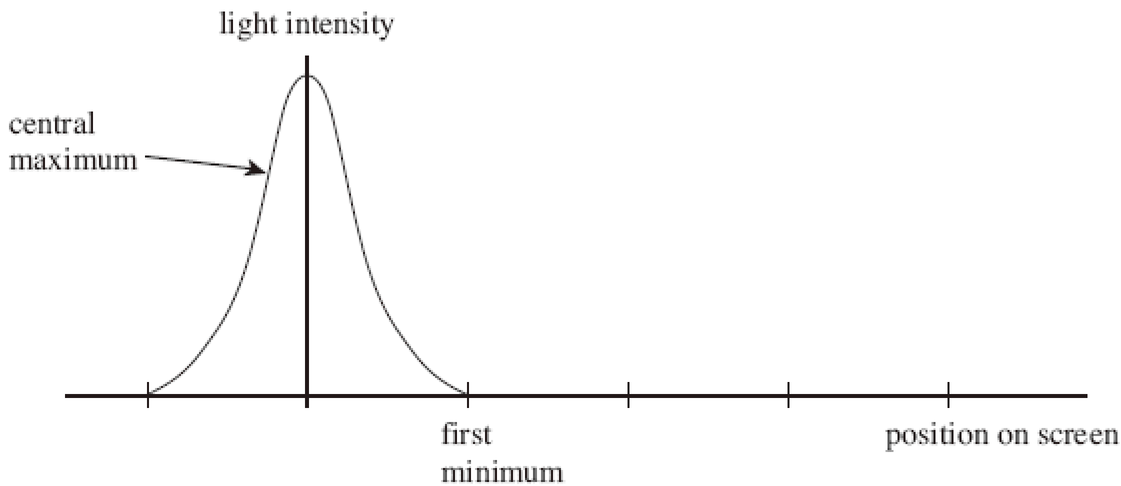
1 A stationary wave is formed on a stretched string. Discuss the formation of this wave.
Your answer should include:

- an explanation of how the stationary wave is formed
- a description of the features of the stationary wave
- a description of the processes that produce these features.

The quality of your written communication will be assessed in your answer.

(Total 6 marks)

2 A single slit diffraction pattern is produced on a screen using a laser. The intensity of the central maximum is plotted on the axes in the figure below.



(a) On the figure above, sketch how the intensity varies across the screen to the right of the central maximum.

(2)

(b) A laser is a source of *monochromatic*, *coherent* light. State what is meant by

monochromatic light ____

____

coherent light ____

____

(2)

(c) Describe how the pattern would change if light of a longer wavelength was used.

____

____

(1)

(d) State **two** ways in which the appearance of the fringes would change if the slit was made narrower.

___

___

(2)

(e) The laser is replaced with a lamp that produces a narrow beam of white light. Sketch and label the appearance of the fringes as you would see them on a screen.

(3)

(Total 10 marks)

3

(a) Define the amplitude of a wave.

___

___

(1)

(b) (i) Other than electromagnetic radiation, give **one** example of a wave that is transverse.

___

(1)

(ii) State **one** difference between a transverse wave and a longitudinal wave.

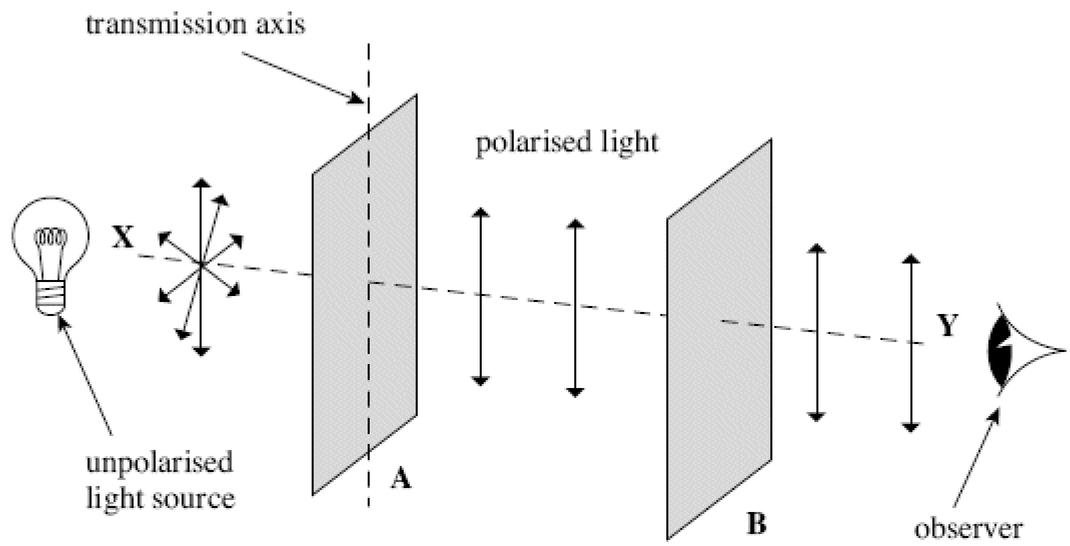
___

___

(1)

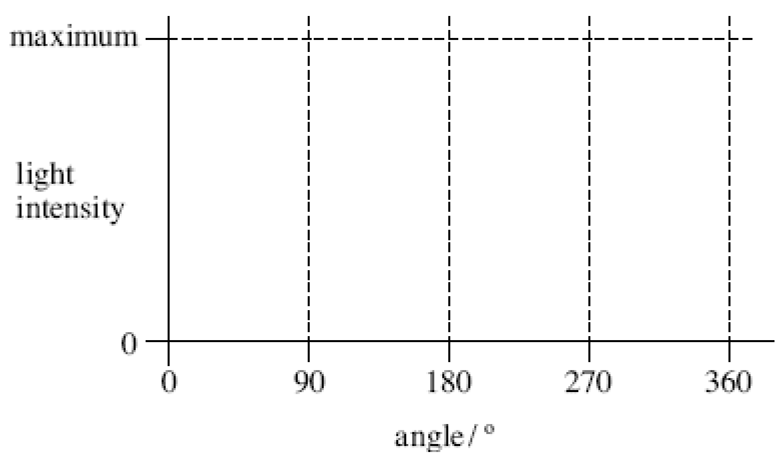
(c) The figure below shows two identical polarising filters, **A** and **B**, and an unpolarised light source. The arrows indicate the plane in which the electric field of the wave oscillates.

(i) If polarised light is reaching the observer, draw the direction of the transmission axis on filter **B** in the figure below.



(1)

(ii) The polarising filter **B** is rotated clockwise through 360º about line **XY** from the position shown in the figure above. On the axes below, sketch how the light intensity reaching the observer varies as this is done.



(2)

(d) State **one** application, other than in education, of a polarising filter and give a reason for its use.

____

____

____

____

(2)
(Total 8 marks)

4 (a) State what is meant by *coherent sources* of light.

(2)

(b)

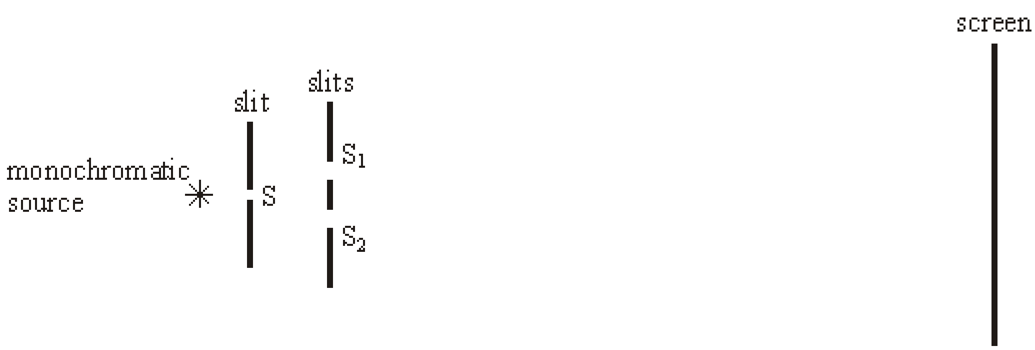


Figure 1

Young's fringes are produced on the screen from the monochromatic source by the arrangement shown in **Figure 1**.

You may be awarded marks for the quality of written communication in your answers.

(i) Explain why slit S should be narrow.

(ii) Why do slits S_1 and S_2 act as coherent sources?

(4)

(c) The pattern on the screen may be represented as a graph of intensity against position on the screen. The central fringe is shown on the graph in **Figure 2**. Complete this graph to represent the rest of the pattern by drawing on **Figure 2**.

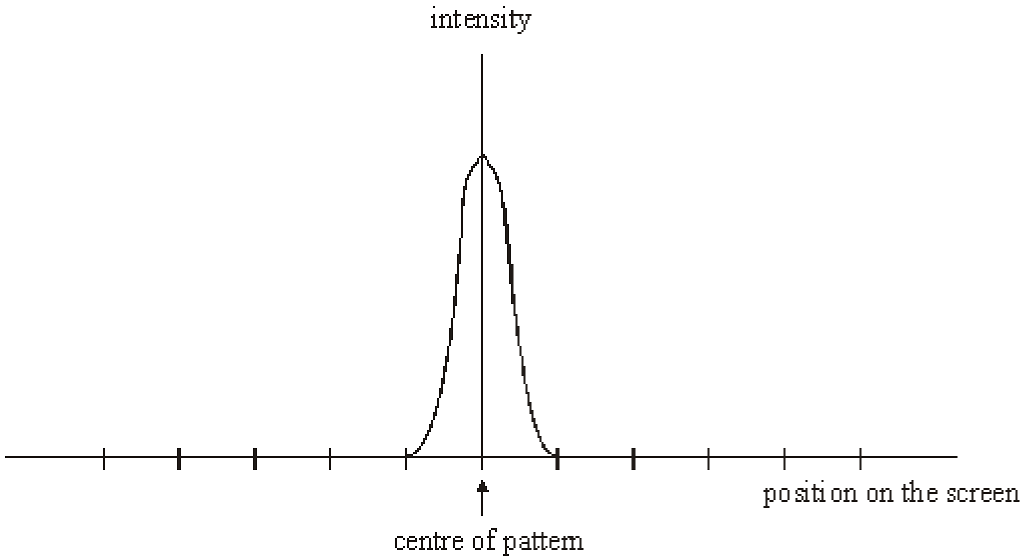
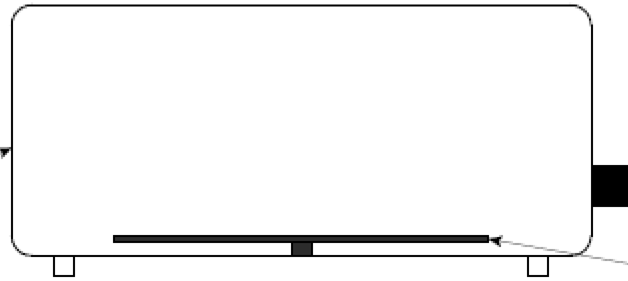


Figure 2

(2)
(Total 8 marks)

5 **Figure 1** is a diagram of a microwave oven.

Figure 1



A student wants to use the stationary waves formed in the microwave oven to measure the frequency of the microwaves emitted by the transmitter.

(a) Suggest how stationary waves are formed in the microwave oven.

___

___

___

___

___

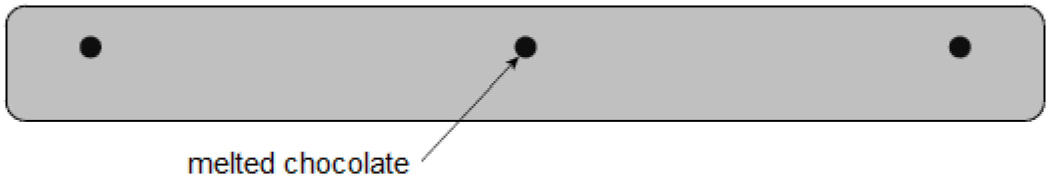
___

___

(2)

(b) The student removes the turntable and places a bar of chocolate on the floor of the oven. He then switches the oven on for about one minute. When the chocolate is removed the student observes that there are three small patches of melted chocolate with unmelted chocolate between them. **Figure 2** is a full-sized diagram of the chocolate bar.

Figure 2



Suggest why the chocolate only melts in the positions shown.

____

____

____

____

(2)

(c) Calculate, by making suitable measurements on **Figure 2**, the frequency of the microwaves used by the oven.

frequency = ____________________ Hz

(5)

(d) Explain why most microwave ovens contain a rotating turntable on which the food is placed during cooking.

____

____

____

(1)

(Total 10 marks)

6 (a) Explain what is meant by a progressive wave.

____

____

____

(2)

(b) **Figure 1** shows the variation with time of the displacement of one point in a progressive wave.

Figure 1

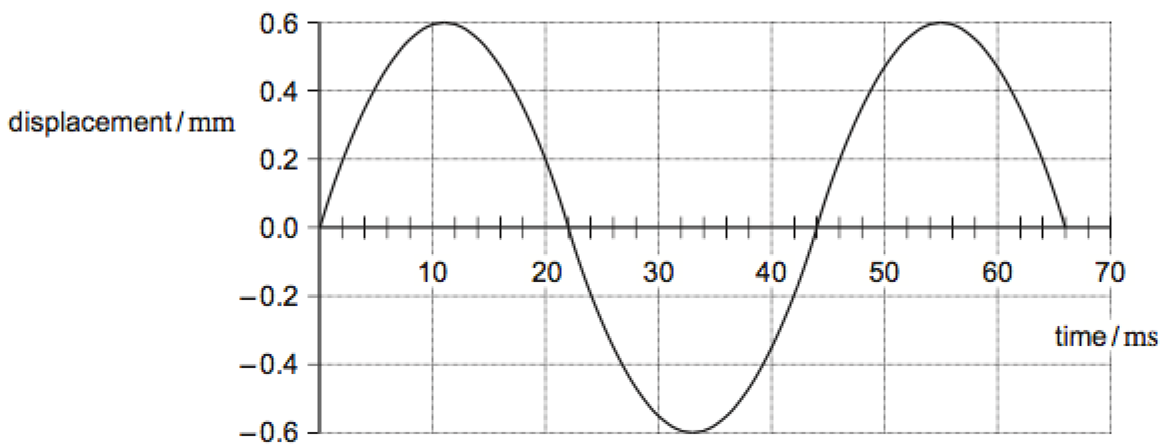
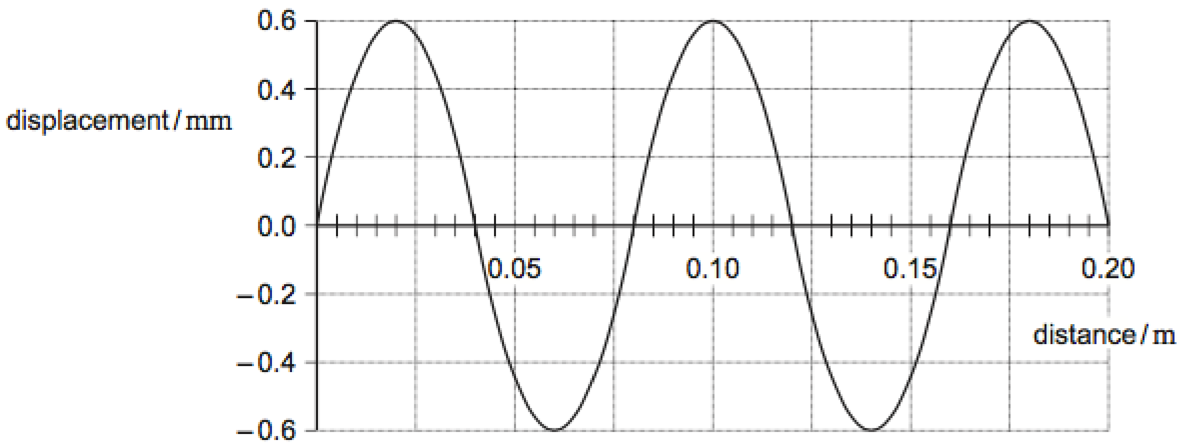


Figure 2 shows the variation of displacement of the same wave with distance.

Figure 2



Use **Figures 1 and 2** to determine

(i) the amplitude of the wave

amplitude = ____________________ mm

(1)

(ii) the wavelength of the wave

wavelength = ____________________ m

(1)

(iii) the frequency of the wave

frequency = ____________________ Hz

(1)

(iv) the speed of the wave

speed = ____________________ m s^{-1}

(1)

(c) Which of the following statements apply?
Place a tick (✓) in the right-hand column for each correct statement.

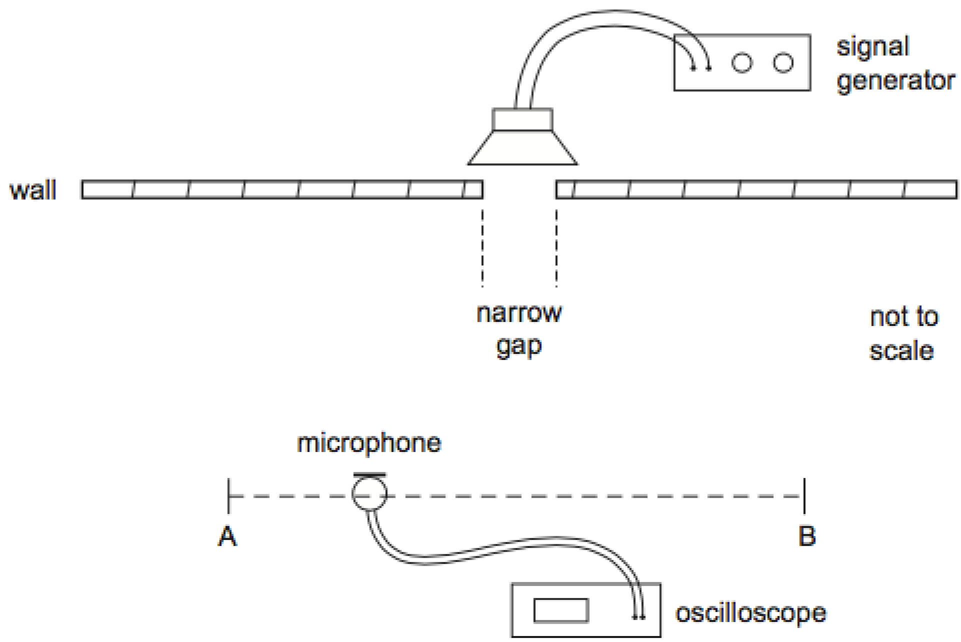
	✓ if correct
sound waves are transverse	
sound waves are longitudinal	
sound waves can interfere	
sound waves can be polarised	

(1)

(d) In an investigation, a single loudspeaker is positioned behind a wall with a narrow gap as shown in **Figure 3**.

A microphone attached to an oscilloscope enables changes in the amplitude of the sound to be determined for different positions of the microphone.

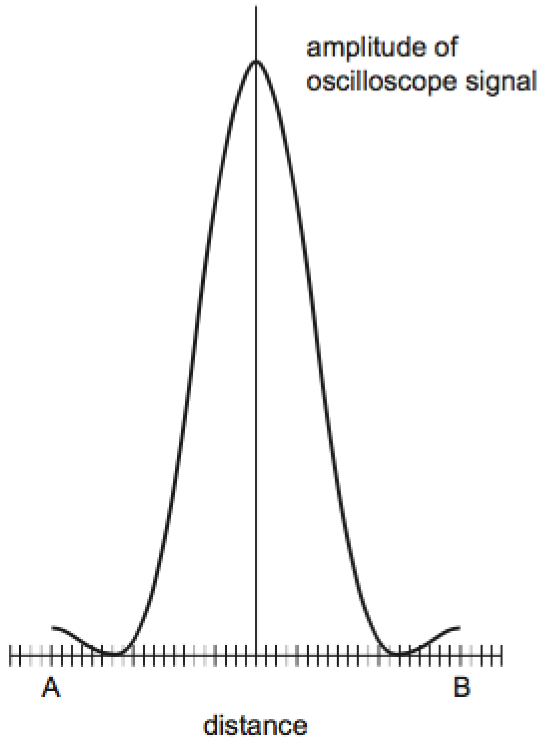
Figure 3



The amplitude of sound is recorded as the microphone position is moved along the line AB a large distance from the gap.

The result of the measurements is shown in **Figure 4**.

Figure 4



The signal generator is adjusted so that sound waves of the same amplitude but of a higher frequency are emitted by the loudspeaker. The investigation using the apparatus shown in **Figure 3** is then repeated.

Explain the effect this has on **Figure 4**.

____

____

____

____

____

____

____

____

____

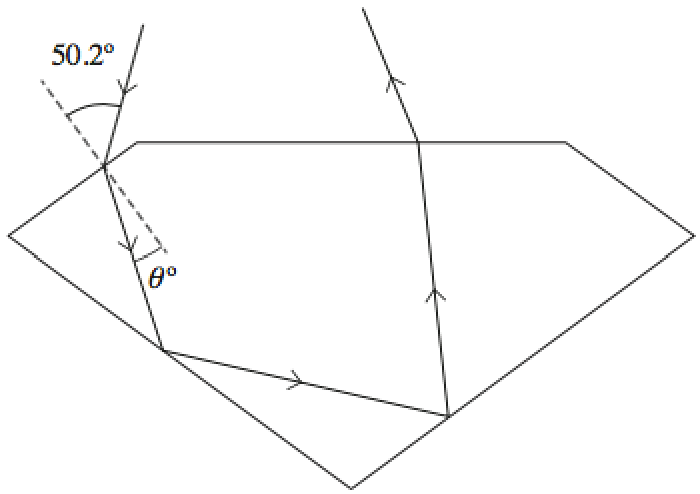
____

(3)

(Total 10 marks)

7 Diamond jewels sparkle because light that enters the diamond at different incident angles is reflected back to an observer. **Figure 1** shows the path of one of these incident rays through a diamond.

Figure 1



(a) (i) Calculate the critical angle for diamond.

Refractive index of diamond = 2.42

critical angle = ____________________ degree

(2)

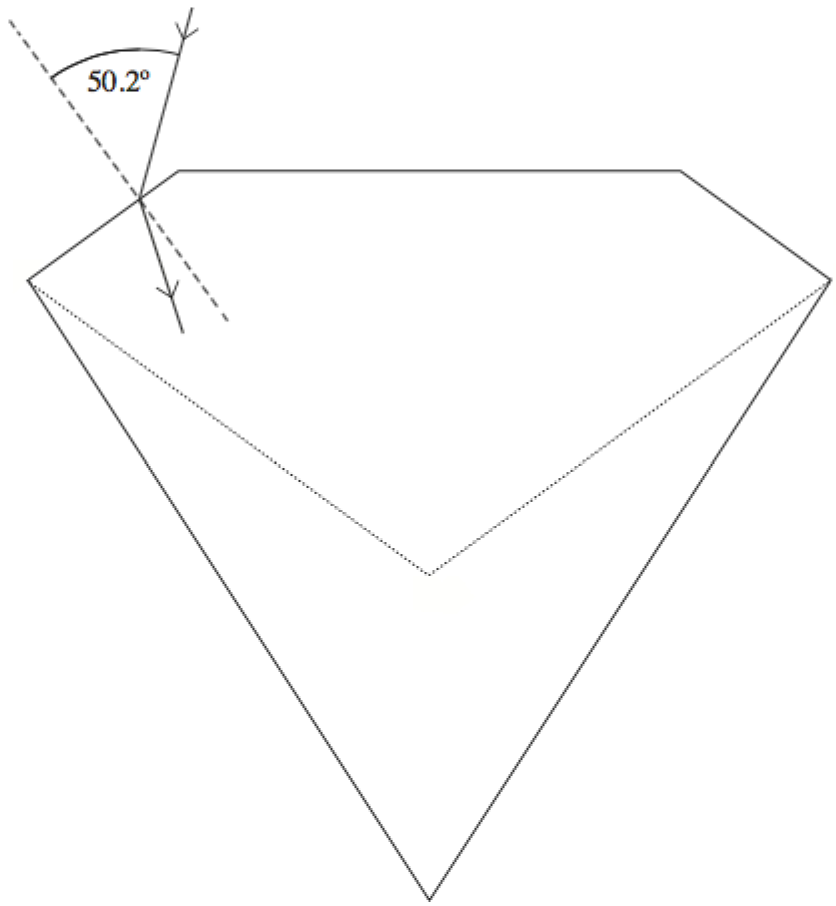
(ii) The ray shown in **Figure 1** enters at an angle of incidence of 50.2°.
Calculate the angle of refraction θ.

θ = ____________________ degree

(2)

(iii) The angles of a diamond are chosen to maximise the amount of light reflected. **Figure 2** shows a diamond with different angles to that of a normally shaped diamond. The dotted lines show the normal shape of a diamond.

Figure 2



Draw on **Figure 2** the path of the ray until it leaves the diamond.

(2)

(iv) Moissanite is a transparent material with a refractive index of 2.67.

Discuss whether this material, if made to the diamond shape shown in **Figure 1**, would reflect light back more or less than diamond.

____

____

____

____

____

____

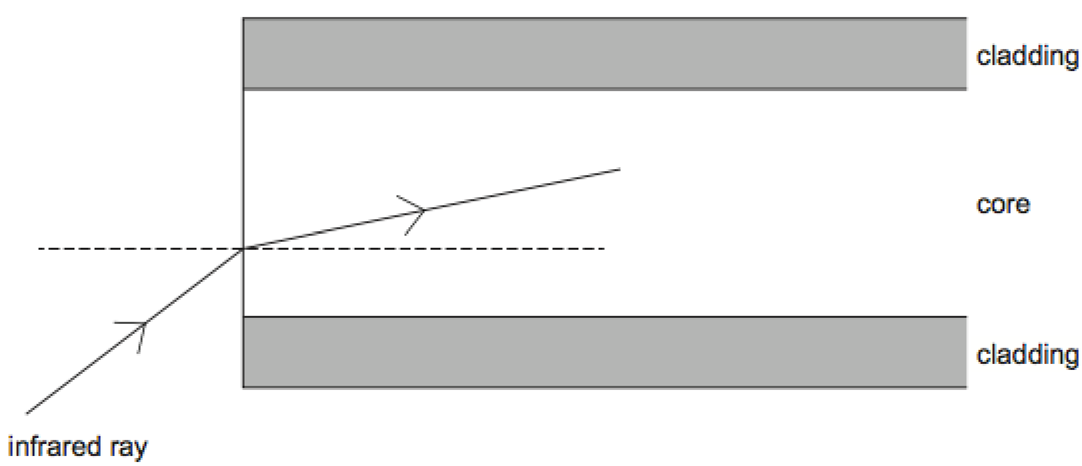
____

____

(2)

(b) **Figure 3** shows an infrared ray entering an optical fibre. The refractive index of the core is 1.55 at infrared frequencies.

Figure 3



(i) Calculate the speed at which infrared radiation travels in the core.

speed = ____________________ m s^{-1}

(1)

(ii) The wavelength of this infrared radiation is 1300 nm in air.
Calculate the wavelength of infrared in the core.

wavelength = ____________________ m

(2)

(iii) State **one** reason for surrounding the core with cladding.

____

____

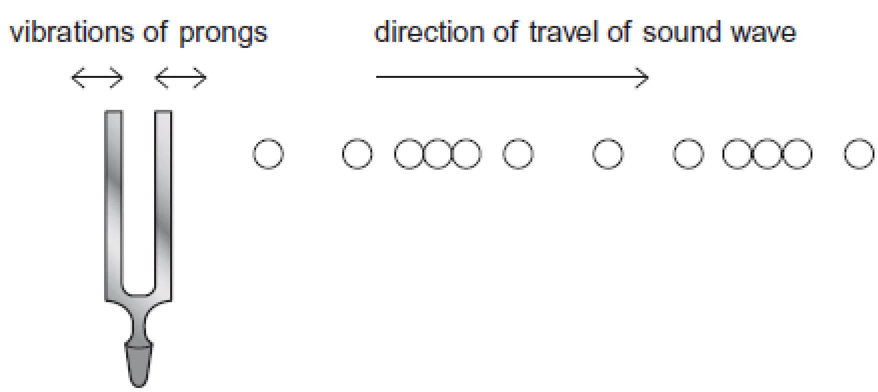
(1)

(Total 12 marks)

8 Musicians can use tuning forks to tune their instruments.
A tuning fork produces a specific frequency when it vibrates.

Figure 1 shows a tuning fork vibrating in air at a single instant in time.
The circles represent the positions of air particles in the sound wave.

Figure 1



(a) The tuning fork emits a wave that has a frequency of 0.51 kHz.

(i) State the meaning of the term frequency of a wave.

____

(1)

(ii) Air particles vibrate in different phases in the direction in which the wave is travelling.

Calculate the minimum separation of particles that vibrate 180° out of phase.

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

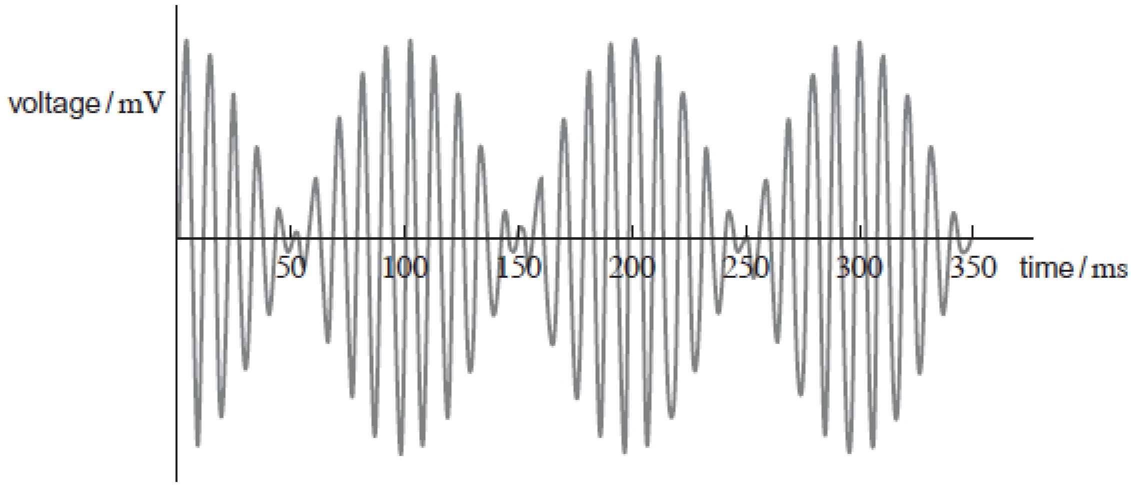
minimum separation ____________________ m

(3)

(b) A student sets a tuning fork of lower frequency vibrating at the same time as the 0.51 kHz tuning fork in part (a).

The student detects the resultant sound wave with a microphone. The variation with time of the voltage generated by the microphone is shown in **Figure 2**.

Figure 2



(i) Explain why the two tuning forks are **not** coherent sources of sound waves.

____

____

____

____

(2)

(ii) Explain why the resultant sound has a minimum amplitude at 50 ms.

____

____

____

____

____

(3)

(iii) Calculate the frequency of the tuning fork that emits the lower frequency.

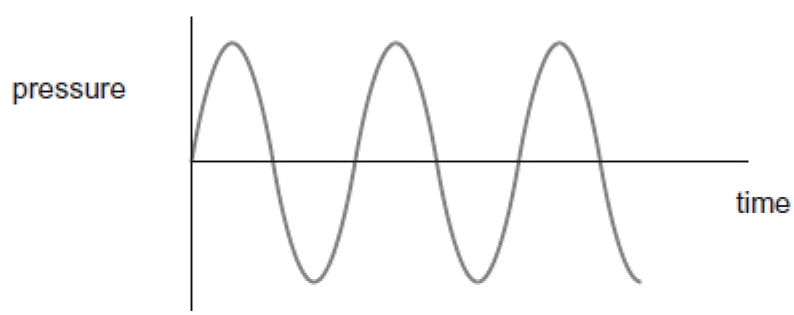
frequency ____________________ Hz

(3)

(c) A signal generator connected to a loudspeaker produces a sinusoidal sound wave with a frequency of 440 Hz.

The variation in air pressure with time for this sound is shown in **Figure 3**.

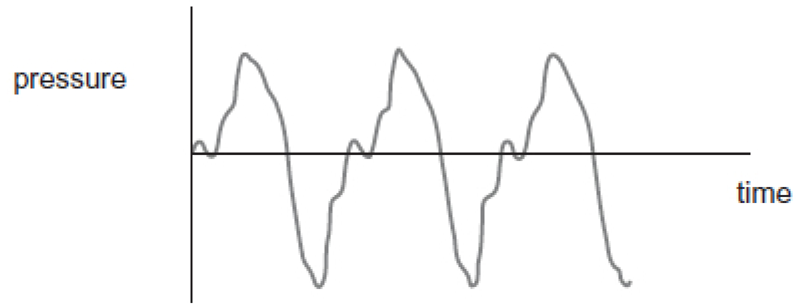
Figure 3



A violin string has a fundamental frequency (first harmonic) of 440 Hz.

Figure 4 shows the variation in air pressure with time for the sound created by the violin string.

Figure 4



(i) The two sounds have the same pitch but sound different.

What term describes the difference between the sounds heard?
Tick (✓) the correct answer.

Frequency modulation	☐
Octaves	☐
Path difference	☐
Quality	☐

(1)

(ii) The complex sound in **Figure 4** can be electronically synthesised.

Describe the process of electronically synthesising this sound.

____

____

____

____

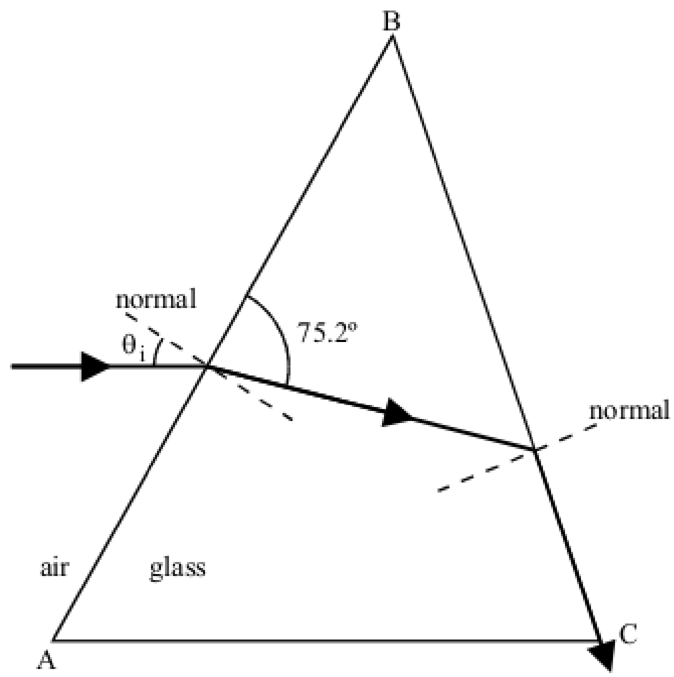
____

____

____

(3)
(Total 16 marks)

9 The diagram shows a ray of light passing from air into a glass prism at an angle of incidence θ_i.
The light emerges from face BC as shown.
refractive index of the glass = 1.55



(a) (i) Mark the critical angle along the path of the ray with the symbol θ_c.

(ii) Calculate the critical angle, θ_c.

___

___

___

___

(3)

(b) For the ray shown calculate the angle of incidence, θ_i.

___

___

___

___

(2)

(c) Without further calculations draw the path of another ray of light incident at the same point on the prism but with a smaller angle of incidence. The path should show the ray emerging from the prism into the air.

(3)

(Total 8 marks)

10 Two waves with amplitudes a and $3a$ interfere.

The ratio $\dfrac{\text{amplitude at an interference maximum}}{\text{amplitude at an interference minimum}}$ is

A 2

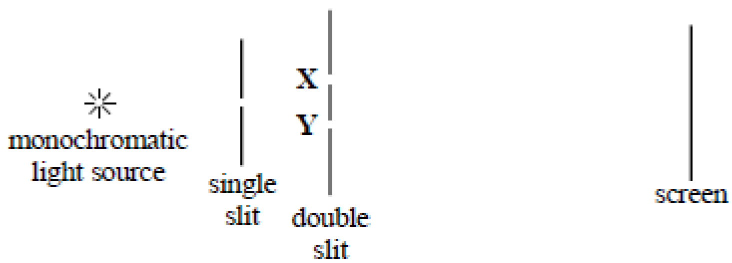
B 3

C 4

D infinity

(Total 1 mark)

11 The diagram represents the experimental arrangement used to produce interference fringes in Young's double slit experiment.



The spacing of the fringes on the screen will increase if

A the width of the single slit is increased

B the distance **XY** between the two slits is increased

C a light source of lower frequency is used

D the distance between the single and double slits is decreased

(Total 1 mark)

12 Young's two slit interference pattern with red light of wavelength 7.0×10^{-7} m gives a fringe separation of 2.0 mm.

What separation, in mm, would be observed at the same place using blue light of wavelength 45×10^{-7} m?

A 0.65

B 1.3

C 2.6

D 3.1

(Total 1 mark)

13 Figures **1** and **2** each show a ray of light incident on a water-air boundary. **A, B, C** and **D** show ray directions at the interface.

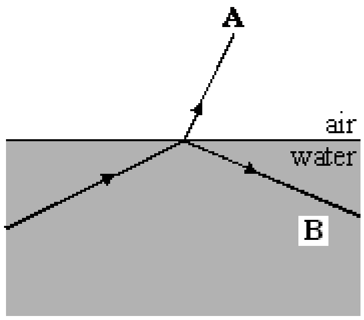


Figure 1

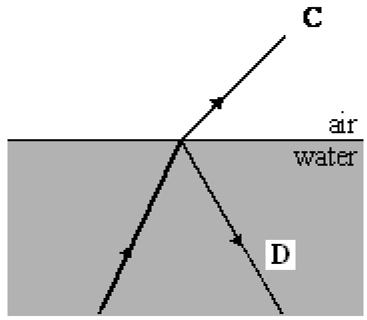


Figure 2

(a) Circle the letter below that corresponds to a direction in which a ray **cannot** occur.

A **B** **C** **D**

(1)

(b) Circle the letter below that corresponds to the direction of the faintest ray.

A **B** **C** **D**

(1)

(Total 2 marks)

14 Which one of the following statements about stationary waves is true?

A Particles between adjacent nodes all have the same amplitude.

B Particles between adjacent nodes are out of phase with each other.

C Particles immediately on either side of a node are moving in opposite directions.

D There is minimum disturbance of the medium at an antinode.

(Total 1 mark)

Mark schemes

1 **The student's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The student's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

Answers may cover some of the following points:

- *(1) a wave and its reflection / waves travelling in opposite directions meet / interact / overlap / cross / pass through etc*

  point (1) must be stated together i.e it should not be necessary to search the whole script to find the two parts namely the directions of the waves and their meeting
- *(2) same wavelength (or frequency)*
- *(3) node − point of minimum or no disturbance*

  points (3) may come from a diagram but only if the node is written in full and the y-axis is labelled amplitude or displacement
- *(4) antinode − is a point of maximum amplitude*

  point (4) may come from a diagram but only if the antinode is written in full and the y-axis is labelled amplitude or displacement
- *(5) node - two waves (always) cancel / destructive interference / 180° phase difference / in antiphase [out of phase is not enough] (of the two waves at the node) [not peak meets trough]*
- *(6) antinode − reinforcement / constructive interference occurs / (displacements) in phase*
- *(7) mention of <u>superposition</u> [not superimpose] of the two waves*
- *(8) energy is not transferred (along in a standing wave)*.

  if any point made appears to be contradicted elsewhere the point is lost − no bod's

High Level (Good to excellent): 5 or 6 marks
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

6 marks: points (1) ***AND*** *(2)* ***with*** *4 other points which must include point (4) or the passage must indicate that the wave is oscillating at an antinode*

5 marks: points (1) ***AND*** *(2)* ***with*** *any three other points*

although point (1) may not be given as a mark the script can be searched to see if its meaning has been conveyed as a whole before restricting the mark and not allowing 5 or 6 marks

Intermediate Level (Modest to adequate): 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

4 marks: (1) ***OR*** *(2)* ***AND*** *any three other points*
3 marks: any three points

Low Level (Poor to limited): 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or

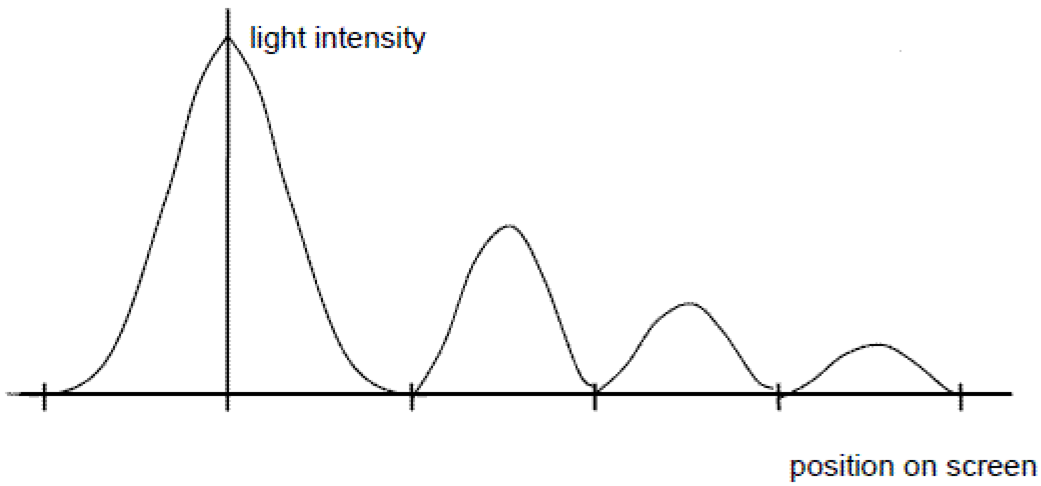
coherent. There is little correct use of specialist vocabulary.
The form and style of writing may be only partly appropriate.

2 marks: any two points
1 marks: any point or a reference is made to both nodes and antinodes

[6]

2 (a) 3 subsidiary maxima in correct positions **(1)**

intensity decreasing **(1)**



2

(b) a single wavelength **(1)**

constant phase relationship/difference **(1)**

2

(c) maxima further apart/central maximum wider/subsidiary maximum wider/maxima are wider **(1)**

1

(d) wider/increased separation **(1)**

lower intensity **(1)**

2

(e) distinct fringes shown with subsidiary maxima **(1)**

indication that colours are present within each subsidiary maxima **(1)**

blue/violet on the inner edge **or** red outer for at least one subsidiary maximum **(1)**

(middle of) central maximum white **(1)**

3

[10]

3 (a) **maximum displacement** from equilibrium/mean position/mid-point/etc **(1)**

1

(b) (i) any **one** from:

surface of water/water waves/in ripple tank **(1)**

rope **(1)**

slinky clearly qualified as transverse **(1)**

secondary ('s') waves **(1)**

max 1

(ii) transverse wave: oscillation (of medium) is perpendicular to wave travel

or transverse can be polarised

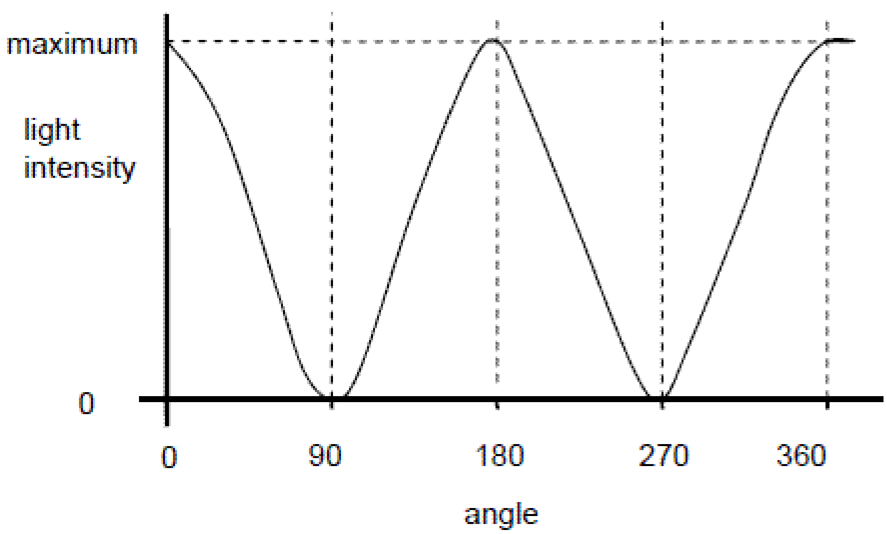
or **all** longitudinal require a medium **(1)**

1

(c) (i) vertical line on B ± 5° **(1)**

1

(ii)



max 0, 180, 360 + min 90, 270 **(1)**

and line reaches same minimum and maximum every time and reasonable shape **(1)**

2

(d) appropriate use **(1)**

reason for Polaroid filter being used **(1)**

eg

Polaroid glasses/**sun**glasses/	to reduce glare windscreens
camera	reduce glare/enhance image
(in a) microscope	to identify minerals/rocks
polarimeter	to analyse chemicals/concentration or type of sugar
stress analysis	reveals areas of high/low stress/ other relevant detail
LCD displays	very low power/other relevant detail
3D glasses	enhance viewing experience, etc

2

[8]

4 (a) same wavelength or frequency **(1)**
(same phase or) constant phase difference **(1)**

2

(b) (i) narrow slit gives wide diffraction **(1)**
(to ensure that) both S_1 and S_2 are illuminated **(1)**

(ii) slit S acts as a point source **(1)**
S_1 and S_2 are illuminated from same source giving monochromatic/same λ **(1)**
paths to S_1 and S_2 are of constant length giving constant phase difference **(1)**
[or $SS_1 = SS_2$ so waves are in phase]

Max 4
QWC 1

(c) graph to show:
maxima of similar intensity to central maximum **(1)**
[or some decrease in intensity outwards from centre]
all fringes same width as central fringe **(1)**

2

[8]

5 (a) waves are <u>reflected</u> (from the oven wall) ✓

1

and superpose/interfere with wave travelling in opposite direction/incident waves/transmitted wave ✓

NOT superimpose

1

(b) energy/amplitude is maximum ✓

1

(chocolate melts at) antinode ✓

if refer to node can still be awarded first mark

1

(c) clear evidence that used first and third antinode ✓

can be from diagram

1

distance from first to third antinodes = 0.118 ± 0.001 (m) OR
distance between two adjacent antinodes = 0.059 ± 0.001(m) ✓

mark for either value

carry their value forward for subsequent marks even if outside tolerance

1

wavelength = 0.118 (m) ✓

mark for using their wavelength (range 0.112 to 0.124)

1

frequency = 3.0×10^8 /0.118 ✓

mark for use of $v = f\lambda$ *allow this mark if use 0.059*

1

frequency = 2.5×10^9 (Hz) ✓

***must** be in range* $2.40 \times 10^9 - 2.60 \times 10^9$

if use 330 for speed lose last 2 marks

1

(d) position of antinode/maximum energy/maximum amplitude/nodes (in food) continually changes ✓

must be clear antinode maximum energy/maximum amplitude changes location

1

[10]

6 (a) A wave transfers energy <u>from one point to another</u> ✓
without transferring material / (causing permanent displacement of the medium) ✓ owtte

2

(b) (i) 0.6 (mm) or 0.60 (mm) ✓

1

(ii) 0.080 (m) ✓

Allow 1 sig fig

1

(iii) $f = 1/T = 1/0.044 = 23$ (Hz) ✓ (22.7 Hz)

1

(iv) $v = f\lambda = 22.7 \times 0.080 = 1.8$ (m s^{-1}) ✓ (1.82 m s^{-1})

allow CE v = (biii) × (bii) but working must be shown

1 sig fig not acceptable

1

(c)

sound waves are transverse	sound waves are longitudinal	sound waves can interfere	sound waves can be polarised
	√	√	

1

(d) the wavelength would be smaller
smaller spread in main peak or more peaks (between A and B)
the central peak is higher (owtte)
as the energy is concentrated over a smaller area (owtte)
reference to ($\sin \theta_{min} = \lambda/d$)
✓ ✓ ✓ any 3 lines max 3

Note that the marks here are for use of knowledge rather than performing calculations.

No bod if writing does not make <u>in</u>crease or <u>de</u>crease clearly distinct.

Marking should be lenient.

3

[10]

7 (a) (i) $\sin C = 1/n = 1/2.42$ ✓ (= 0.413)
$C = 24.4°$ ✓ (allow 2 or more sig figs)

Answer only gains both marks

2

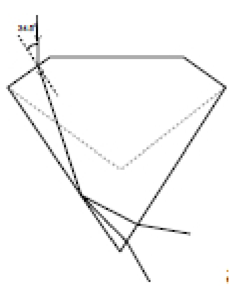
(ii) $\sin \theta_{dia} = \sin \theta_{air} / n = \sin 50.2 / 2.42$ ✓ (= 0.317)
$\theta_{dia} = 18.5°$ ✓ (allow 2 or more sig figs)

Answer only gains both marks

Answer can be 18° or 19° depending on rounding

2

(iii) TIR shown at bottom left surface ✓(If the reflected ray were extended it would pass through the writing below the diagram between the 'i' in 'it' and the full stop at the end of 'diamond'.) ray leaves bottom right surface either with an increased emergent angle or straight though if hitting normally ✓
(The second mark is consequential on gaining the first mark)



acceptable emergent rays

2

(iv) it has smaller critical angle / critical angle is 22°
allowing more / same number / greater chance / increased probability of TIR's occurring
greater/same sparkle ✓✓ max 2

'reflect more' is insufficient for a mark

2

(b) (i) $c_{core} = c_{air} / n = 3.00 \times 10^8 /1.55 = 1.9 \times 10^8$ (ms^{-1})✓(1.94×10^8 ms^{-1})

1 sig fig is not acceptable if no other answer is given

1

(ii) ($n = c_{air} / c_{core} = f\,\lambda air / f\lambda core = \lambda air / \lambda core$)
$\lambda core = \lambda air / n$ or $1300 \times (10^{-9}) / 1.55$✓
$= 8.4 \times 10^{-7}$ (m)✓(8.39×10^{-7} m or 839 nm)

The first mark is for the equation or substitution ignoring powers of 10 errors

1st mark can be gained from calculating the frequency ($f = 3.0 \times 10^8 / 1300 \times 10^{-9} = 2.3 \times 10^{14}$ (Hz) which then can be used to find the the wavelength

Using this method the answer can range between $8.4 \times 10^{-7} \longrightarrow 8.7 \times 10^{-7}$ (m) and consider ecf's from (b)(i)

2

(iii) protects the core (from scratches etc)
prevents crosstalk / stops signal crossing from one fibre to another / increases critical angle / reduces pulse broadening / reduces smearing / prevents multipath dispersion
allows fibre to be supported / touched (without losing light)
✓any one point

Preventing signal loss is not enough for the mark.

1

[12]

8 (a) (i) Number of complete waves passing a point **in one second** / number of complete waves produced by a source **in one second** / number of complete vibrations (oscillations) **per second** / number of compressions passing a fixed point **per second**

1

(ii) 180° phase difference corresponds to ½ λ
Use of $v = f\lambda$ with correct powers of 10
0.33 (m)

3

(b) (i) Do not have the same frequency
do not have a constant phase difference

2

(ii) Waves meet antiphase
Undergo superposition
Resulting in destructive interference

3

(iii) T = 100 ms
Use of $T = 1 / f$ or beat frequency (Δf) = 10 Hz
500 (Hz) (allow 510 –their beat frequency)

3

(c) (i) Only box ticked: Quality

1

(ii) Add regular alternating voltages together
With appropriate amplitudes
Where frequencies of voltages match the harmonics of sound / where frequencies are multiples of 440 Hz

Allow 2 for sampling sound (at twice max frequency) B1

Convert to binary (and replay through D to A converter). B1

3

[16]

9 (a) (i) θ_c marked **(1)**

(ii) $\sin \theta_c = \frac{1}{n}$ **(1)** $\left(= \frac{1}{1.55}\right)$

$\theta_c = 40.2°$ **(1)**

3

(b) $n = \frac{\sin \theta_1}{\sin \theta_2}$ **(1)**

(θ_2 = 90 – 75.2 = 14.8°)

θ_1 (= $\sin^{-1}${1.55 sin 14.8}) = 23.3° **(1)**

2

(c) Mark scheme not available.

3

[8]

10 A

[1]

11 C

[1]

12 B

[1]

13 (a) A

B1

(b) D

B1

[2]

14 C

[1]

Examiner reports

1 Almost all students made a good effort at answering this question and almost all of those knew that standing waves are constructed from two waves. This being the case it was appropriate that this question was the basis of the quality of written communication assessment in this examination. Weaker students often spent too long setting the scene. They gave details of the apparatus and explained how the string was plucked or vibrated before the bullet points were addressed. Often at this stage these were answered with very brief responses that gave very little detail. The middle ability group of students fared much better. They could describe what nodes and antinodes were and how they came about in terms of the interference of two waves. What was often missing was the fact that the two waves that superpose have the same frequency or wavelength. Many of this group and a large percentage of the top ability group understood that an antinode was a maximum of the motion but they referred to the maximum displacement rather than the maximum amplitude. A couple of points separated this top group from the middle students as well as the quality of the structure of their writing and spelling. First they referred to the waves superposing unlike the majority who thought the waves superimposed on each other. Secondly, they sometimes included a point about the lack of energy transmission in a standing wave.

2 Most candidates gained at least one mark in part (a) for showing that the intensity of peaks reduced with distance from the centre. However, many did not recall the key difference between the pattern for single and double slits – the single slit pattern has a central maximum which is double the width of the subsidiary maxima.

There were many correct definitions of monochromatic and coherent in part (b). A few stated ‘same colour’ for monochromatic and ‘in phase’ for coherent. Neither of these were accepted.

In part (c), many candidates incorrectly used the equation for two slits to show that the maxima were further apart. This was not penalised since an explanation was not asked for.

Many candidates got part (d) the wrong way around, saying that the fringes would be more closely spaced and more intense. There seemed to be some guess work evident here. Candidates need to be able to describe the appearance of the single slit pattern and be aware of how it will change for different wavelengths, slit widths and for monochromatic and white light. Some teachers introduce the equation for the single slit although it is not in the specification. This is not necessary but can certainly help the more mathematically minded students. To illustrate the change in the pattern, a simple demonstration can be carried out with a red and a green laser shone through the same slit onto a screen.

A pleasing number of candidates produced very detailed and high quality answers to part (e), with many gaining all three marks. Some drew a graph of intensity, which did not gain a mark on its own.

3 In part (a), the strict definition of amplitude was expected. Candidates needed to say ‘maximum displacement’ and then indicate in some way that this was relative to the equilibrium position.

The majority, however, chose to define amplitude as the **distance** between the centre and the peak.

For part (b) (i), the majority of candidates could not give an example of a transverse wave other than electromagnetic waves. Most gave a form of electromagnetic radiation (most commonly ‘light’) or even sound. Common answers that were accepted included ‘water waves’, ‘waves on strings’ or ‘s-waves’.

Most candidates realised that a comparison between the direction of wave travel and the oscillation of the medium was a good way to answer part (b) (ii). It was common, however, for candidates to struggle to express this clearly. The most common error was to say that a transverse wave ‘moves’ perpendicular to the direction of wave travel rather than ‘oscillation is perpendicular to direction of wave travel’.

The vast majority of candidates found part (c) (ii) very straight forward.

The majority of candidates had no problem with part (c) (ii). The exact shape of the line was not important as long as the maximum and minimum intensities appeared in the right place.

There were many very good answers to part (d), such as ‘sunglasses/ski goggles reduce glare from light reflected from water/snow’ and ‘a camera filter reduces unwanted reflections’. Common inadequate responses included saying that polarising sunglasses ‘reduce light intensity’ because the lenses are ‘darker’, or that polarising filters reduce UV.

4 Whilst it was generally recognised in part (a) that coherent sources provide waves of the same wavelength (or frequency), the requirement about phase was less well understood. The common answer was that the waves must be ‘in phase’, whilst the accepted answer was that there has to be a *constant phase relation* between them. Although monochromatic sources that are in phase will be coherent, coherence does not *require* the sources to be in phase. In part (b), the single monochromatic source is the reason for fulfilling the same *A* criterion; this was correctly quoted by most. Satisfactory explanations of how the phase criterion is satisfied were very rare indeed, with few references to the paths SS_1 and SS_2.

Had part (c) required candidates to sketch Young’s fringes, there can be no doubt that the responses would have been much more rewarding. Most candidates were unable to translate their knowledge of the appearance of a familiar phenomenon into the required intensity/position graph. Near the centre of the pattern, the fringes are all of very similar intensity and all should have been drawn with the same width as the central fringe. The majority of wrong answers showed either the single slit diffraction pattern, or fringes having the same width as the central one but with much lower intensity.

5 This question about the formation of stationary waves in a microwave oven was answered well by a good proportion of students. In part (a) the idea of reflection taking place was clearly stated in the majority of answers. The second marking point explaining how this resulted in the reflected and incident wave superposing was more discriminating. A significant proportion of students stated that the waves superimposed rather than superposed. Part (b) was only fully answered by those students who, having identified the melted chocolate positions as antinodes were then able to explain that this is where the amplitude of the wave was a maximum. Weaker responses tended to identify these positions as nodes or did not link the melted chocolate to stationary waves at all. Part (c) was a five mark calculation and this produced very good discrimination. About a third of students were awarded 4 or 5 marks. To obtain full marks students were required to give a clear indication, either on the diagram or in their working, that they had measured the distance between the first and third dot rather than measuring from the first to second dot and then doubling. It was sometimes hard to establish exactly what students had measured and it should be appreciated that showing full working in these extended calculations is very important. A lot of vague answers were seen to question 2.4 and it was the physics that needed to be explained. A common response was ‘to cook the food evenly’ and this was not seen as a physics explanation.

6 (a) For a majority this was a piece of work that was never committed to memory and the marks were low. Only about half the students scored the mark about the wave being able to transport energy from one place to another. Then only a small subgroup of these students referred to matter not being transported.

(b) (i) Almost all students found this basic question straightforward.

(ii) Almost all students found this basic question straightforward.

(iii) Again the vast majority of students had no problems but a few got into difficulty in reading the time scale correctly.

(iv) The equation for velocity was known by almost all the students and most scored the mark.

(c) A majority of students chose the correct responses but there was a significant number tempted away by one or more of the distractors.

(d) This question discriminated between students very effectively. Many did appreciate that a higher frequency meant a shorter wavelength. This in turn had the effect of compressing the diffraction pattern. Students had some difficulty in expressing this idea. Instead of simply saying the central peak was narrower they might say the wave is shorter. Only the very able students obtained a third mark. Most said the pattern shown would have the same height because the amplitude was the same.

7

(a) Both the geometric optics calculations in parts (i) and (ii) were done very well by students.

(iii) This question gave a good spread of marks. Although a majority scored well, errors were seen at each stage. The most common error was to simply copy what happened in the figure, which resulted in an incorrect angle of reflection on the first surface. In other cases the reflections were drawn from the dotted lines in the figure. The other common mistake was for the TIR on the first surface to be drawn with the angle of reflection not looking close to the angle of incidence.

(iv) This question was very discriminating. More able students knew exactly what they were doing but many others either simply suggested it would reflect more or less and gave the reason as the refractive index was higher. Even when they related the refractive index to the critical angle they often related this to the conclusion in the wrong way. For example they may have said 'lower critical angle so the rays of light are less likely to be reflected.

(b) (i) This straightforward calculation was done well by a majority.

(ii) This was again done well but it gave rise to a few more errors compared to the previous part.

(iii) There was a huge number of correct possible answers for using cladding and a majority of students chose one of them. However a significant number of students thought that the cladding made TIR more likely or prevented light escaping from the core.

8 (a) (i) Acceptable definitions were given by a good majority of the students. Those who failed to produce a satisfactory response usually omitted reference to time.

(ii) Most gained credit for the use of $v = f\lambda$. The common errors were ignoring the k in kHz and not calculating $\lambda/2$.

(b) (i) This question was a ‘twist’ on a commonly asked question that requires students to explain what is meant by waves being coherent. This question required students to identify that the tuning forks had different frequencies and would not have a constant phase difference when they arrive at a point so would not be coherent. This proved to be too challenging for many students.

(ii) This was poorly done and fewer than half the students were able to give at least one acceptable point worthy of credit and there were relatively few who gained full credit. One can only speculate that students have difficulty understanding interference that occurs due to changes in phase difference that take place at a point with time as is the case in this instance.

(iii) A high proportion of the students gained credit for use of $f = 1/T$ and many of these arrived at the correct beat frequency. Many did no more than this and relatively few of these went on to calculate the correct frequency of the fork that emitted the lower frequency.

(c) (i) Almost three quarters of the students selected the correct response to this question.

(ii) Relatively few appreciated the meaning of synthesis of sound ie the process of adding together sinusoidal waves of appropriate frequencies and amplitude to produce a required sound. Students were given compensatory credit for explaining the process of sampling a sound and storing it digitally.

9 Not for the first time in the history of this paper the optics question proved to be the most difficult in the paper. Only the best candidates could identify the critical angle. Candidates were a little more successful in calculating the critical angle but the units of degree were frequently omitted. In (b) candidates failed to get the correct answer because they did not calculate the angle in the glass as (90.0° – 75.2°) and often did not use the correct equation. The ray diagram in part (c) was done badly by a vast majority of candidates and the average mark was about one out of possible three.

13 Although many candidates scored full marks on this simple opening question, there was a significant number who could not relate the diagram on the paper to the practical situation of light rays moving across the boundary between two media.