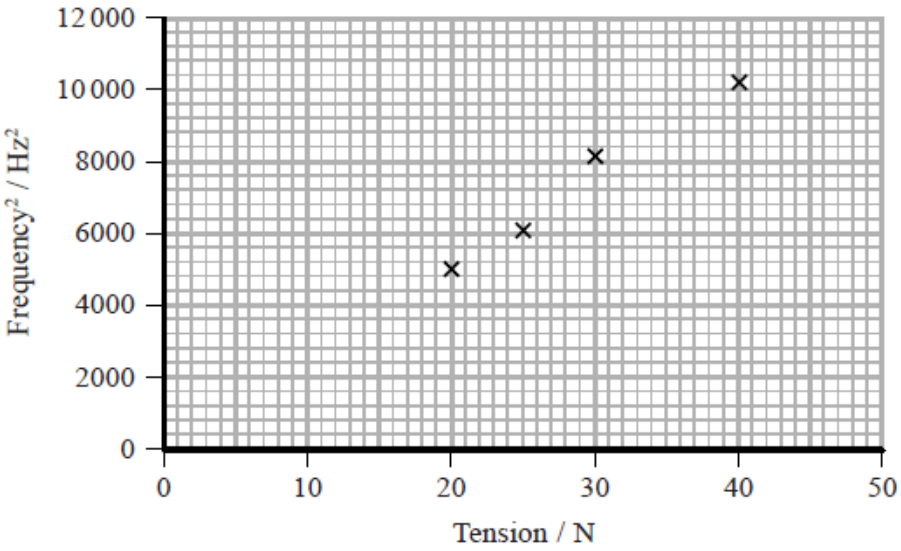
A student carries out an experiment using a guitar string. She investigates the effect of varying the tension in the guitar string on the frequency of sound produced when the string is plucked.

(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

(5)

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(Total for question = 8 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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)

Q5.

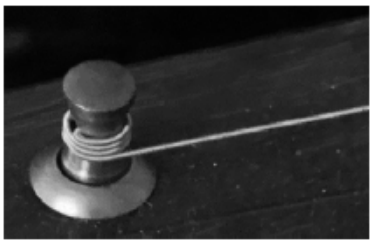
The photograph shows a guitar.



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 = $1.8 \times 10^{9}\,\text{N m}^{-2}$

cross-sectional area of string = $6.6 \times 10^{-7}\,\text{m}^{2}$

(4)

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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.

(2)

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(Total for question = 6 marks)

Q6.

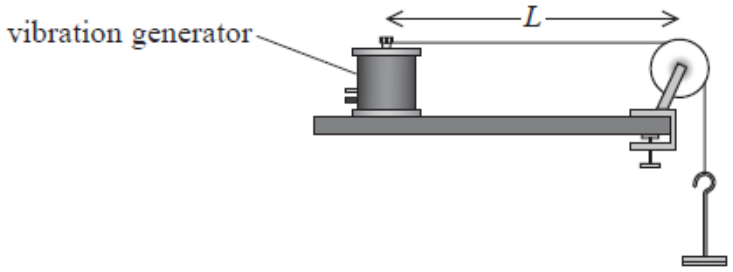
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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

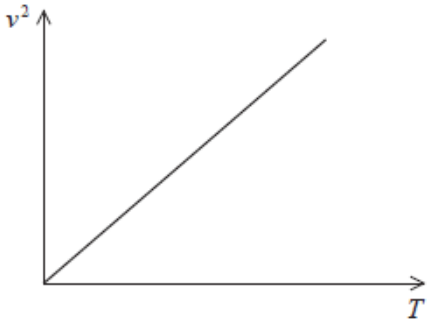
(Total for question = 1 mark)

Q7.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

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)

Q8.

The velocity of a wave on a string is given by $v = \sqrt{\dfrac{T}{\mu}}$ where T is the tension in the string and μ is a constant.

Which of the following pairs of variables, if plotted, would produce a straight line graph?

(1)

	x-axis	y-axis
☒ A	T	$\sqrt{v}$
☒ B	v	T
☒ C	$\frac{1}{v}$	T
☒ D	$\sqrt{T}$	v

(Total for question = 1 mark)

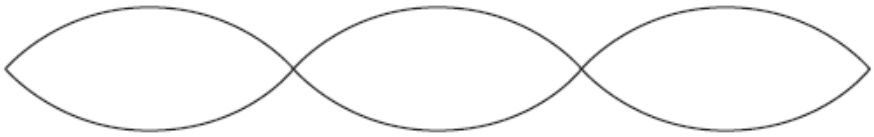
Q9.

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)

Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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)

Q1.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A detector is placed 30 cm from a gamma source, the count rate is 64 counts per minute.

The detector is then placed 60 cm from the source. The background rate is presumed to be a constant 24 counts per minute.

Which of the following gives the expected counts per minute?

☒ **A** 16

☒ **B** 32

☒ **C** 34

☒ **D** 44

(Total for question = 1 mark)

Q2.

The photograph shows a 'quiet boil' electric kettle. The makers of the kettle claim that it boils water with much less noise than a standard kettle.



A laboratory technician takes some measurements to compare a 'quiet boil' electric kettle with a standard electric kettle.

The table shows the results recorded by the technician.

	Quiet boil kettle	Standard kettle
Mass of water / kg	1.20	1.20
Initial temperature of water / °C	10	10
Final temperature of water / °C	100	100
Potential difference / V	243	247
Current / A	11.9	11.8
Time taken to heat water to boiling point / s	168	172
Average sound intensity / mW m^{-2}	3.72	10.5

A student uses the values in the table to calculate the efficiency of each kettle at heating the water to boiling point. He calculates the efficiency of the 'quiet boil' kettle to be 0.93

Calculate the efficiency of the standard kettle.

specific heat capacity of water = 4180 J kg^{-1} K^{-1}

(4)

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Efficiency = ...

(b) The intensity of the sound produced by each kettle was measured with a sound meter which was 30.0 cm from the centre of the kettle.

Calculate the energy transferred by sound while the water in the standard kettle is brought to the boil. You may treat the kettle as a point source.

(4)

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Energy transferred = ...

(c) The label on the original packaging of the quiet boil electric kettle states, 'This kettle is much more efficient than a standard kettle because it produces less sound.'

Explain the extent to which this statement is supported by your calculations.

(2)

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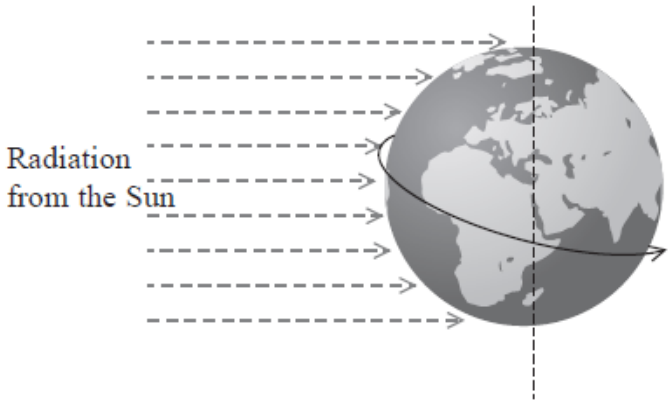
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(Total for question = 10 marks)

Q3.

Solar panels consisting of combinations of photovoltaic cells use energy in the radiation received from the Sun to generate electricity.

The average intensity of radiation from the Sun incident at the Earth's surface over a 24-hour period has been determined to be 164 $W\,m^{-2}$.



(i) The average intensity of radiation from the Sun at the Earth's surface is much less than the intensity incident at the top of the Earth's atmosphere.

Explain why.

(4)

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(ii) It is claimed that the area of solar panels needed to generate 100 GW of power is about 0.5% of the surface area of the Earth.

Assess the validity of this claim.

radius of Earth = 6.4×10^6 m

typical efficiency of solar panels = 25%

(4)

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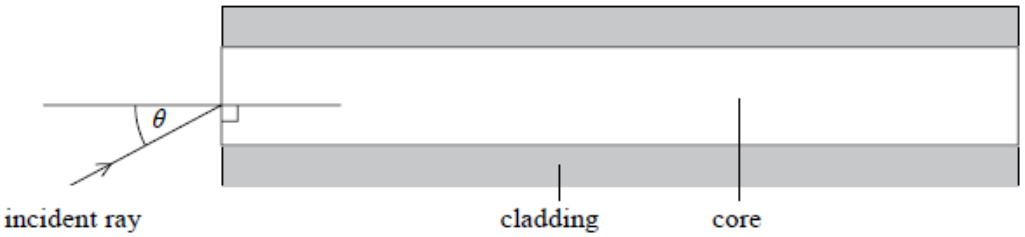
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(Total for question = 8 marks)

Q4.

One type of optical fibre is made from a glass core surrounded by a glass cladding of lower refractive index. The light ray passes along the fibre by total internal reflection. The diagram shows a light ray incident on one end of the fibre.



A light ray enters the core with an angle of incidence θ and the angle of refraction is 20°.

Show that the light ray will be totally internally reflected when it meets the boundary between the core and the cladding.

$n_{core} = 1.56$

$n_{cladding} = 1.44$

(4)

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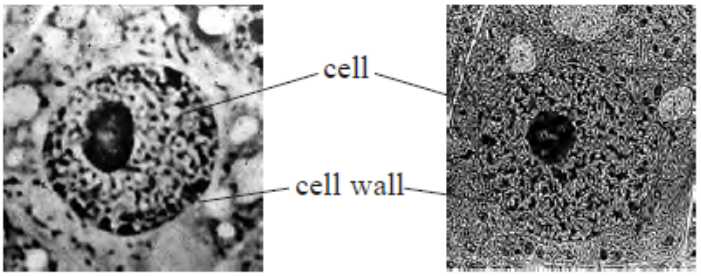
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(Total for question = 4 marks)

Q1.

An optical microscope uses a beam of visible light. An electron microscope uses a beam of electrons.

A biologist looked at an animal cell using both microscopes. The two images are shown; both have the same magnification.



using optical microscope using electron microscope

www.udel.edu

The image of the animal cell produced by the electron microscope is less blurred than the image produced by the optical microscope.

Explain why.

(2)

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(Total for question = 2 marks)

Q2.

The effect of diffraction is more noticeable, in everyday life, with sound than with light. This is because

☒ **A** sound has a much longer wavelength than light.

☒ **B** sound is a longitudinal wave, light is a transverse wave.

☒ **C** sound is a mechanical wave, light is an electromagnetic wave.

☒ **D** sound travels more slowly in air than light does.

(Total for question = 1 marks)

Q3.

When food is cooked in a microwave oven, microwave radiation is absorbed by water molecules, increasing the internal energy of the food.

(a) The photograph shows a microwave leakage detector.



The detector is held next to the microwave oven to see if any microwave radiation is leaking to the surroundings.

Suggest why microwave radiation leaking to the surroundings could be dangerous to people.

(2)

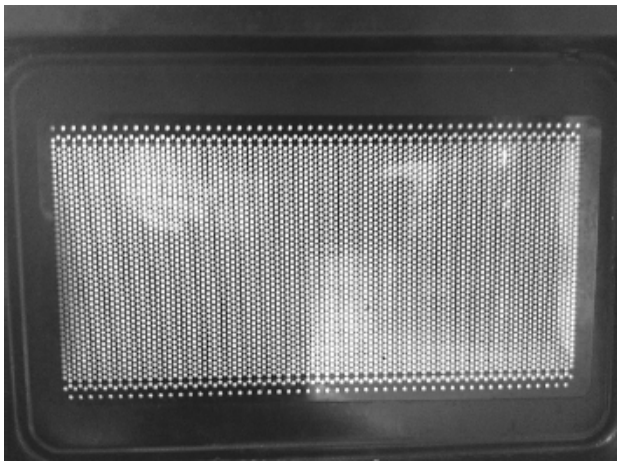
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(b) The internal walls of the microwave oven are solid metal. The photograph shows the door of a microwave oven.



The door consists of two sheets of glass with a layer of metal between. The layer of metal has many small holes in it, so that food inside the microwave oven may be seen while it is being heated without exposing the user to dangerous levels of microwave radiation. It has been suggested that, due to diffraction effects, light can pass through the holes but microwaves

cannot.

(i) Explain what is meant by diffraction.

(2)

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(ii) Calculate the wavelength of the microwave radiation used in the oven.

microwave frequency = 2.5 GHz.

(2)

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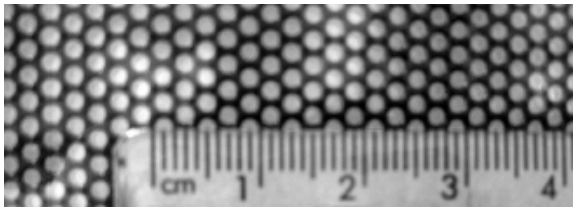
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Wavelength = ...

(iii) The photograph shows a section of the microwave oven door. Use the photograph to determine the diameter of the holes.



(1)

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Diameter = ...

*(iv) Discuss the suggestion that, due to diffraction effects, light can pass through the holes but microwaves cannot.

(3)

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Q4.

In everyday life the effect of diffraction is more significant for sound than for light.

This is because

☒ **A** light has a much shorter wavelength than sound.

☒ **B** light is a transverse wave but sound is a longitudinal wave.

☒ **C** light is an electromagnetic wave but sound is a mechanical wave.

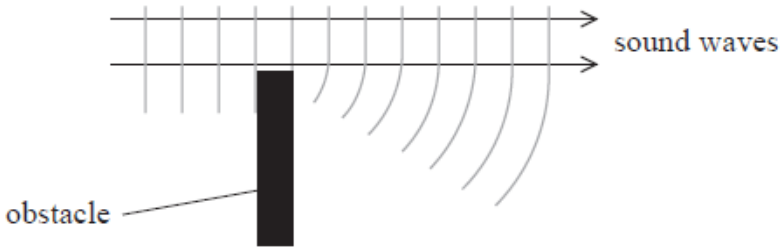
☒ **D** the speed of light in air is much higher than the speed of sound.

(Total for question = 1 mark)

Q5.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Sound waves can diffract around obstacles as shown in the diagram.



The diffraction effect is

☒ **A** greater for large amplitude sound waves.

☒ **B** greater for low frequency sound waves.

☒ **C** independent of the frequency of the sound waves.

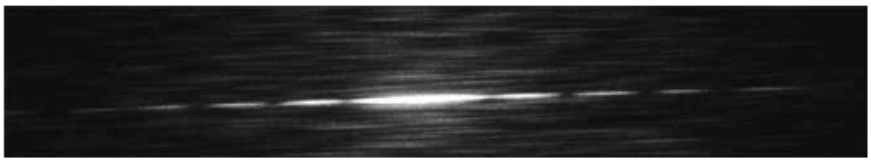
☒ **D** independent of the speed of the sound waves.

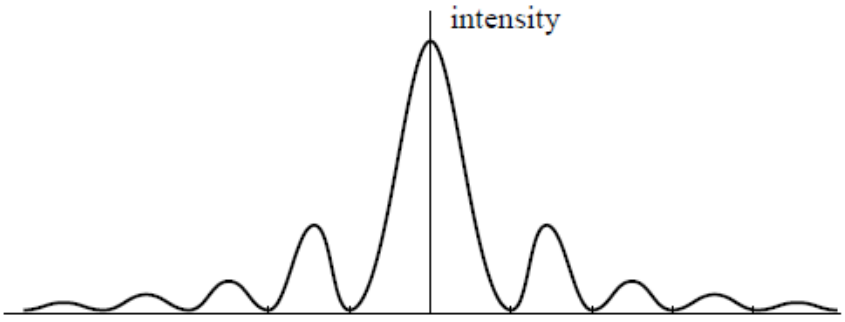
(Total for question = 1 mark)

Q6.

A student obtains the following diffraction pattern on a wall by shining a red laser beam through a single narrow slit.

The corresponding graph of intensity against position is shown below.





(a) Explain how the diffraction pattern is created.

(3)

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(b) Explain how the pattern would differ if green laser light were used instead of red laser light.

(3)

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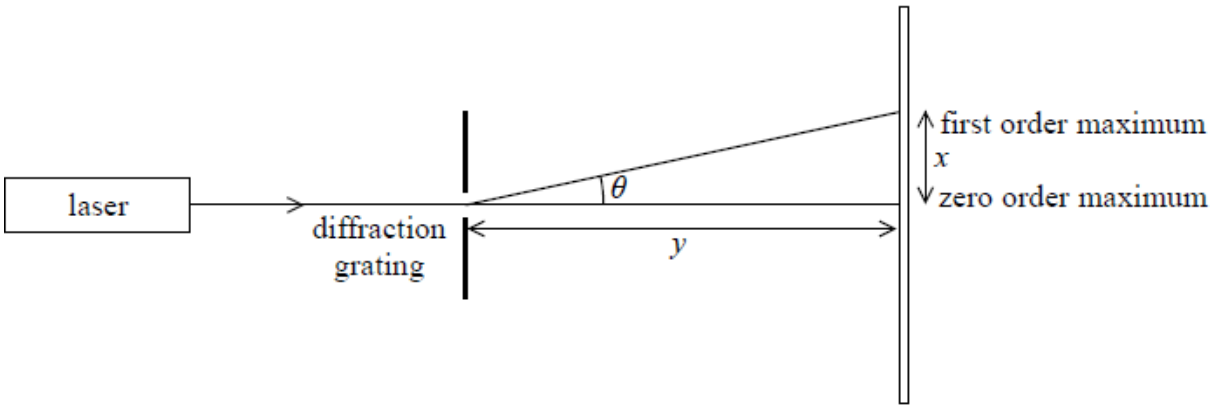
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(c) A student replaces the single slit with a diffraction grating and obtains the pattern shown in the photograph.



The photograph shows the zero order maximum and the first and second orders on either side.

The student takes measurements to determine the grating spacing.



The student measures x, the distance between the zero order maximum and the first order maximum, and y, the distance between the slit and the screen.

x = 23 cm
y = 1.5 m
Number of lines per millimetre = 300

Calculate the wavelength of light from the laser.

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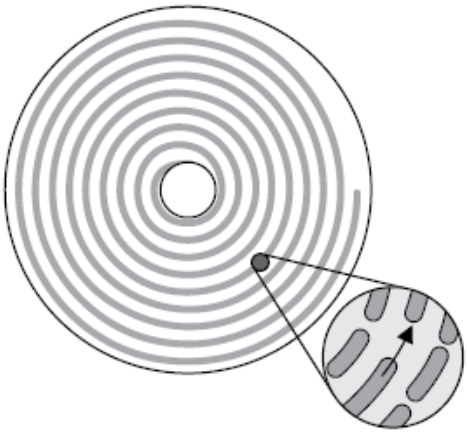
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Wavelength = ...

(Total for question = 9 marks)

Q7.

* The light from a lamp is reflected from the surface of a CD, which consists of a spiral track of elongated bumps.



CD surface showing spiral track of bumps with a smooth reflective surface in between.

(Source: http://gantisreerajiv.blogspot.co.uk/2012/04/you-cant-imagine-world-if-there-are.html:)

A physics student notices that although the light from the lamp is white, different colours are seen in the reflected light. He suggests that the colours are produced when diffraction occurs at the surface of the CD.

Discuss the extent to which the student's suggestion explains the presence of colours in the light reflected from the surface of the CD.

(6)

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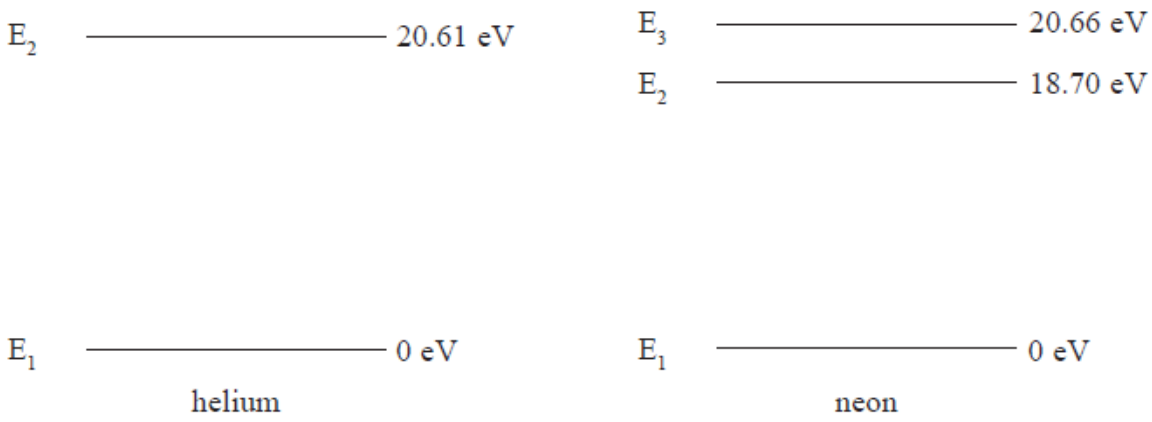
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(Total for question = 6 marks)

Q8.

A helium-neon gas laser is often used in the laboratory as a source of high intensity, coherent, monochromatic light.

The diagram shows some of the energy levels above the ground level E_3 for helium atoms and for neon atoms. The highest shown levels for helium atoms and neon atoms are almost identical.



Helium atoms in the gas are excited to level E_2 by the current passing through the laser. They collide at high speed with neon atoms. Because the energies are so similar, the energy is transferred from the helium atoms to the neon atoms. The neon atoms become excited in turn to level E_3. As the neon atoms subsequently drop to level E_2 they emit photons.

(a) Explain what is meant by a photon.

(2)

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(b) Calculate the frequency of the photons produced as the neon atoms drop from level E_3 to level E_2.

(3)

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Frequency = ...

(c) An electron in level E_3 of neon has 0.05 eV more energy than an electron in level E_2 of helium.

Suggest the source of the energy to make up this difference.

(1)

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(d) The photograph shows a device for making a vertical slit with variable width.



© THORLABS, Inc.

When the slit is fully open a laser beam is shone through it and a single point of light is seen on a screen.

As the slit is reduced in width the point of light becomes a horizontal line that gets longer as the slit gets narrower.

Explain this observation

(3)

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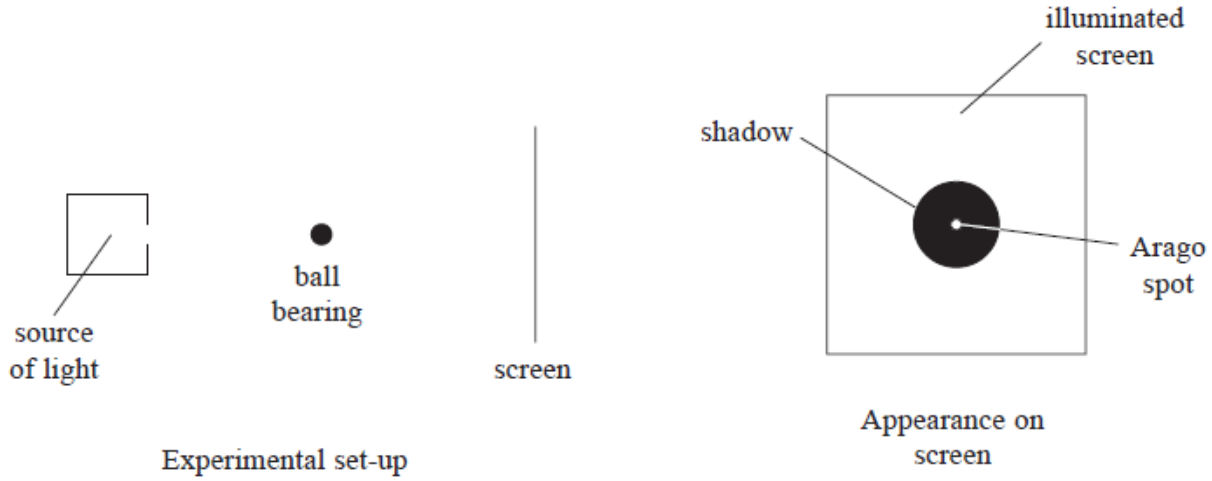
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(Total for question = 9 marks)

Q9.

The diagram shows a coherent beam of light incident on a metal ball bearing.

A dark shadow is seen on a screen behind the ball bearing. There is a small spot of light in the centre of the shadow. This spot of light is known as the Arago spot.



(a) Use Huygens' construction to explain the behaviour of light as it travels past the edge of the ball bearing.

(2)

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(b) Explain why a spot of light is produced at the centre of the shadow.

(3)

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(Total for question = 5 marks)

Q10.

Light can be modelled as a wave.

Diffraction provides evidence for the wave nature of light.

Use Huygens' construction to describe what happens to light waves after passing through a narrow gap.

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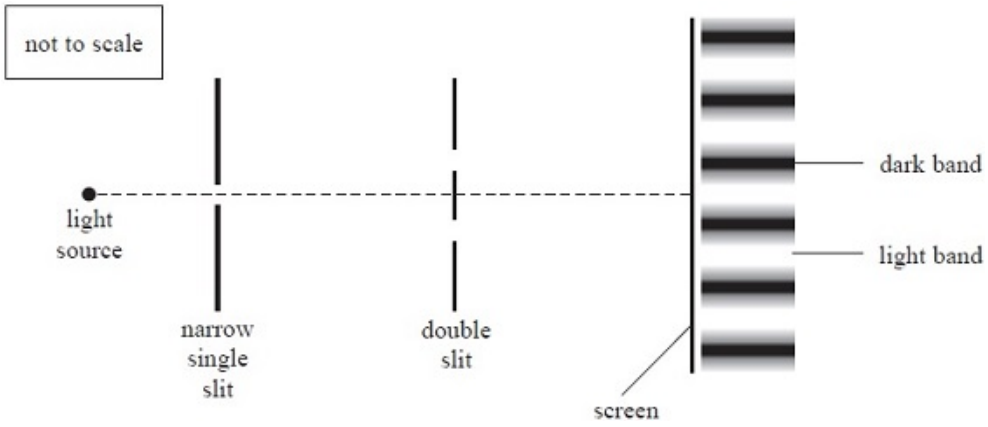
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(Total for question = 3 marks)

Q11. In the 17th century, Isaac Newton suggested that light was made up of very small particles which he called corpuscles.

Newton's theory was favoured in England throughout the 18th century because of his great reputation although scientists elsewhere applied the wave theory.

In 1801 Thomas Young demonstrated his double slit experiment. Monochromatic light from a narrow single slit was passed through a double slit and a pattern of light and dark bands was seen on a screen, as shown in the diagram.



*(a) Explain how the light and dark bands are formed in the double slit experiment.

(4)

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(b) The observation of light and dark bands with the double slit experiment depends on the light from the slits being coherent.

Explain why coherence is necessary to observe the light and dark bands.

(2)

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(c) State why Young's experiment disproved Newton's corpuscular theory.

(1)

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(Total for Question = 7 marks)

Q12.

An electron beam is directed onto crystalline graphite. A fluorescent screen on the other side of the crystal shows the pattern in Figure 1. The brighter areas correspond to higher electron intensity.

The speed of the electrons is increased and the resulting pattern is shown in Figure 2.

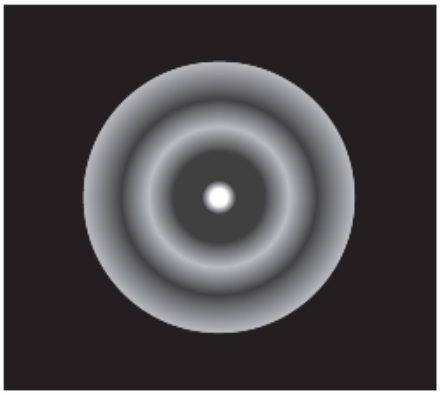


Figure 1

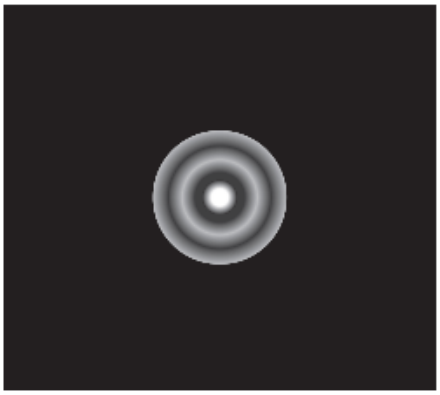


Figure 2

* Discuss the conclusions that can be drawn from this information about the behaviour of electrons and the structure of graphite.

(6)

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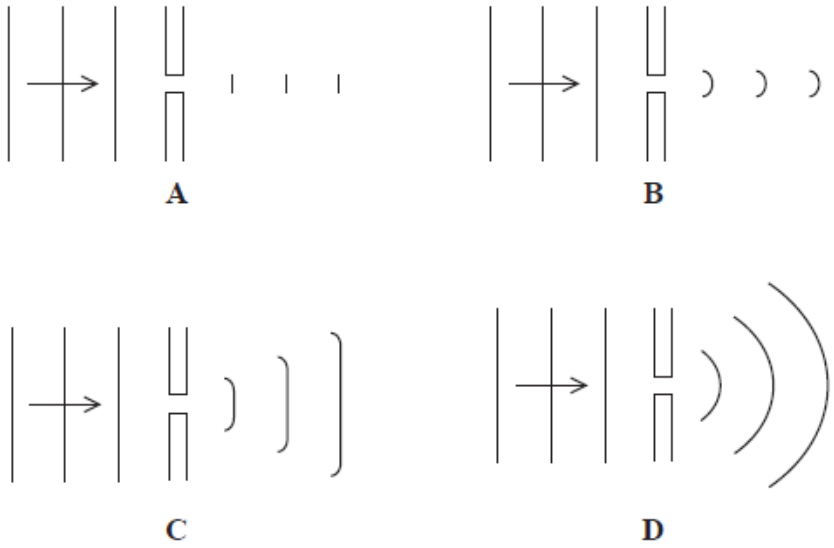
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(Total for question = 6 marks)

Q13.

Plane wavefronts pass through a gap in a barrier. The gap is much smaller than the wavelength of the wave.



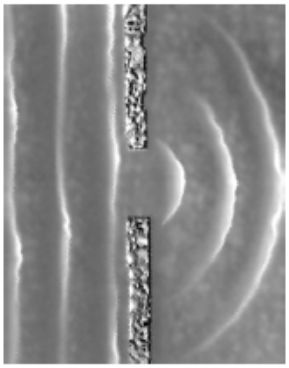
Which diagram best shows the resultant shape of the wavefronts?

- ☒ **A**
- ☒ **B**
- ☒ **C**
- ☒ **D**

(Total for question = 1 mark)

Q14.

The photograph shows plane wavefronts meeting a gap in a harbour wall.



Which phenomenon is illustrated here?

☒ **A** diffraction

☒ **B** polarisation

☒ **C** reflection

☒ **D** refraction

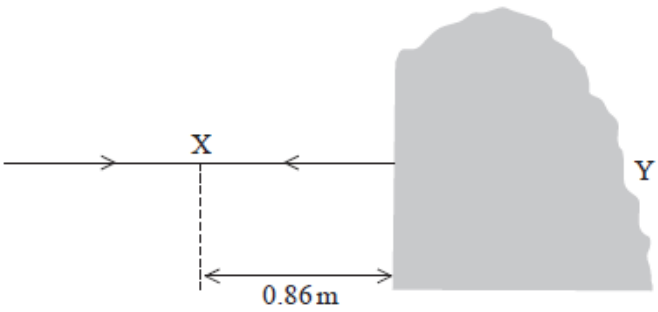
(Total for question = 1 mark)

Q15.

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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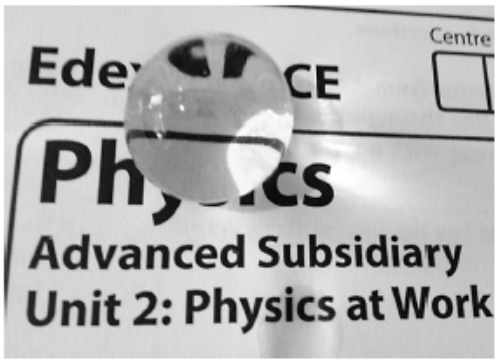
(Total for question = 5 marks)

Q1.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photograph below shows some writing seen through one of these gel balls. The writing is distorted because the gel ball refracts light.



(a) Explain what is meant by refraction.

(2)

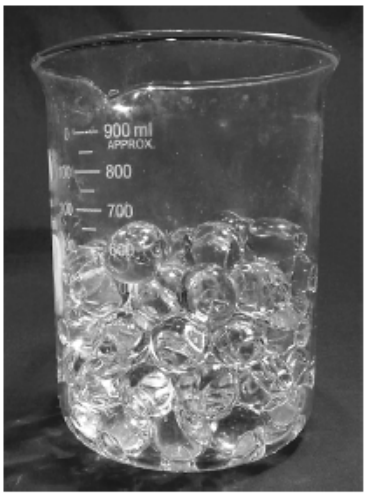
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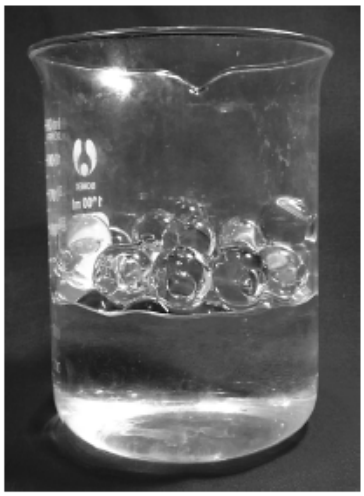
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(b) The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.





Explain how this shows that the gel has the same refractive index as water.

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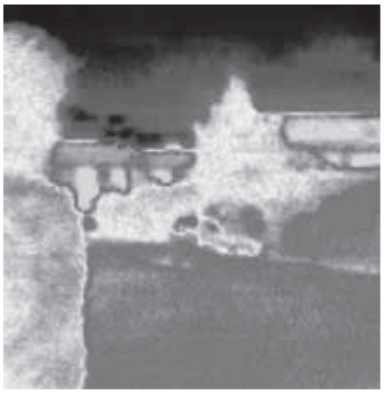
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Q2.

Infrared cameras are used to create images that show the infrared radiation emitted by objects.

The photographs show the same scene taken first with an ordinary camera and then with an infrared camera.





The photograph shows the result when someone tries to take an infrared photograph of the

same scene through a window. The image does not show the outdoor scene but does show an image of the photographer.



State what can be concluded about glass and infrared radiation.

(2)

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(Total for question = 2 marks)

Q3. Ultrasonic testing can be used for detecting corrosion inside metal pipes.

(a) Describe how the ultrasound travels through a metal.

(3)

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(b) A steel pipe was manufactured with a wall thickness of 4.0 cm.

After several years of use this pipe is tested for corrosion. A pulse of ultrasound is sent into the steel from the outer surface and the reflection from the inner surface is detected after a time of 5.1×10^{-6} s.

Determine whether the steel is corroded at this point.

speed of sound in steel = 5900 m s^{-1}

(4)

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(c) In this technique the ultrasound is emitted as pulses.

Explain why pulses are used rather than a continuous wave and how the duration of the pulse affects the thickness of the pipe wall that can be accurately measured.

(3)

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(Total for Question = 10 marks)

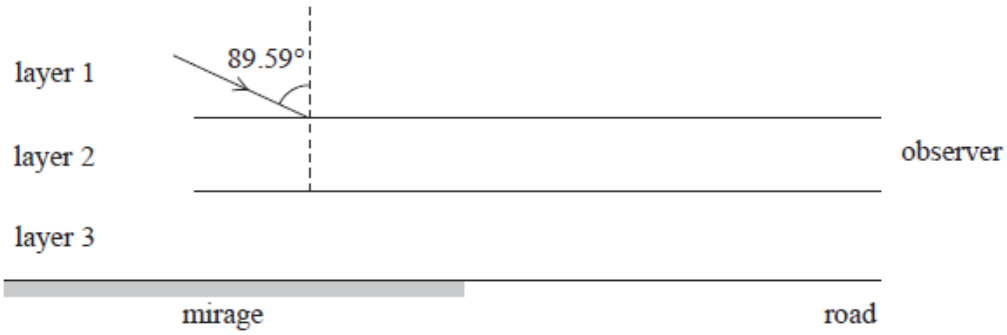
Q4.

On sunny days a mirage can sometimes be observed when a virtual image of the sky is seen on the surface of a road.



The Sun's rays heat up the surface of the road. The heated road then heats the surrounding air so that the layer of air just above the road is at a higher temperature than the air above it. Warm air has a lower refractive index than cool air.

The diagram represents a simple model which is sometimes used to explain how a mirage is formed. The three layers, each with a different refractive index, represent air at three different temperatures. Layer 3 represents the air at the highest temperature closest to the road. A light ray is shown incident at the interface between layer 1 and layer 2.



	refractive index
layer 1	1.00032
layer 2	1.00030
layer 3	1.00028

critical angle for light travelling from layer 1 to layer 2 = 89.64°
critical angle for light travelling from layer 2 to layer 3 = 89.64°

Use the information to discuss whether the observer sees a mirage on the road in the position shown.

(6)

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(Total for question = 6 marks)

Q5.

An ultrasonic distance estimator can be used to measure the length of a room.



The estimator is held against one wall. It emits pulses of ultrasound and detects them when they return after reflection by the opposite wall.

(a) Explain why the ultrasound must be emitted in pulses.

(1)

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(b) The shortest distance the estimator can measure is 40 cm.
Calculate the longest pulse duration that would allow this distance to be measured.

speed of ultrasound in air = 330 m s^{-1}

(3)

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Pulse duration = ...

(c) When the estimator is pointed at a sloping wall, as shown in the photograph, it is unable to measure this distance.



Suggest why the estimator is unable to measure the distance to the sloping wall.

(1)

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(Total for question = 5 marks)

Q6. When light rays enter the Earth's atmosphere from space they undergo refraction. This can lead to a star appearing to be in a different position from its actual position.

(a) Explain what is meant by refraction and why it occurs for light entering the Earth's atmosphere.

(3)

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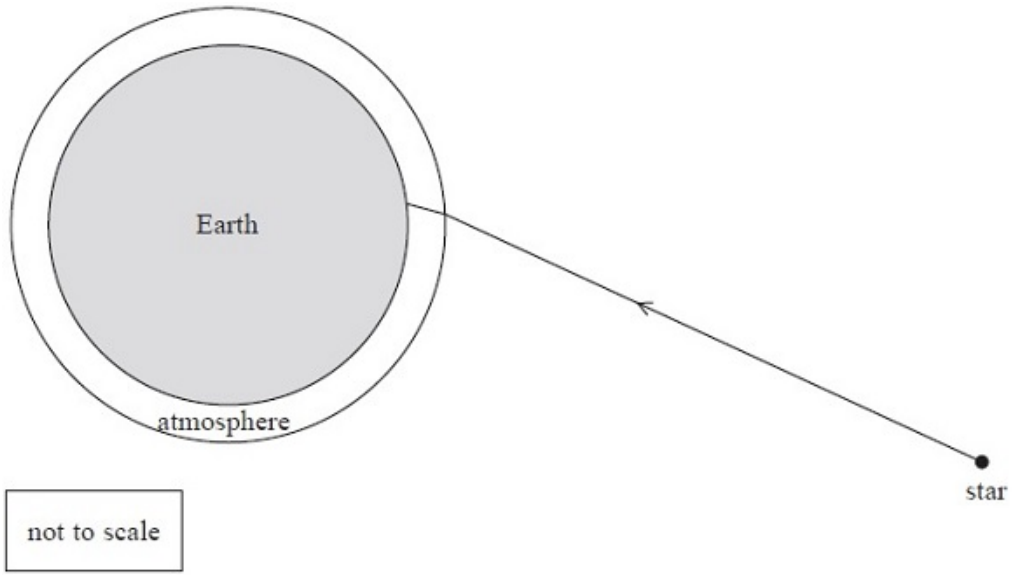
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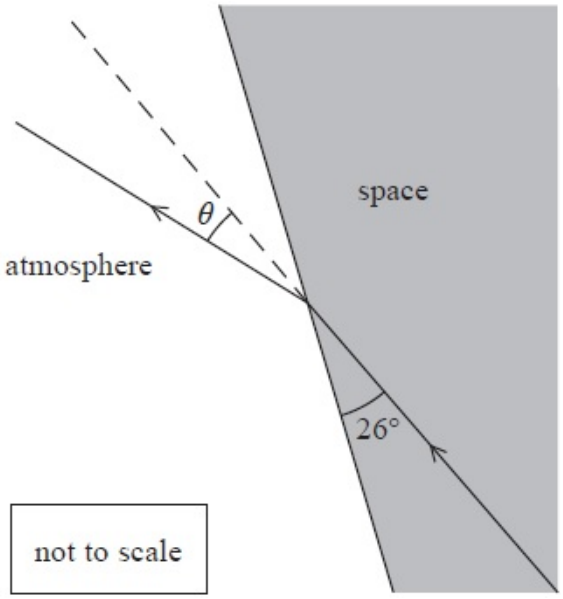
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(b) The diagram shows a ray of light from a star reaching the Earth's surface.



The diagram shows in more detail the ray of light as it enters the atmosphere.



Calculate the change in direction θ of the ray.

refractive index of atmosphere = 1.001

(4)

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θ = ...

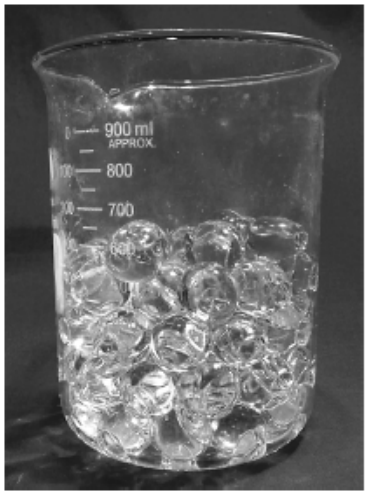
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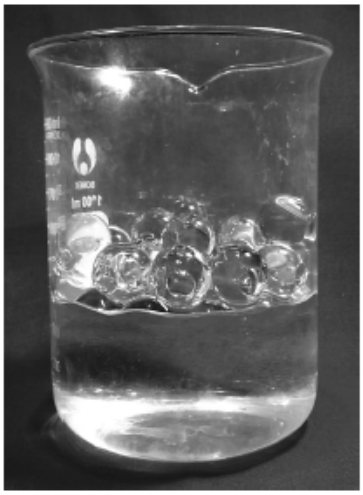
Q7.

Flower arrangers sometimes use gel balls instead of water to fill vases.



The photographs below show a beaker containing gel balls. When water is added to the beaker, the gel balls below the water surface are no longer visible.





(a) A student decides to use a gel ball to model the formation of a rainbow by raindrops. He wants to see if total internal reflection occurs.

Explain what is meant by total internal reflection.

(2)

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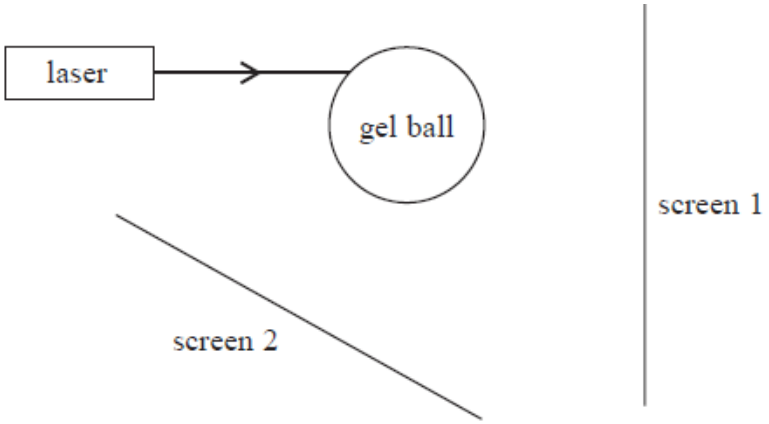
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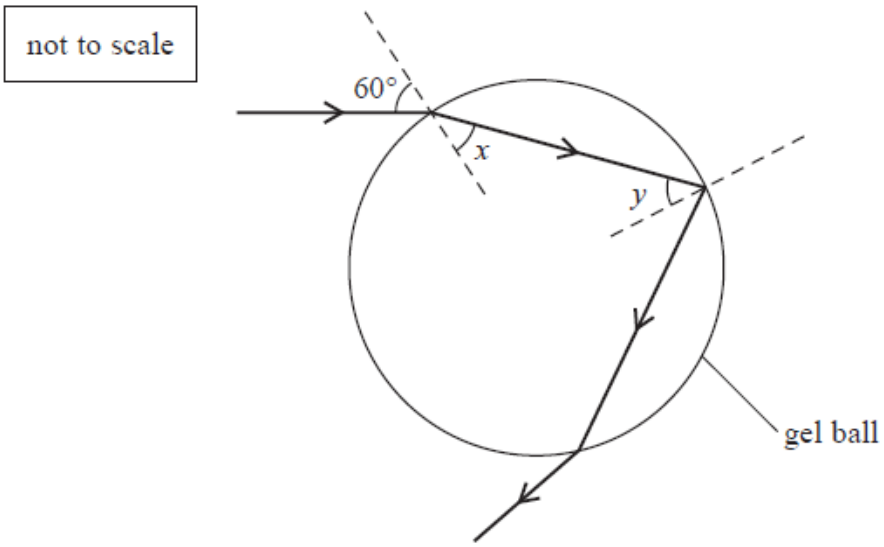
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(b) The student shines a narrow laser beam at a gel ball using the arrangement shown.



When the angle of incidence of the laser beam with the gel ball is 60°, light from the laser illuminates screen 2 following the path shown.



(i) Show that the angle x is about 40°.

refractive index of gel = 1.33

(2)

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(ii) Show that the critical angle for light striking the boundary of gel with air is about 50°.

(2)

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(iii) Angle x has the same value as angle y.
Explain whether light from the laser will be observed on screen 1.

(2)

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Q1.

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.

(1)

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

(2)

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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.

(2)

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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.

(2)

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(Total for question = 9 marks)

Q2.

Which of the following would increase the amount of detail (resolution) in an ultrasound scan?

☒ **A** faster wave speed

☒ **B** larger wavelength

☒ **C** lower frequency

☒ **D** shorter pulses

(Total for question = 1 mark)

Q3. Ultrasonic testing can be used for detecting corrosion inside metal pipes.

(a) Describe how the ultrasound travels through a metal.

(3)

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(b) A steel pipe was manufactured with a wall thickness of 4.0 cm.

After several years of use this pipe is tested for corrosion. A pulse of ultrasound is sent into the steel from the outer surface and the reflection from the inner surface is detected after a time of 5.1×10^{-6} s.

Determine whether the steel is corroded at this point.

speed of sound in steel = 5900 m s^{-1}

(4)

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(c) In this technique the ultrasound is emitted as pulses.

Explain why pulses are used rather than a continuous wave and how the duration of the pulse

affects the thickness of the pipe wall that can be accurately measured.

(3)

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(Total for Question = 10 marks)

Q4.

Weather stations monitor the position of storm clouds.

A microwave pulse is emitted from a transducer at a weather station. The pulse reflects from a storm cloud and is detected at the same transducer 340 μs later.

Calculate the distance between the storm cloud and the weather station.

(3)

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Distance = ...

(Total for question = 3 marks)

Q5.

An ultrasonic distance estimator can be used to measure the length of a room.



The estimator is held against one wall. It emits pulses of ultrasound and detects them when they return after reflection by the opposite wall.

(a) Explain why the ultrasound must be emitted in pulses.

(1)

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(b) The shortest distance the estimator can measure is 40 cm.
Calculate the longest pulse duration that would allow this distance to be measured.

speed of ultrasound in air = 330 m s^{-1}

(3)

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Pulse duration = ...

(c) When the estimator is pointed at a sloping wall, as shown in the photograph, it is unable to measure this distance.



Suggest why the estimator is unable to measure the distance to the sloping wall.

(1)

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(Total for question = 5 marks)

Q6.

Oilbirds are nocturnal birds. As they fly, they produce a high-pitched clicking sound to locate obstacles using a pulse-echo technique.

(a) Describe how the oilbirds use the pulse-echo technique to locate obstacles.

(2)

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(b) The frequency of sound in an oilbird's click is 2.0 kHz and a click is 2.0 ms in duration.

Determine whether these clicks can be used to locate obstacles at a distance of 50 cm.

speed of sound = 330 m s^{-1}

(5)

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(c) Explain why oilbirds emit pulses with shorter time intervals between them when they are close to an obstacle than when they are further from an obstacle.

(2)

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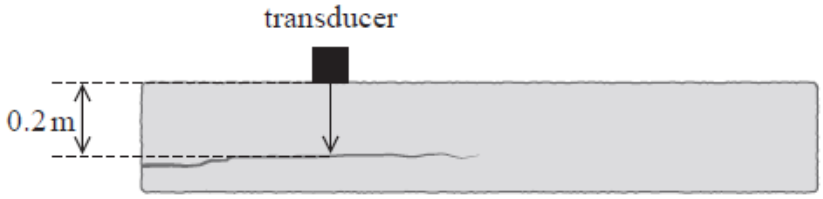
(Total for question = 9 marks)

Q7.

Concrete is a material used in buildings due to its high compressive strength.

A concrete post can be checked for internal cracks using a pulse-echo technique.
A transducer that transmits and receives ultrasound pulses is positioned against the side of the

post as shown.



A pulse hits a crack and is reflected and is then detected by the transducer.

Deduce whether a crack at a depth of 0.2 m can be detected.

time between pulses = 160 μs
speed of sound in concrete = 3200 m s^{-1}

(3)

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(Total for question = 3 marks)

Q8.

* In 1969, astronauts placed an array of mirrors on the surface of the Moon. Scientists can use these to monitor the distance from Earth to the Moon. Light from a laser is used with a pulse-echo technique.

Describe how the distance of the Moon from Earth can be determined using a pulse-echo technique.

(6)

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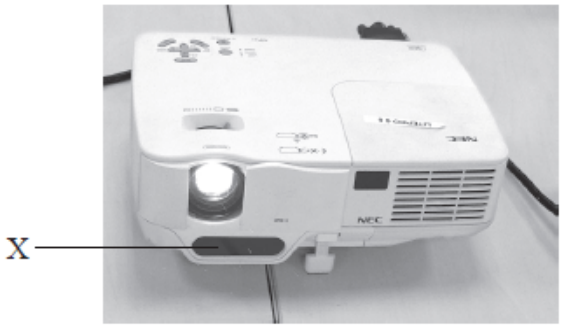
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(Total for question = 6 marks)

Q9.

The photograph shows a projector with an automatic focusing system that detects the distance to the screen so it can adjust the position of the lens to produce a clear image.



The part of the projector labelled X emits a pulse of infrared radiation and detects the pulse after it is reflected from a screen.

(a) The screen is 2.5 m from the projector.

Calculate the time taken between the emission and detection of the pulse.

(2)

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Time taken = ...

(b) State why the infrared radiation is emitted in pulses rather than as a continuous beam.

(1)

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(c) Suggest why infrared radiation is used rather than visible light.

(1)

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(Total for question = 4 marks)

Q10.

The idea of energy quantisation was used to explain the photoelectric effect, first observed by Heinrich Hertz.
When ultraviolet radiation is shone onto a metal surface, electrons may be released.
A cadmium surface is illuminated with light of wavelength 2.54×10^{-7} m.

Calculate the maximum kinetic energy of the photoelectrons released from the surface.

Work function of cadmium = 4.07 eV

(4)

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Maximum kinetic energy = ... J

(Total for question = 4 marks)

Q11.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

Fishermen use ultrasound pulses to detect shoals of fish under the surface of the water. Some fish are at a depth of 90 m below the surface.

Which of the following is the expression for the time *t*, in seconds, between the transmitted and the received pulse?

speed of sound in water = 1500 m s^{-1}

☒ **A** $t = \frac{90}{1500}$

☒ **B** $t = \frac{1500}{90}$

☒ **C** $t = \frac{90 \times 2}{1500}$

☒ **D** $t = \frac{1500}{90 \times 2}$

(Total for question = 1 mark)

Q12.

Prenatal ultrasound scans are performed to produce an image of a fetus.



The ultrasound wave is transmitted in pulses so that

(1)

☒ **A** exposure of the patient to ultrasound radiation is reduced.

☒ **B** smaller distances can be measured.

☒ **C** the reflected pulse can be detected before the next pulse is transmitted.

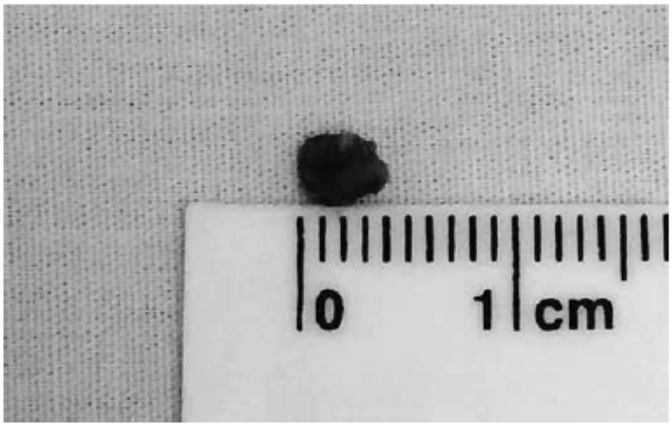
☒ **D** there is less diffraction.

(Total for question = 1 mark)

Q13.

Kidney stones can form from the deposit of minerals in a human kidney.

The photograph shows a kidney stone that has been removed from a hospital patient.



This kidney stone was detected using pulses of ultrasound.
The ultrasound used to detect this kidney stone had a frequency of 2.5 MHz.

Justify whether this was a suitable frequency for detecting this kidney stone.

Speed of sound in body tissue = 1500 m s^{-1}

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(Total for question = 4 marks)

Q14.

Radar is used to detect the position of an aircraft. Microwave pulses are emitted from the radar transducer. The pulses reflect from the aircraft and are received back at the same transducer. The time in seconds between emission and reception of the pulse is t.

The distance of the aircraft in metres from the transducer is given by

☐ **A** $2 \times 3.0 \times 10^8 \times t$

☐ **B** $2 \times 340 \times t$

☐ **C** $\frac{3.0 \times 10^8 \times t}{2}$

☐ **D** $\frac{340 \times t}{2}$

(Total for question = 1 mark)

Q15.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Ultrasound can be used to investigate the structure of organs of the human body using the pulse-echo technique.
The level of detail obtained depends on the wavelength and the length of the pulses.

Which line of the table shows a change to wavelength and a change to pulse length that would each improve the level of detail?

	Wavelength	Pulse length
☒ **A**	decrease	decrease
☒ **B**	increase	decrease
☒ **C**	decrease	increase
☒ **D**	increase	increase

(Total for question = 1 mark)