Name: ________________________________________

interference

**Date:**

**Time:**

**Total marks available:**

**Total marks achieved:** ______

## Questions

Q1.

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)**

Q2. 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)**

Q3. 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.

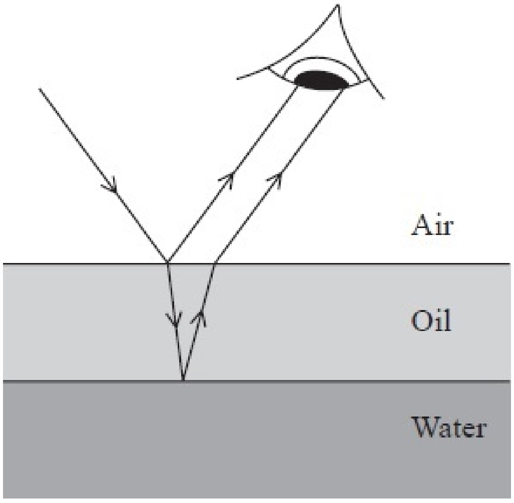
☒ **B** There is a node in the centre.

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

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

**(Total for Question = 1 mark)**

Q4. The diagram shows a ray of white light striking a thin layer of oil on water. Light reflects from the upper and lower surfaces of the oil, so that two rays reach the eye of an observer. With the eye in different positions the observer sees different colours from the oil.




Which of the following phenomena is not involved in the production of the colours seen?

☐ **A** polarisation

☐ **B** reflection

☐ **C** refraction

☐ **D** superposition

**(Total for Question = 1 mark)**

Q5.

Two coherent sources emit waves of wavelength λ which are in phase. The two waves meet at a point, having travelled slightly different distances. The waves now have a phase difference of 180º (π radians).

Which of the following could be the path difference at this point?

$\frac{3\lambda}{4}$ **A** $\frac{\lambda}{4}$

$\frac{3\lambda}{4}$ **B** $\frac{\lambda}{2}$

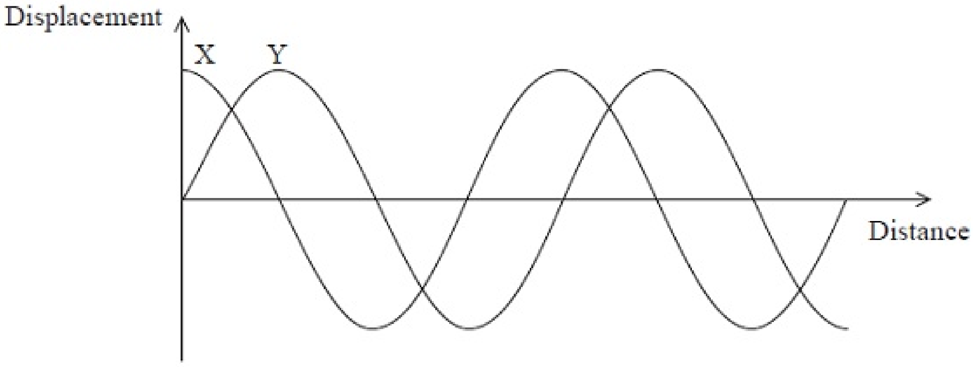
$\frac{3\lambda}{4}$ **C**

$\frac{3\lambda}{4}$

$\frac{3\lambda}{4}$ **D** $\frac{P_O}{P_I}$

**(Total for question = 1 marks)**

Q6. 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

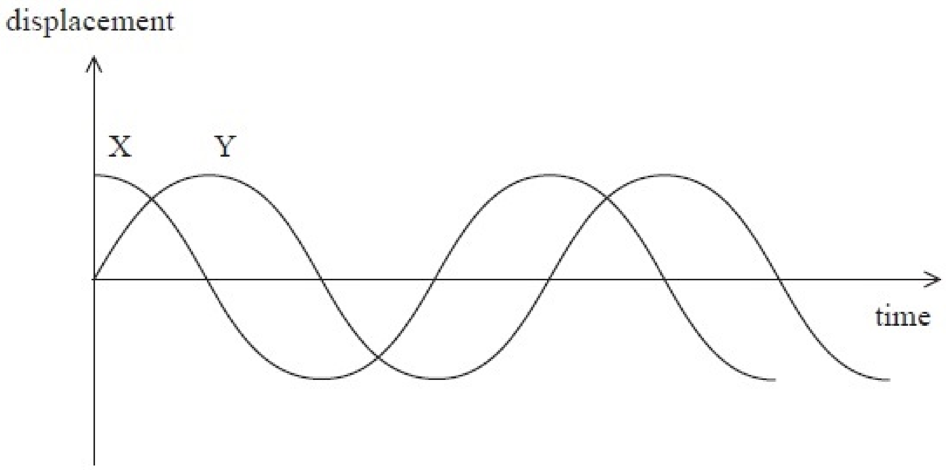
☒ **B** X and Y are in phase

☒ **C** X is π/2 radians ahead of Y

☒ **D** Y is π/2 radians ahead of X

**(Total for Question = 1 mark)**

Q7. 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

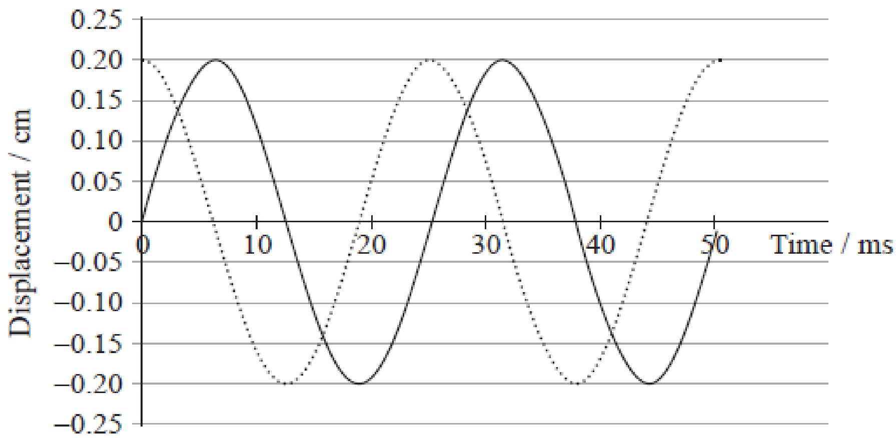
☒ **C** X is π/2 radians ahead of Y

☒ **D** Y is π/2 radians ahead of X

**(Total for Question = 1 mark)**

Q8.

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




What is the phase difference between these two waves?

**(1)**

☒ **A** 6 ms

☒ **B** 0.20 cm

☒ **C** π radians

☒ **D** 90 degrees

**(Total for question = 1 mark)**

Q9.

Waves from a point light source follow separate paths and recombine at a point after travelling different distances.

When the waves recombine the path difference is $\lambda/2$. The corresponding phase difference is

☒ **A** 360°

☒ **B** π/2 radians

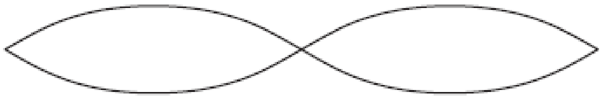
☒ **C** 180°

☒ **D** 2π radians

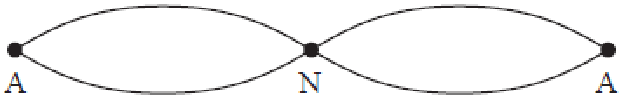
**(Total for question = 1 mark)**

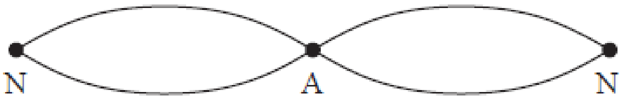
Q10.

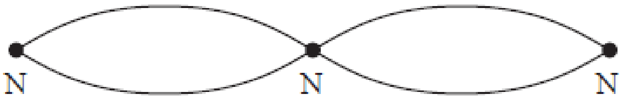
The diagram represents a stationary wave on a string.

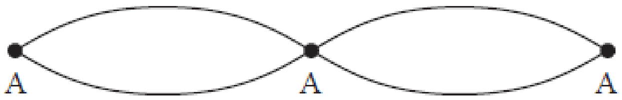


Which diagram correctly shows the position of nodes N and/or antinodes A?

☒ **A** 


☒ **B** 

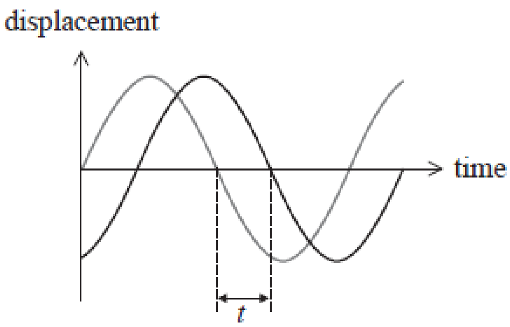

☒ **C** 


☒ **D** 


**(Total for question = 1 mark)**

Q11.

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




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

**(1)**

☒ **A** $\frac{2\pi t}{T}$

☒ **B** $\frac{\pi t}{T}$

☒ **C** $\frac{2\pi t}{f}$

☒ **D** $\frac{\pi t}{f}$

**(Total for question = 1 mark)**

Q12.

For two waves of light to be coherent the waves must

**(1)**

☒ **A** always have a phase difference equal to 0.

☒ **B** oscillate in the same plane.

☒ **C** have a similar amplitude.

☒ **D** originate from one source.

**(Total for question = 1 mark)**

Q13.

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

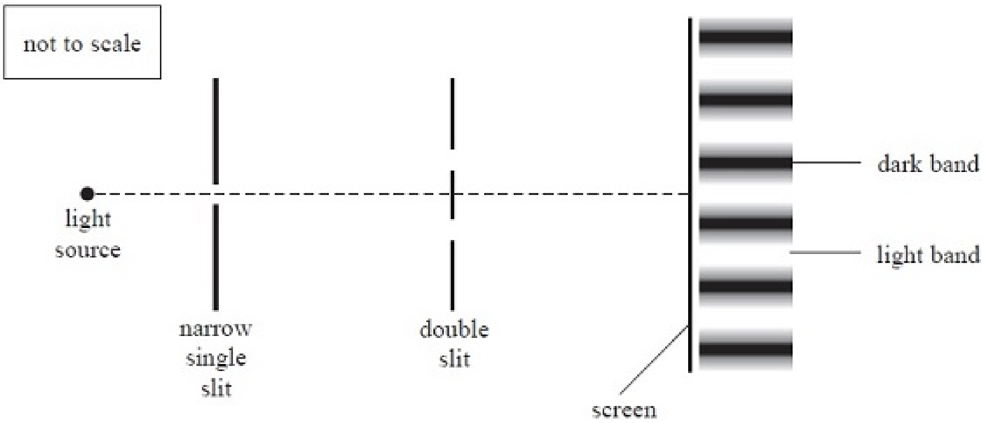
☒ **D** 8 m

**(Total for question = 1 mark)**

Q14. 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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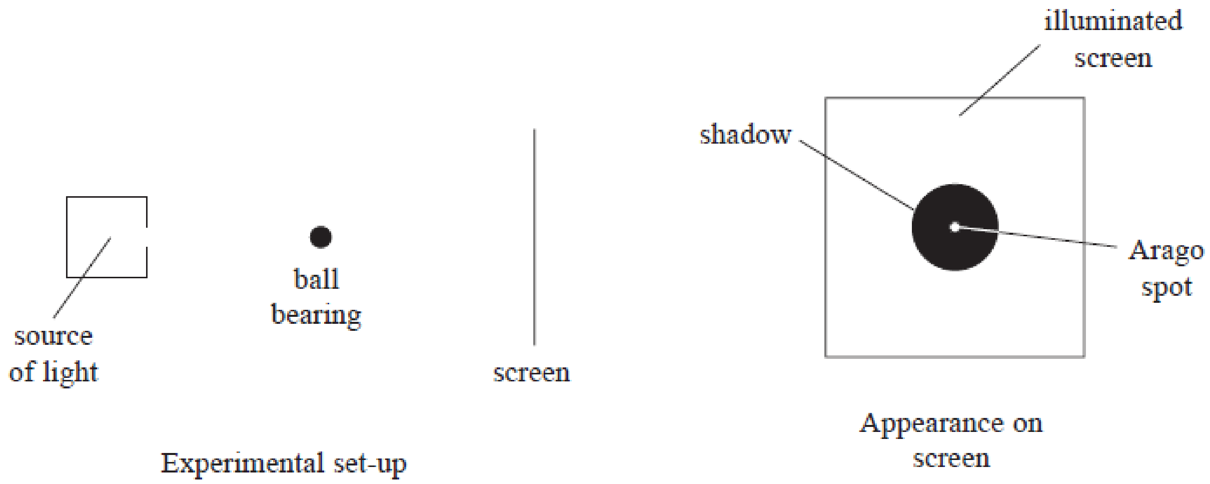
**(Total for Question = 7 marks)**

Q15.

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.

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**(Total for question = 5 marks)**

Q16.

(a) State what is meant by the principle of superposition of waves.

**(2)**

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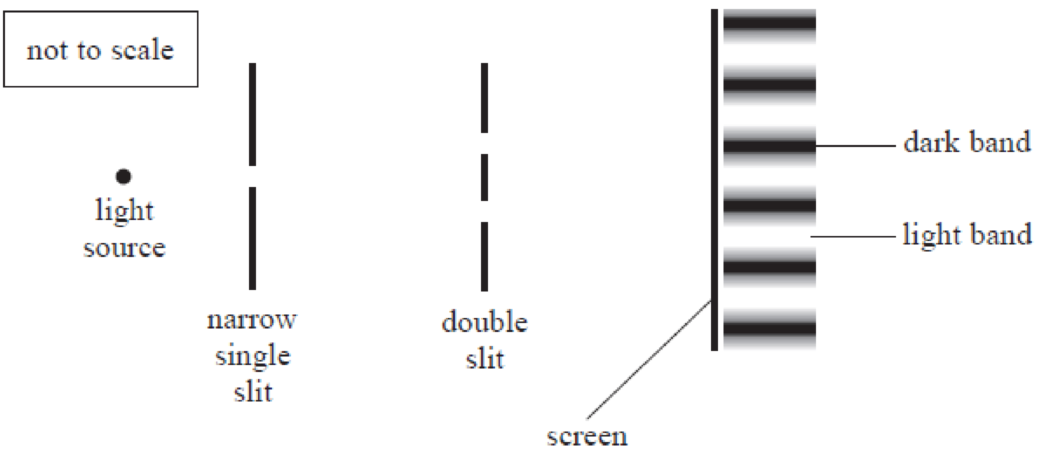
(b) The arrangement in the diagram demonstrates the effect of superposition. When a monochromatic light source is used, a series of dark and light bands is formed on the screen.




*(i) Explain how the dark and light bands are formed by light reaching the screen from the two slits of the double slit.

**(3)**

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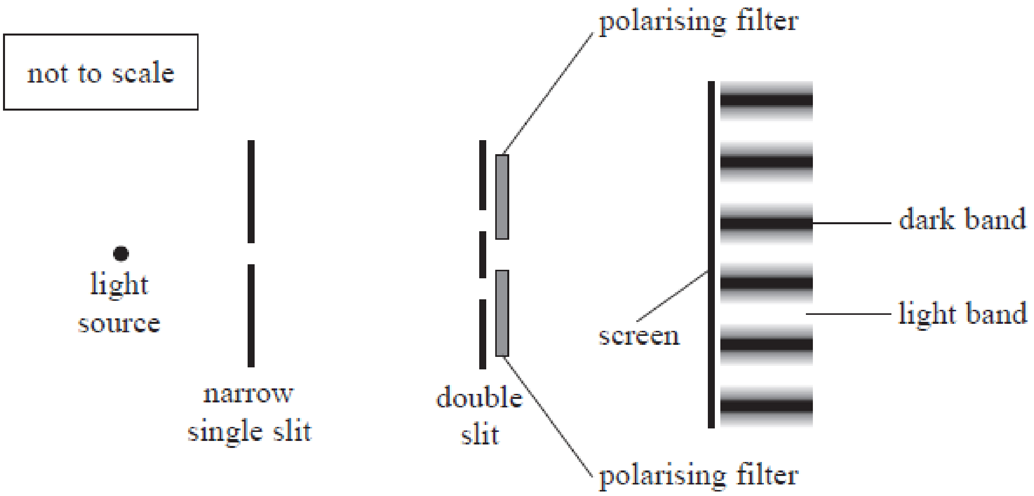
(ii) Polarising filters are placed behind the slits as shown. When the planes of polarisation are parallel, the pattern of light and dark bands is still seen.




If one polarising filter is rotated through 90° there are no dark bands and the screen is illuminated evenly.

Explain why there are no dark bands when one filter has a plane of polarisation at 90° to that of the other filter.

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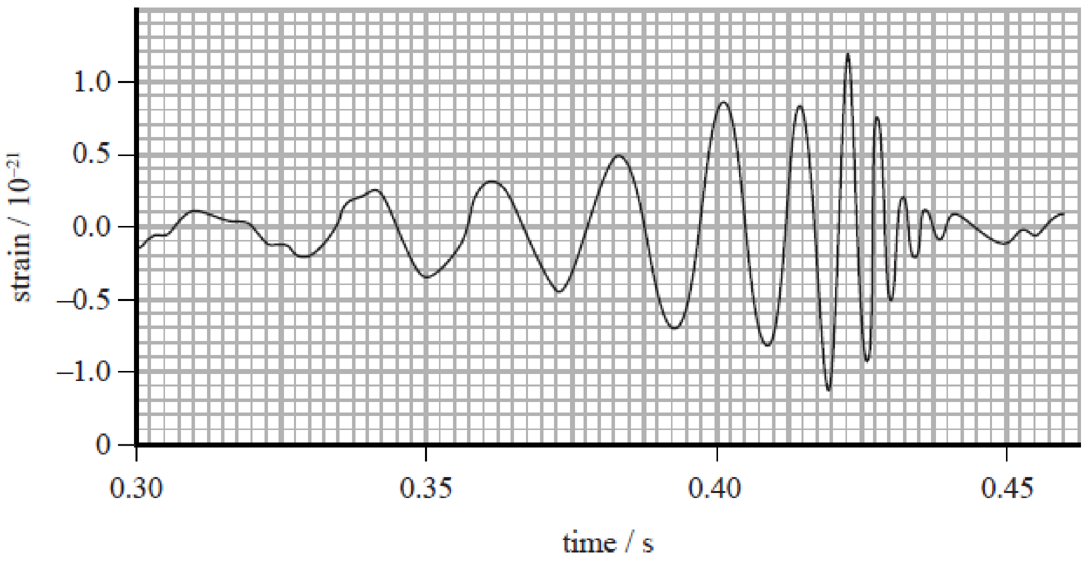
Q17.

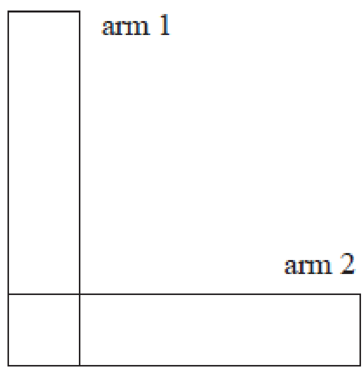
In 2016 scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that gravitational waves had been detected.

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 = $8.8 \times 10^{-16}$ m

**(3)**

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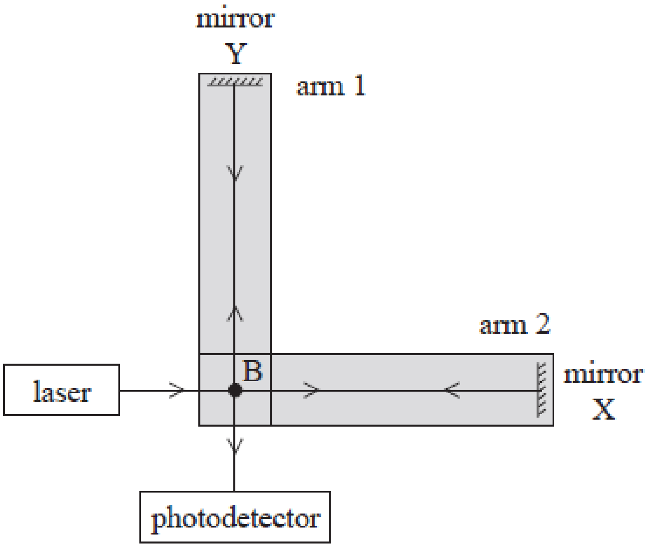
(ii) In the LIGO detector, any change in the lengths of the arms is detected using a laser beam and photodetector.




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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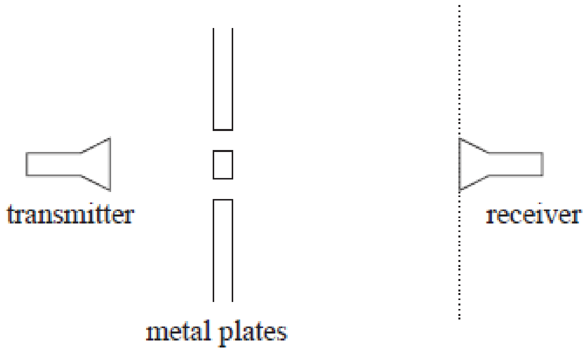
**(Total for question = 9 marks)**

Q18.

Details supplied with a school microwave transmitter and receiver include the following information:

| |
|---|
| Transmitter supplies a 10 GHz polarised EM wave.<br>Receiver detects EM waves in a single plane containing the direction of propagation, producing an audible output proportional to the microwave intensity. |

A student uses the microwave transmitter and receiver to investigate interference using the set-up shown.




As the receiver is moved along the dotted line, alternate points of maximum and minimum intensity are detected.

Explain why points of maximum and minimum intensity are detected.

(4)

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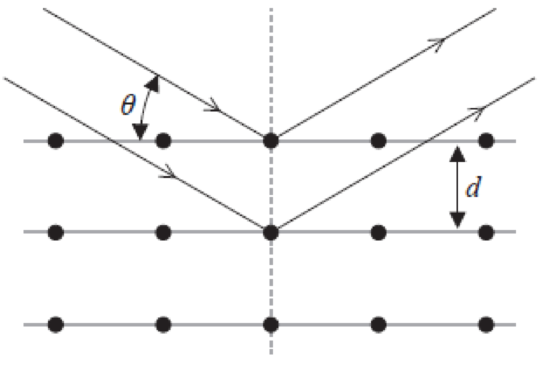
**(Total for question = 4 marks)**

Q19.

An electron beam can be used to explore the structure of solid materials. The diagram shows an electron beam reflected by the top two layers of atoms within a material. The two layers are separated by a distance *d*.




(i) Show that the extra distance travelled by the electron beam reflecting off the second layer of atoms is given by $2d\sin\theta$.

$\theta$ is the angle between the beam and each layer of atoms.

You may add to the diagram.

**(2)**

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(ii) Give one reason why there is more than one ring shown in both Figure 1 and Figure 2.

**(1)**

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**(Total for question = 3 marks)**

Q20.

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.

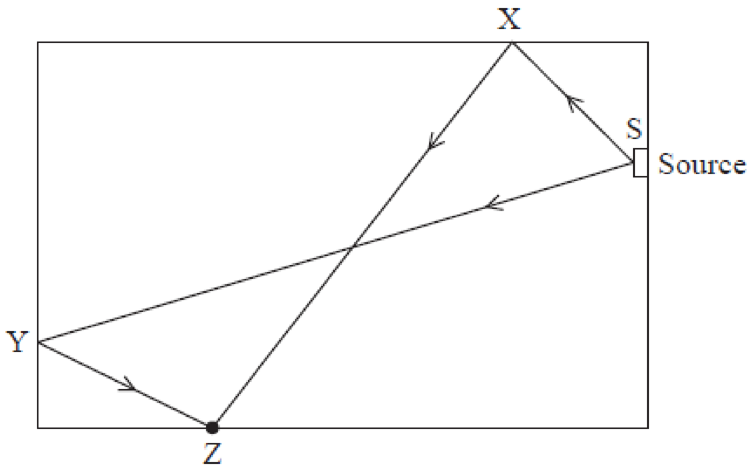
The photograph shows some lighter areas where the chocolate is melting and some darker areas where the chocolate remains hard.

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.

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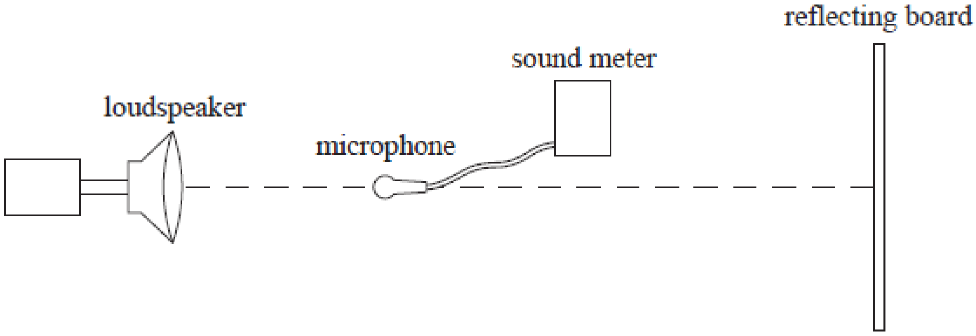
**(Total for question = 11 marks)**

Q21.

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

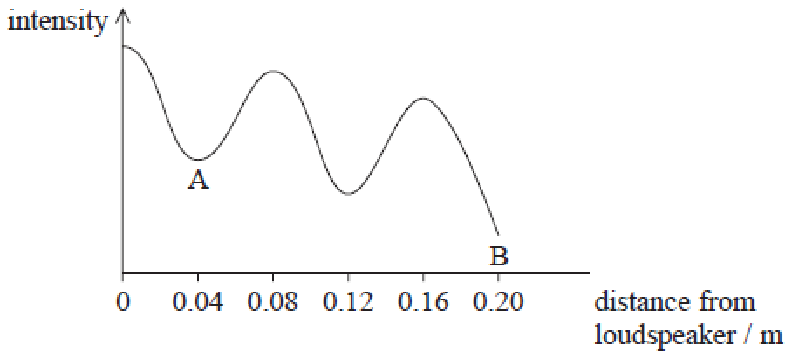
They stand 80 m from a building. One student hits two pieces of wood together to make a loud sound and a short time later an echo is heard. The other student uses a stopwatch to measure the time interval *t* between the two pieces of wood being hit and the echo being heard. The procedure is repeated.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

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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)**

Q22.

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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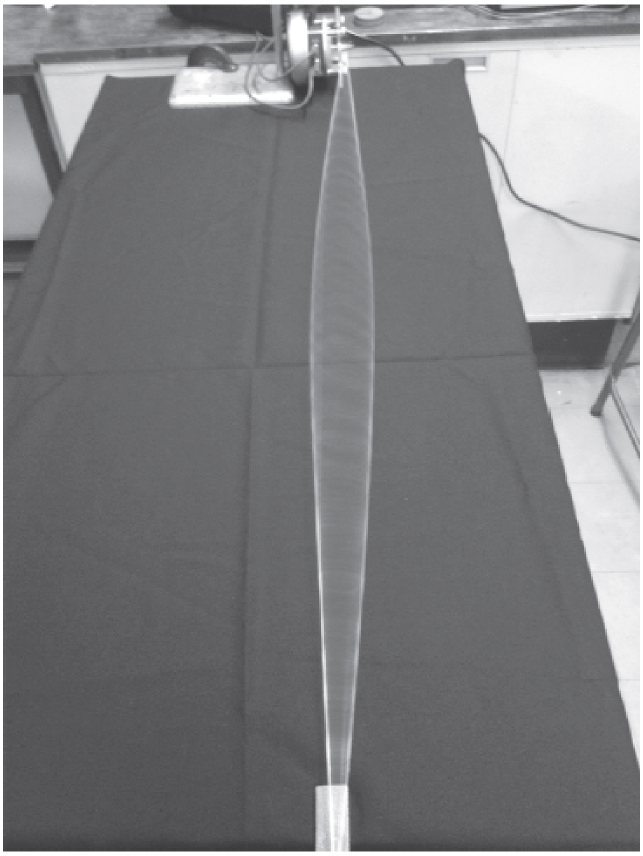
**(Total for question = 12 marks)**

Q23.

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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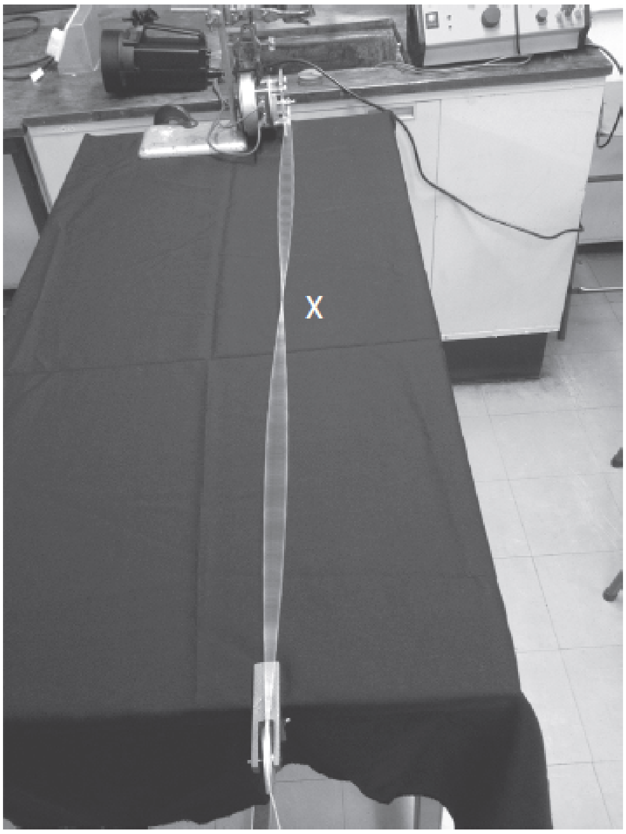
Speed of the waves = ..........................................................

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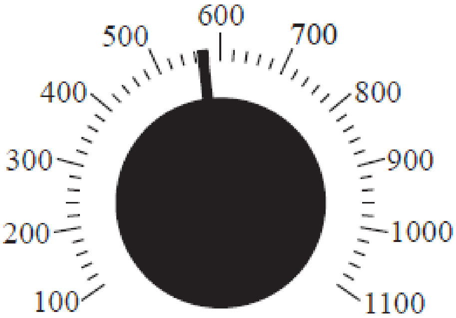
(d) The frequency of the vibration generator is adjusted by turning the dial shown below. The student measures the frequency of vibration by reading from the scale shown on the dial.




Explain a disadvantage of this method of measuring the frequency.

**(2)**

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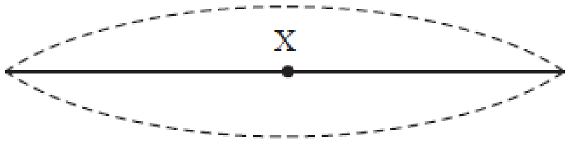
**(Total for question = 14 marks)**

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)**