Waves and Optics AS Revision Pack

Name:

Class:

Date:

Time: **358 minutes**

Marks: **297 marks**

Comments:

1 (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

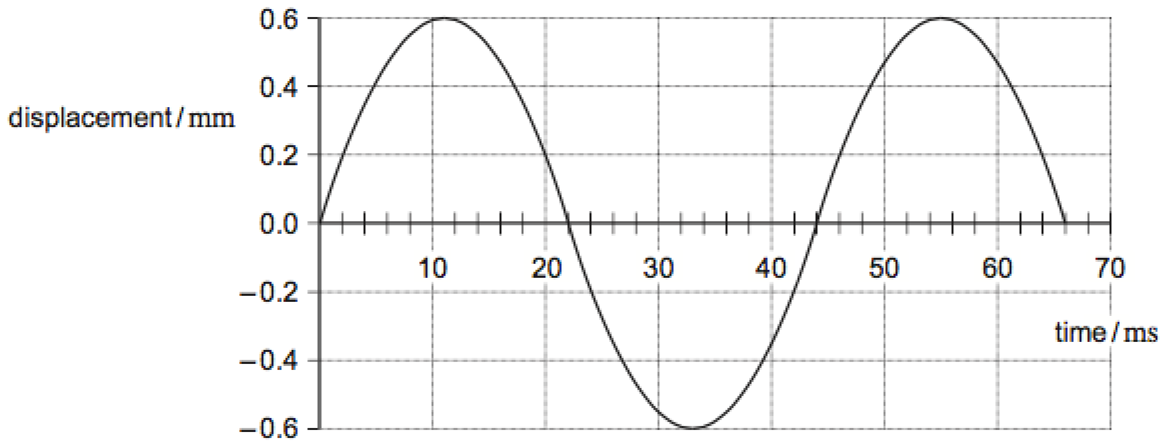
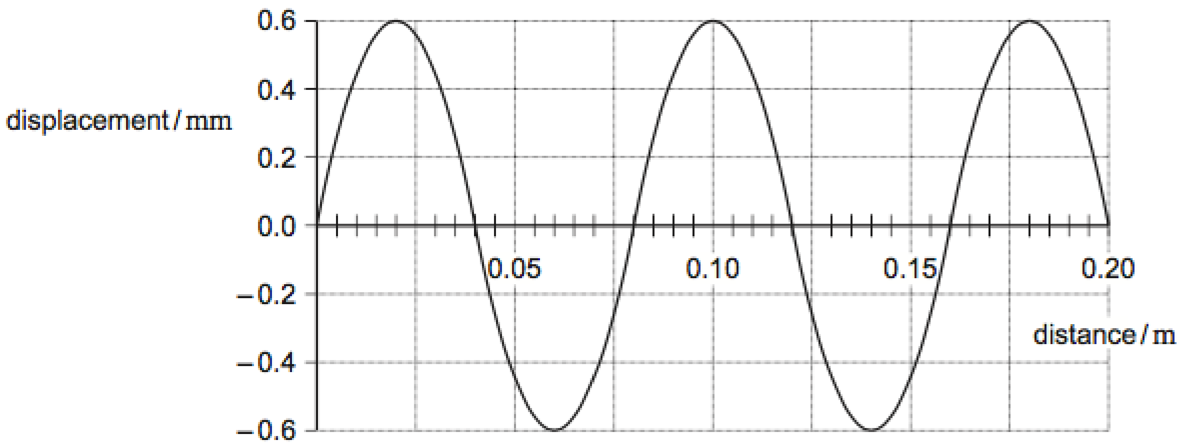


Figure 2 shows the variation of displacement of the same wave with distance.

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.

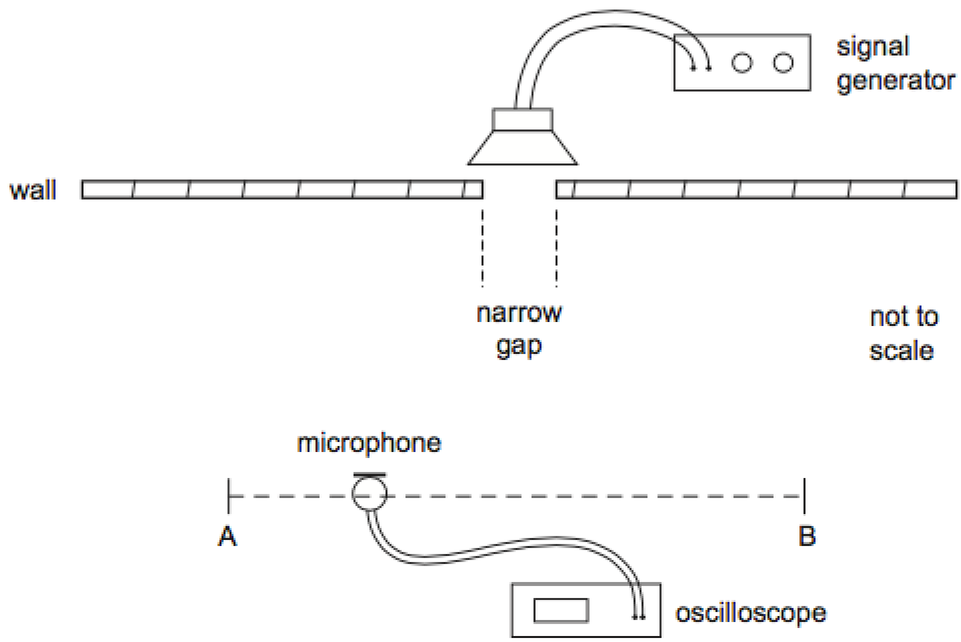
	✓ if correct
sound waves are transverse	
sound waves are longitudinal	
sound waves can interfere	
sound waves can be polarised	

(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.

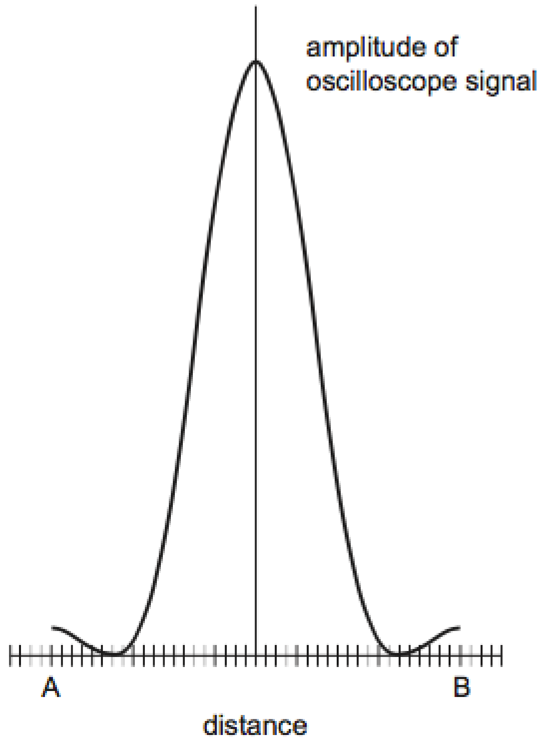
Figure 3



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**.

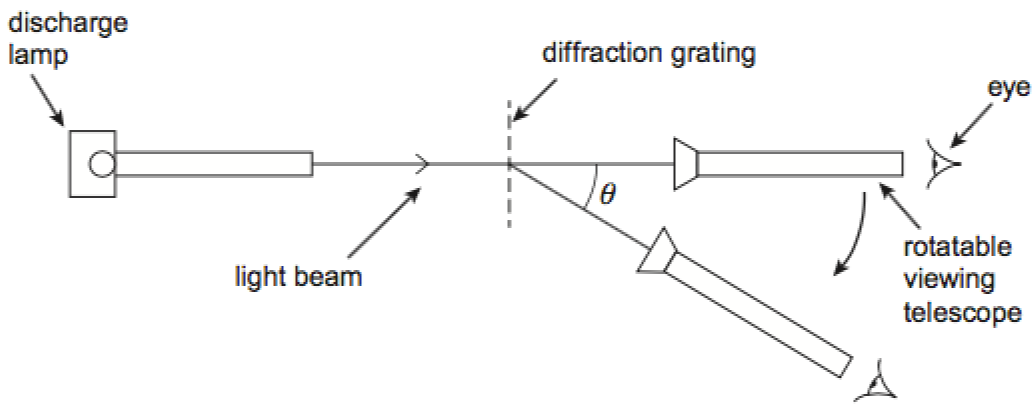
Figure 4



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)

2 A discharge lamp emits light of four colours: red, green, blue and violet. The diagram shows light from the lamp incident normally on a diffraction grating with slit separations of 1.8×10^{-6} m. The light is viewed through a telescope which can be rotated as shown.



As the telescope is rotated from the straight-through position, each of the four colours is observed as a bright line at its corresponding first-order diffraction angle.

(a) Which colour would be observed first as the telescope is rotated from the straight-through position?

Place a tick (✓) in the right-hand column to show the correct answer.

	✓ if correct
red	
green	
blue	
violet	

(1)

(b) Explain how a bright line is formed by the diffraction grating at the first-order diffraction angle.

____

____

____

____

____

____

____

(3)

(c) (i) The wavelength of the green light is 5.3×10^{-7} m.

Calculate the first-order diffraction angle for this colour.

angle = ____________________ degree

(2)

(ii) As the telescope is rotated further, higher-order diffraction maxima are observed. Calculate the highest order observed for the green light.

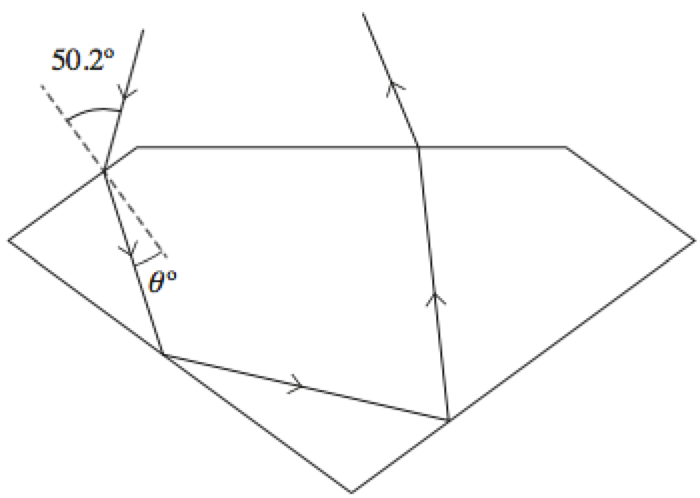
highest order = ____________________

(3)

(Total 9 marks)

3 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)

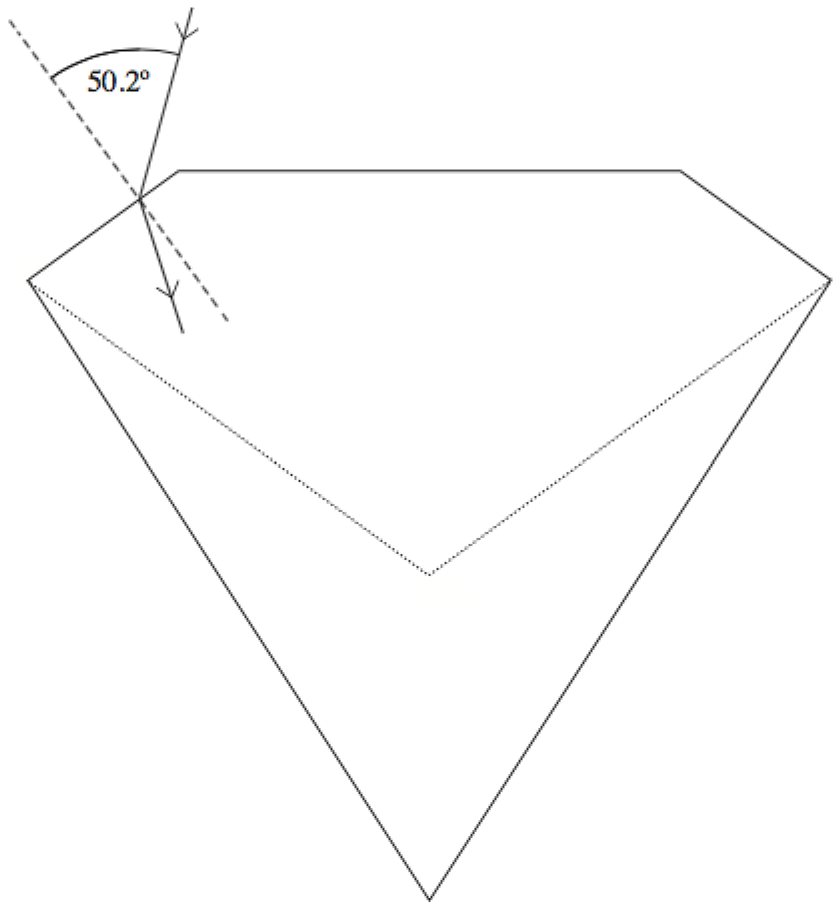
(ii) The ray shown in **Figure 1** enters at an angle of incidence of 50.2°. Calculate the angle of refraction θ.

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.

____

____

____

____

____

____

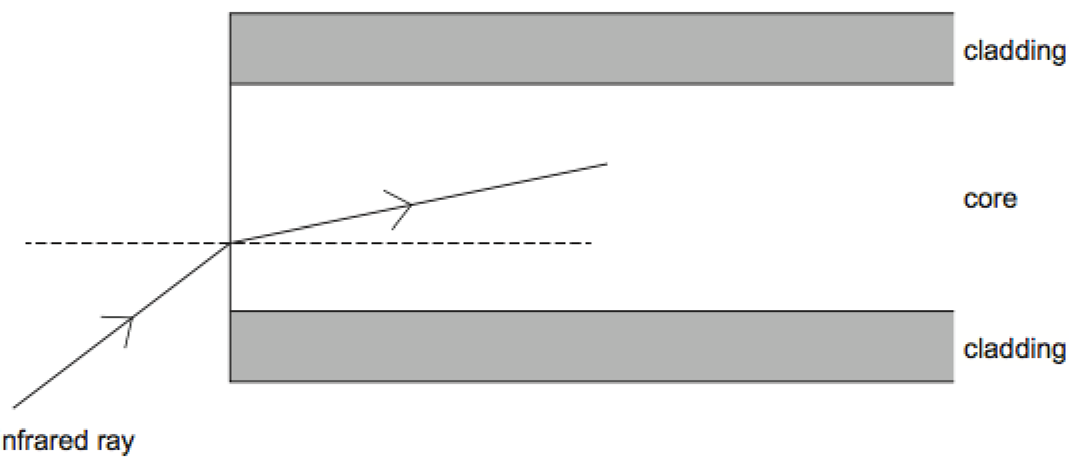
____

____

(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.

____

____

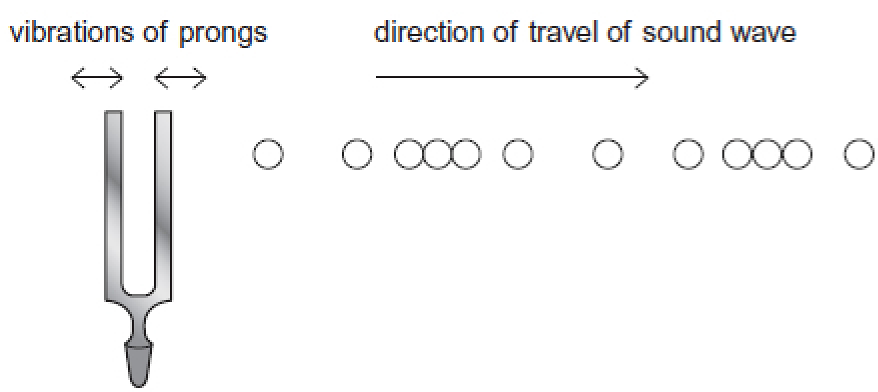
(1)

(Total 12 marks)

4 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}

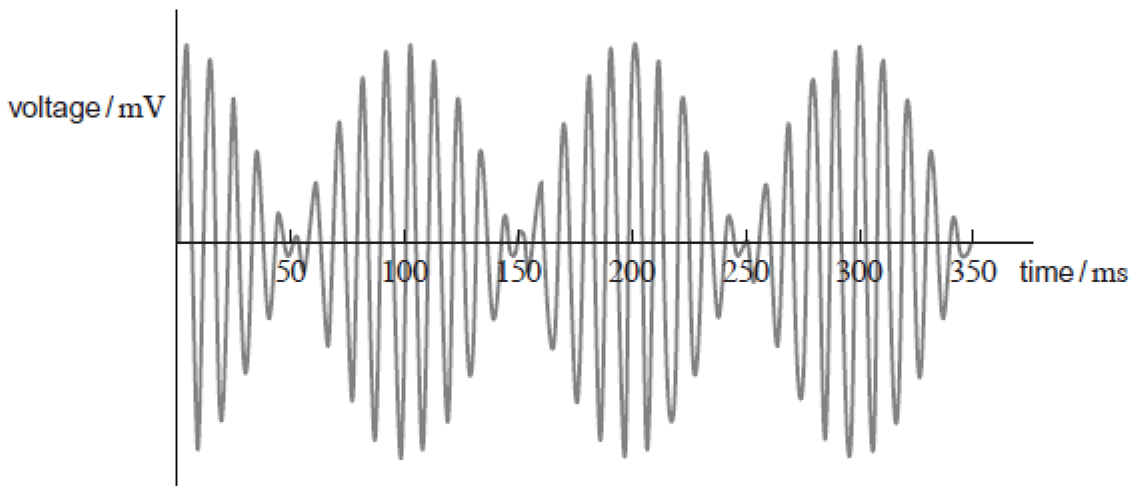
minimum separation ____________________ m

(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.

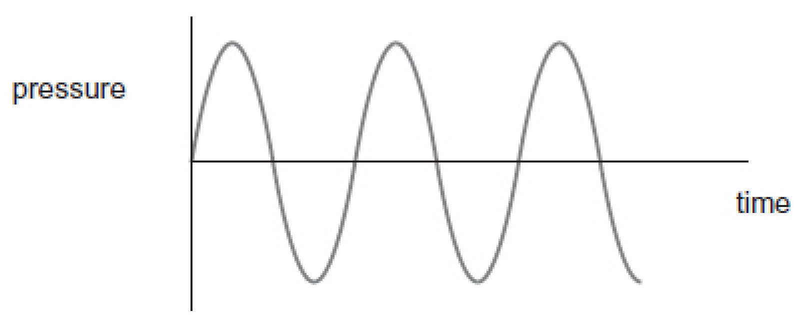
frequency ____________________ Hz

(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**.

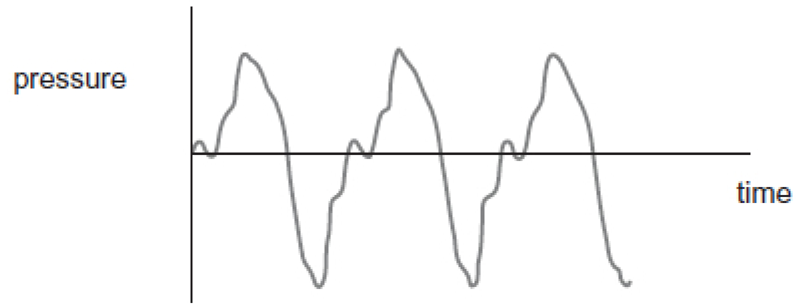
Figure 3



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)

5 Describe a laboratory experiment to investigate how the fundamental frequency of a stretched string depends on the tension in the string.

The stretched string has a mass per unit length of 1.5×10^{-3} kg m^{-1}.

Your detailed method should include:

- a labelled diagram of the experiment arrangement
- suitable estimates of any quantities involved in the experiment
- how you would use the data to demonstrate the relationship between fundamental frequency and tension.

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

(Total 6 marks)

6 **Figure 1** and **Figure 2** show a version of Quincke's tube, which is used to demonstrate interference of sound waves.

Figure 1

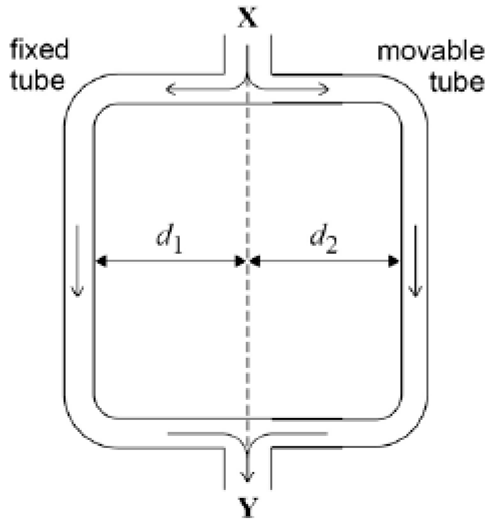
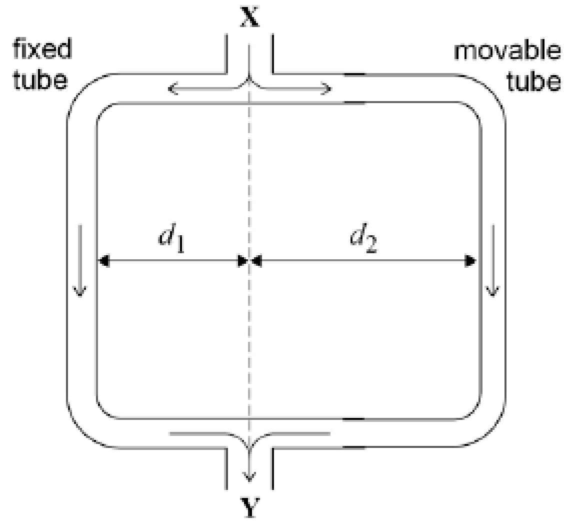


Figure 2



A loudspeaker at **X** produces sound waves of one frequency. The sound waves enter the tube and the sound energy is divided equally before travelling along the fixed and movable tubes. The two waves superpose and are detected by a microphone at **Y**.

(a) The movable tube is adjusted so that $d_1 = d_2$ and the waves travel the same distance from **X** to **Y**, as shown in **Figure 1**. As the movable tube is slowly pulled out as shown in **Figure 2**, the sound detected at **Y** gets quieter and then louder.

Explain the variation in the loudness of the sound at **Y** as the movable tube is slowly pulled out.

____

____

____

____

____

____

____

(4)

(b) The tube starts in the position shown in **Figure 1**.

Calculate the minimum distance moved by the movable tube for the sound detected at **Y** to be at its quietest.

frequency of sound from loud speaker = 800 Hz
speed of sound in air = 340 m s^{-1}

minimum distance moved = ____________________ m

(3)

(c) Quincke's tube can be used to determine the speed of sound.

State and explain the measurements you would make to obtain a value for the speed of sound using Quincke's tube and a sound source of known frequency.

____

____

____

____

____

____

____

____

____

(4)

(Total 11 marks)

7 A student has a diffraction grating that is marked 3.5×10^3 lines per m.

(a) Calculate the percentage uncertainty in the number of lines per metre suggested by this marking.

percentage uncertainty = ____________________ %

(1)

(b) Determine the grating spacing.

grating spacing = ____________________ mm

(2)

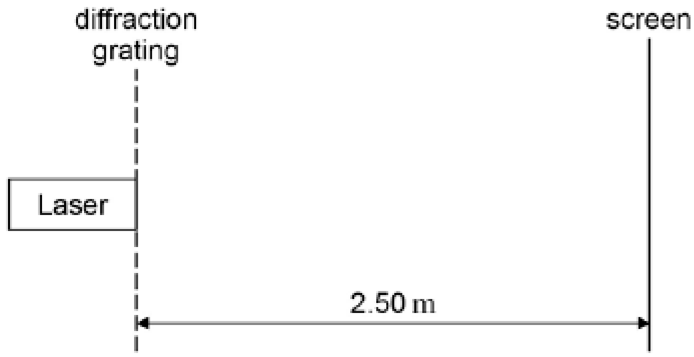
(c) State the absolute uncertainty in the value of the spacing.

absolute uncertainty = ____________________ mm

(1)

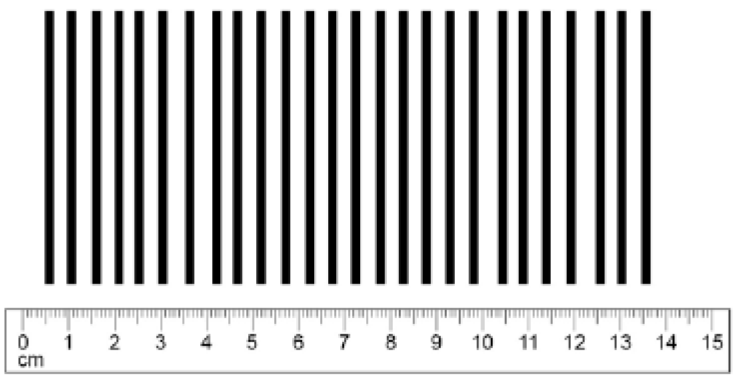
(d) The student sets up the apparatus shown in **Figure 1** in an experiment to confirm the value marked on the diffraction grating.

Figure 1



The laser has a wavelength of 628 nm. **Figure 2** shows part of the interference pattern that appears on the screen. A ruler gives the scale.

Figure 2



Use **Figure 2** to determine the spacing between two adjacent maxima in the interference pattern. Show all your working clearly.

spacing = ____________________ mm

(1)

(e) Calculate the number of lines per metre on the grating.

number of lines = ____________________

(2)

(f) State and explain whether the value for the number of lines per m obtained in part (e) is in agreement with the value stated on the grating.

___

___

___

(2)

(g) State **one** safety precaution that you would take if you were to carry out the experiment that was performed by the student.

___

___

___

(1)

(Total 10 marks)

8 (a) Describe the structure of a step-index optical fibre outlining the purpose of the core and the cladding.

___

___

___

___

___

___

___

___

___

(3)

(b) A signal is to be transmitted along an optical fibre of length 1200 m. The signal consists of a square pulse of white light and this is transmitted along the centre of a fibre. The maximum and minimum wavelengths of the light are shown in the table below.

Colour	**Refractive index of fibre**	**Wavelength / nm**
Blue	1.467	425
Red	1.459	660

Explain how the difference in refractive index results in a change in the pulse of white light by the time it leaves the fibre.

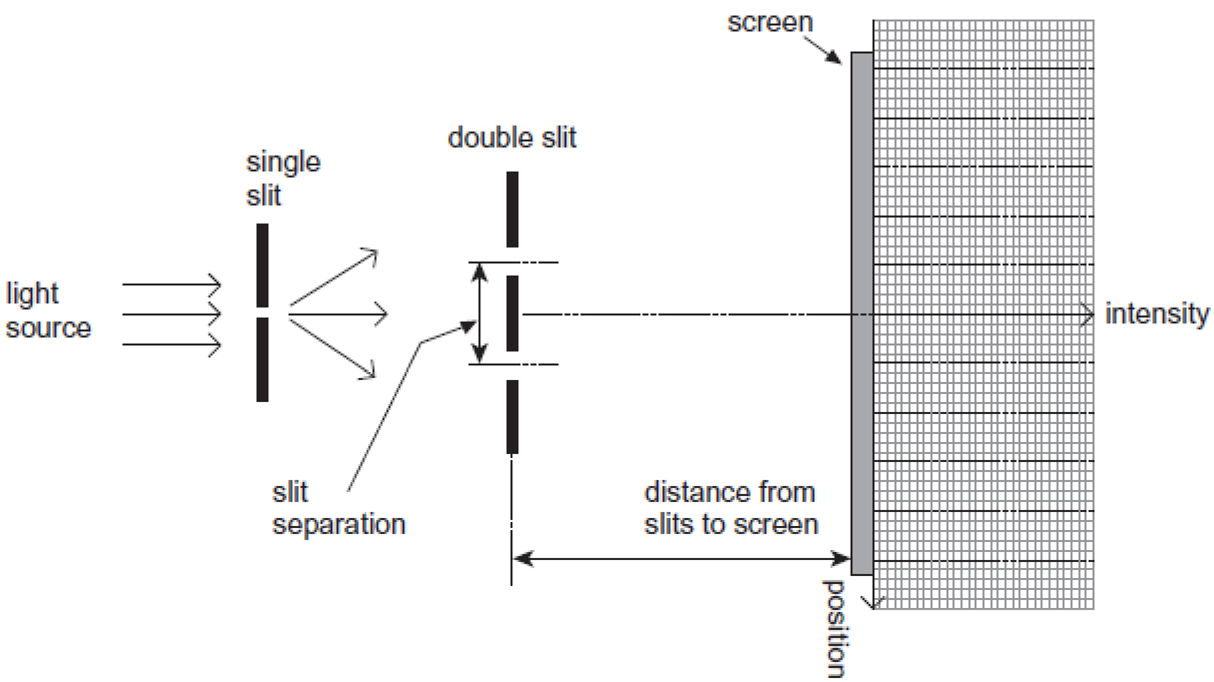
(2)

(c) Discuss **two** changes that could be made to reduce the effect described in part (b).

(2)

(Total 7 marks)

9 The diagram shows Young's double-slit experiment performed with a tungsten filament lamp as the light source.



not to scale

(a) On the axes in the diagram above, sketch a graph to show how the intensity varies with position for a **monochromatic** light source.

(2)

(b) (i) For an interference pattern to be observed the light has to be emitted by two **coherent sources**.
Explain what is meant by coherent sources.

____

____

____

____

(1)

(ii) Explain how the use of the single slit in the arrangement above makes the light from the two slits sufficiently coherent for fringes to be observed.

____

____

____

____

(1)

(iii) In this experiment light behaves as a wave.
Explain how the bright fringes are formed.

____

____

____

____

____

____

____

____

(3)

(c) (i) A scientist carries out the Young double-slit experiment using a laser that emits violet light of wavelength 405 nm. The separation of the slits is 5.00×10^{-5} m.

Using a metre ruler the scientist measures the separation of two adjacent bright fringes in the central region of the pattern to be 4 mm.

Calculate the distance between the double slits and the screen.

distance = ____________________ m

(2)

(ii) Describe the change to the pattern seen on the screen when the violet laser is replaced by a green laser. Assume the brightness of the central maximum is the same for both lasers.

____

____

____

(1)

(iii) The scientist uses the same apparatus to measure the wavelength of visible electromagnetic radiation emitted by another laser.
Describe how he should change the way the apparatus is arranged and used in order to obtain an **accurate** value for the wavelength.

___

___

___

___

___

___

___

___

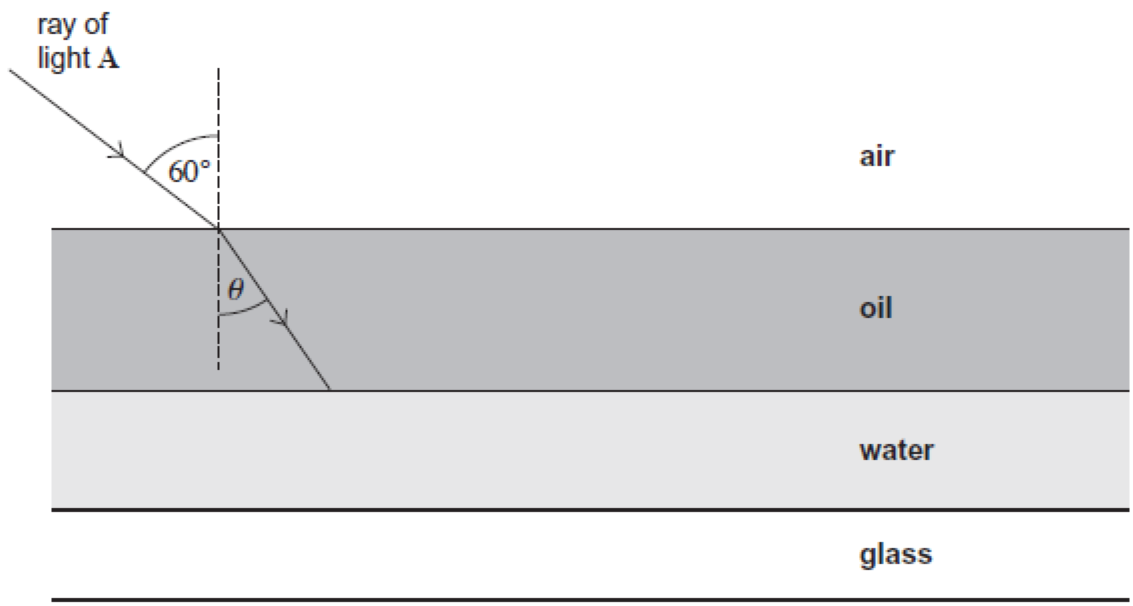
(3)
(Total 13 marks)

10 **Figure 1** shows a ray of light **A** incident at an angle of 60° to the surface of a layer of oil that is floating on water.

refractive index of oil = 1.47

refractive index of water = 1.33

Figure 1



(a) (i) Calculate the angle of refraction θ in **Figure 1**.

angle ____________________ degrees

(2)

(ii) Calculate the critical angle for a ray of light travelling from oil to water.

angle ____________________ degrees

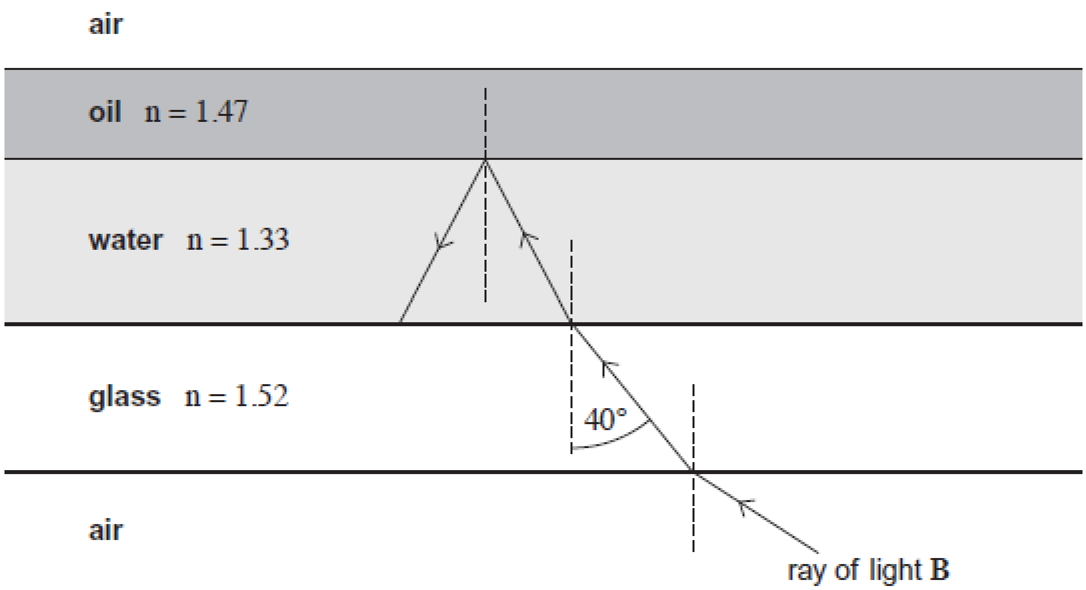
(2)

(iii) On **Figure 1** continue the path of the ray of light **A** immediately after it strikes the boundary between the oil and the water.

(2)

(b) In **Figure 2** a student has incorrectly drawn a ray of light **B** entering the glass and then entering the water before totally internally reflecting from the water–oil boundary.

Figure 2



The refractive index of the glass is 1.52 and the critical angle for the glass–water boundary is about 60°.

Give **two** reasons why the ray of light **B** would **not** behave in this way. Explain your answers.

reason 1 ____

____

explanation ____

____

____

reason 2 ____

____

explanation ____

____

____

(4)

(Total 10 marks)

11 Ultrasound waves are used to produce images of a fetus inside a womb.

(a) Explain what is meant by the frequency of a wave.

____

____

____

(1)

(b) Ultrasound is a longitudinal wave. Describe the nature of a longitudinal wave.

____

____

____

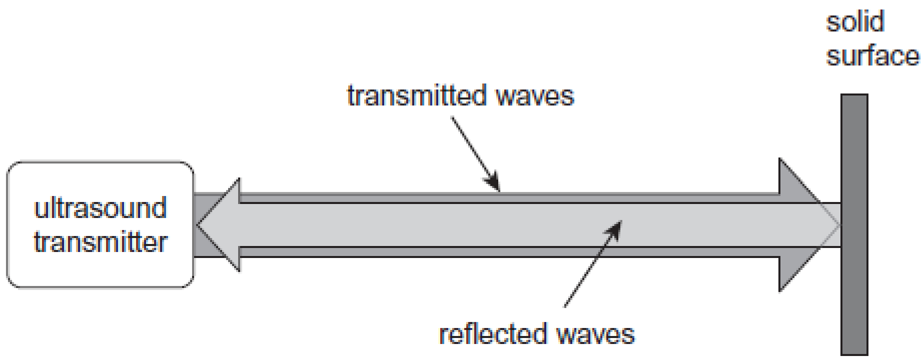
(2)

(c) In order to produce an image with sufficient detail, the wavelength of the ultrasound must be 0.50 mm. The speed of the ultrasound in body tissue is 1540 m s^{-1}. Calculate the frequency of the ultrasound at this wavelength.
Give your answer to an appropriate number of significant figures.

frequency ____________________ Hz

(2)

(d) A continuous ultrasound wave of constant frequency is reflected from a solid surface and returns in the direction it came from.



Assuming there is no significant loss in amplitude upon reflection, describe and explain the effect the waves have on the particles in the medium between the transmitter and the solid surface.

(3)

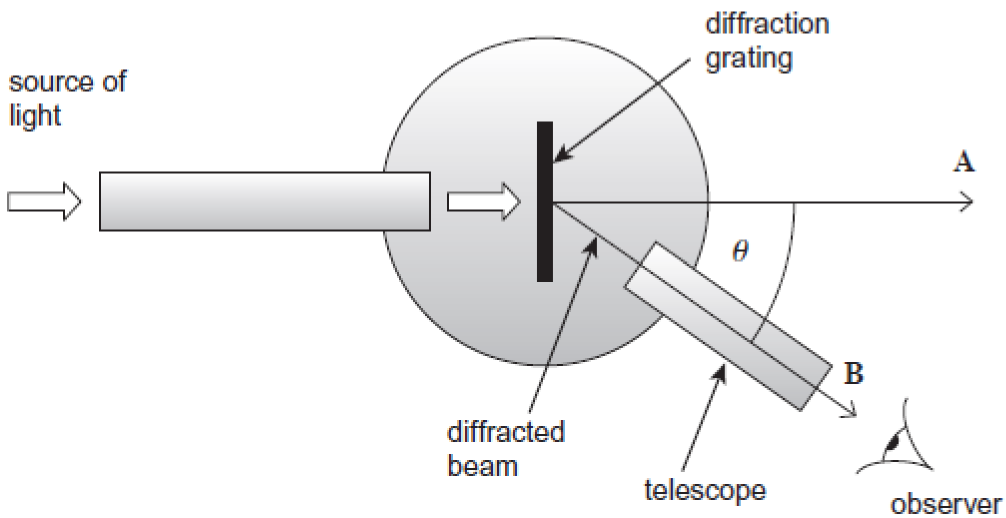
(Total 8 marks)

12 The figure below shows a spectrometer that uses a diffraction grating to split a beam of light into its constituent wavelengths and enables the angles of the diffracted beams to be measured.

(a) Give **one** possible application of the spectrometer and diffraction grating used in this way.

____

____



(1)

(b) (i) When the spectrometer telescope is rotated from an initial angle of zero degrees, a spectrum is not observed until the angle of diffraction θ is about 50°. State the order of this spectrum.

____

(1)

(ii) White light is directed into the spectrometer. Light emerges at **A** and **B**. State **one** difference between the light emerging at **B** compared to that emerging at **A**.

____

____

____

(1)

(c) The angle of diffraction θ at the centre of the observed beam $\mathbf{B}$ in the image above is 51.0° and the grating has 1480 lines per mm.

Calculate the wavelength of the light observed at the centre of beam $\mathbf{B}$.

wavelength ____________________ m

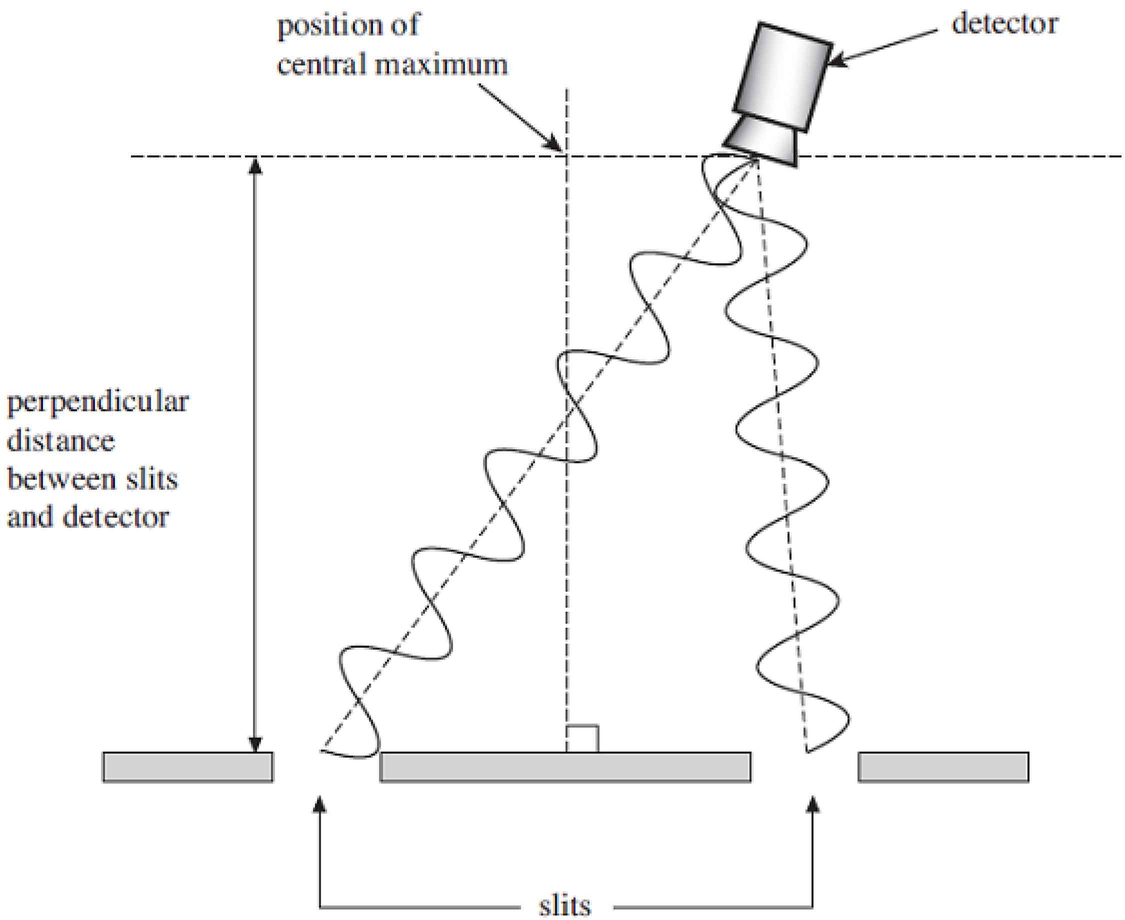
(3)

(d) Determine by calculation whether any more orders could be observed at the wavelength calculated in part (c).

(2)

(Total 8 marks)

13 The diagram below shows the paths of microwaves from two narrow slits, acting as coherent sources, through a vacuum to a detector.



(a) Explain what is meant by *coherent sources.*

____

____

____

____

(2)

(b) (i) The frequency of the microwaves is 9.4 GHz.

Calculate the wavelength of the waves.

wavelength = ____________________ m

(2)

(ii) Using the diagram above and your answer to part (b)(i), calculate the path difference between the two waves arriving at the detector.

path difference = ____________________ m

(1)

(c) State and explain whether a maximum or minimum is detected at the position shown in the diagram above.

____

____

____

____

(3)

(d) The experiment is now rearranged so that the perpendicular distance from the slits to the detector is 0.42 m. The interference fringe spacing changes to 0.11 m.

Calculate the slit separation. Give your answer to an appropriate number of significant figures.

slit separation = ____________________ m

(3)

(e) With the detector at the position of a maximum, the frequency of the microwaves is now doubled. State and explain what would now be detected by the detector in the same position.

____

____

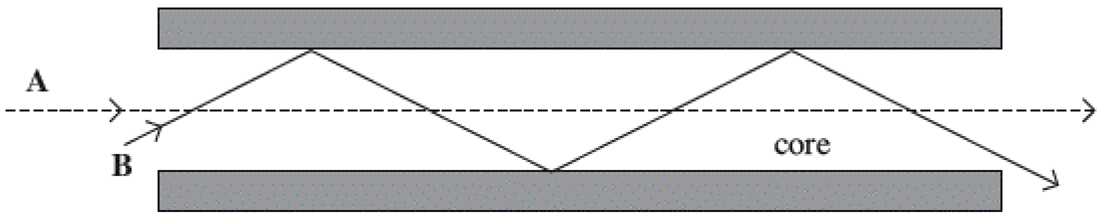
____

____

(3)

(Total 14 marks)

14 The figure below shows two rays of light **A** and **B** travelling through a straight optical fibre.



(a) Calculate the speed of light in the core of the optical fibre.

absolute refractive index of the core of the optical fibre = 1.6

___

___

___

___

speed of light in the core ____________________ ms^{-1}

(2)

(b) The overall length of the optical fibre is 0.80 km. As shown in the figure above, ray **A** travels down the centre of the core of the optical fibre. The path of ray **B** has an overall length of 0.92 km as it travels through the core.

(i) Ray **A** and ray **B** enter the fibre at the same instant.
Calculate the difference in time taken for ray **A** and ray **B** to travel through the core of the optical fibre.

___

___

___

___

time difference ____________________ s

(2)

(ii) Explain how a graded-index optical fibre prevents this time difference occurring for rays such as **A** and **B** in the figure above.

____

____

____

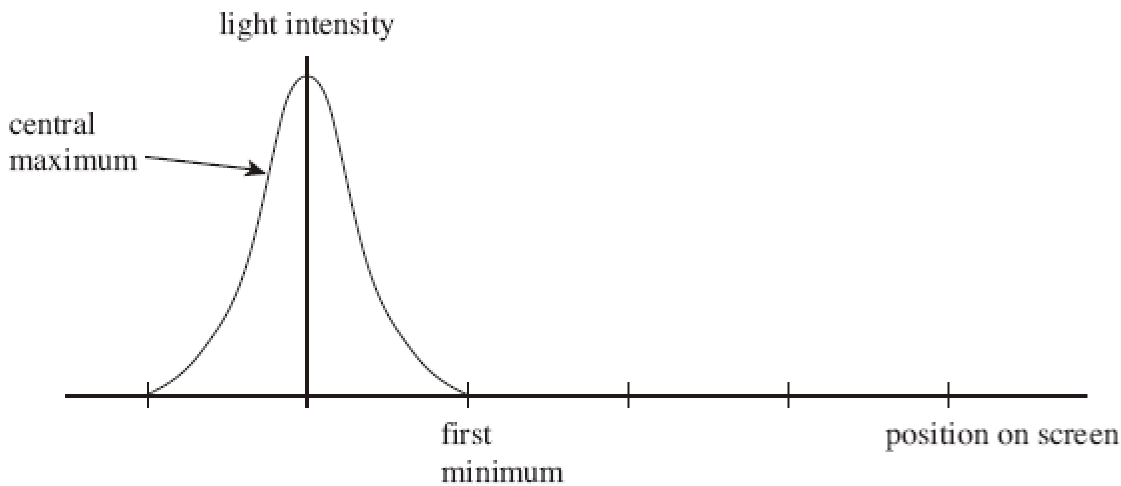
____

____

(2)

(Total 6 marks)

15 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)

16 (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.

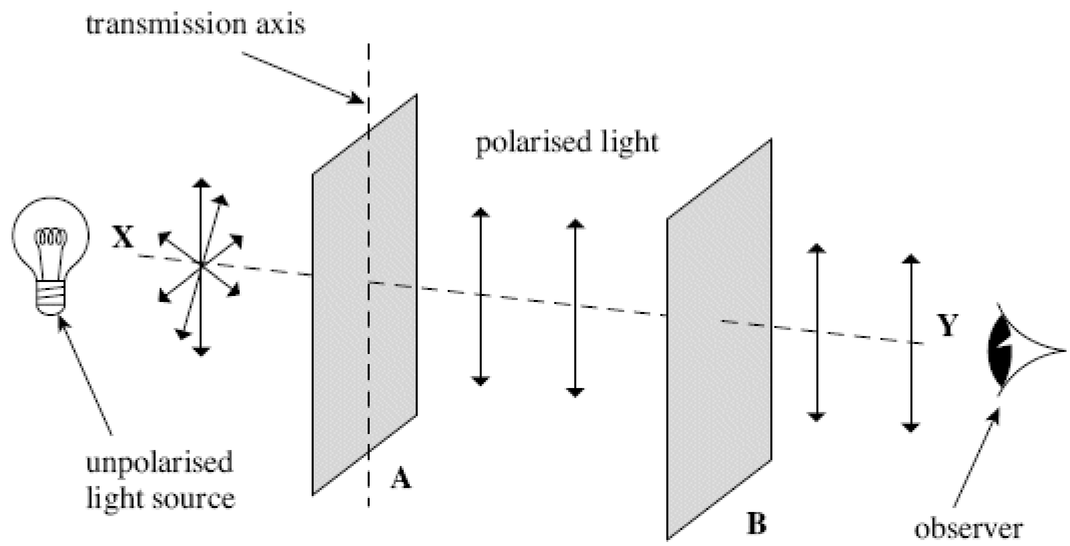
____

____

(1)

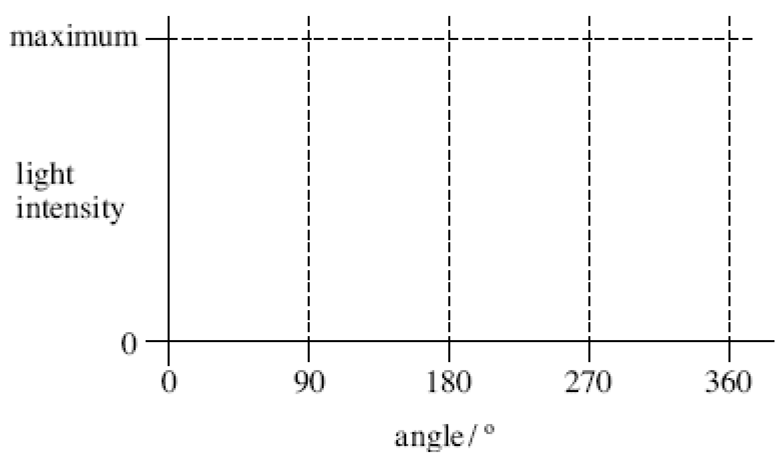
(c) The figure below shows two identical polarising filters, **A** and **B**, and an unpolarised light source. The arrows indicate the plane in which the electric field of the wave oscillates.

(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)

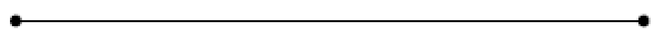
(Total 8 marks)

17 (a) (i) A piano string has a tension of 681 N. It vibrates with a fundamental frequency (first harmonic) of 92.5 Hz and has a mass per unit length of 1.87×10^{-2} kg m^{-1}.
Calculate the length of the string.

length of string ______________________ m

(3)

(ii) The figure below shows a string stretched between fixed ends.
Draw onto the figure the first overtone (second harmonic) mode of vibration.



(1)

(iii) State how you could make a string on a stringed instrument vibrate in this mode of vibration.

(2)

(b) Describe how you would investigate the variation of the fundamental frequency (first harmonic) of a string with its length.
State which variable(s) you would need to control and how you would do so.
You may wish to assist your account by drawing a diagram.

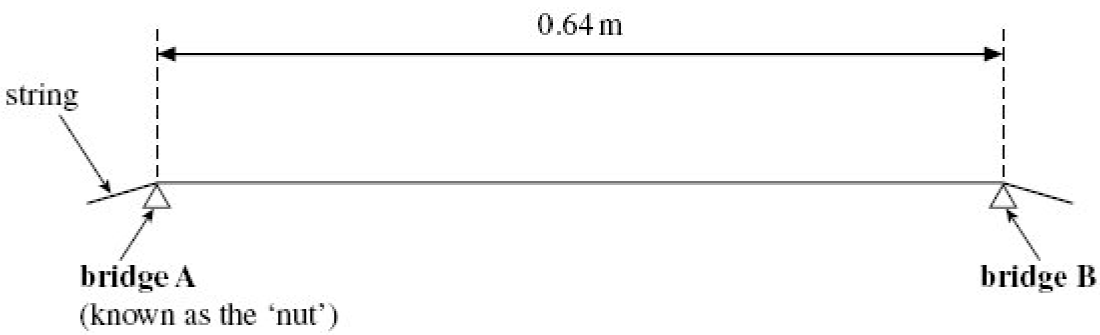
(4)

(Total 10 marks)

18 **Figure 1** shows a side view of a string on a guitar. The string cannot move at either of the two bridges when it is vibrating. When vibrating in its fundamental mode the frequency of the sound produced is 108 Hz.

(a) (i) On **Figure 1**, sketch the stationary wave produced when the string is vibrating in its fundamental mode.

Figure 1



(1)

(ii) Calculate the wavelength of the fundamental mode of vibration.

answer = ____________________ m

(2)

(iii) Calculate the speed of a progressive wave on this string.

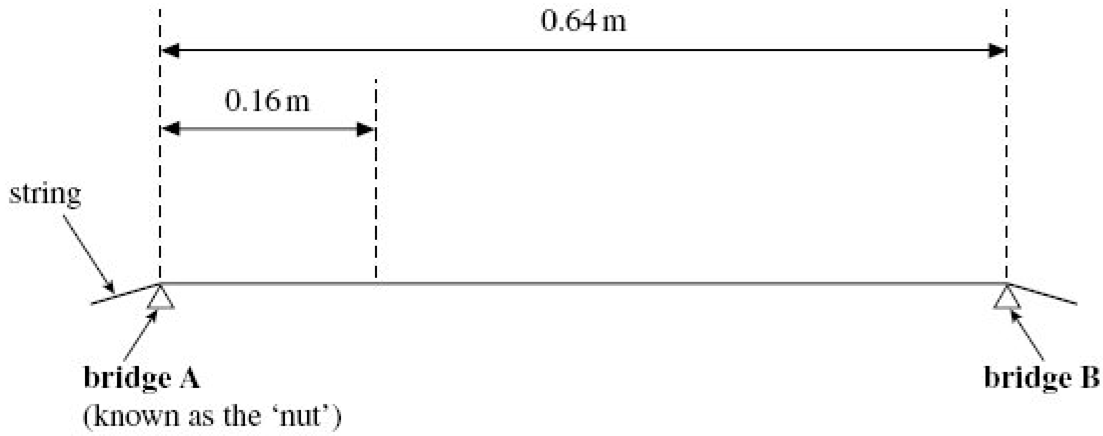
answer = ____________________ m s^{-1}

(2)

(b) While tuning the guitar, the guitarist produces an overtone that has a node 0.16 m from **bridge A**.

(i) On **Figure 2**, sketch the stationary wave produced and label all nodes that are present.

Figure 2



(2)

(ii) Calculate the frequency of the overtone.

answer = ____________________ Hz

(1)

(c) The guitarist needs to raise the fundamental frequency of vibration of this string. State **one** way in which this can be achieved.

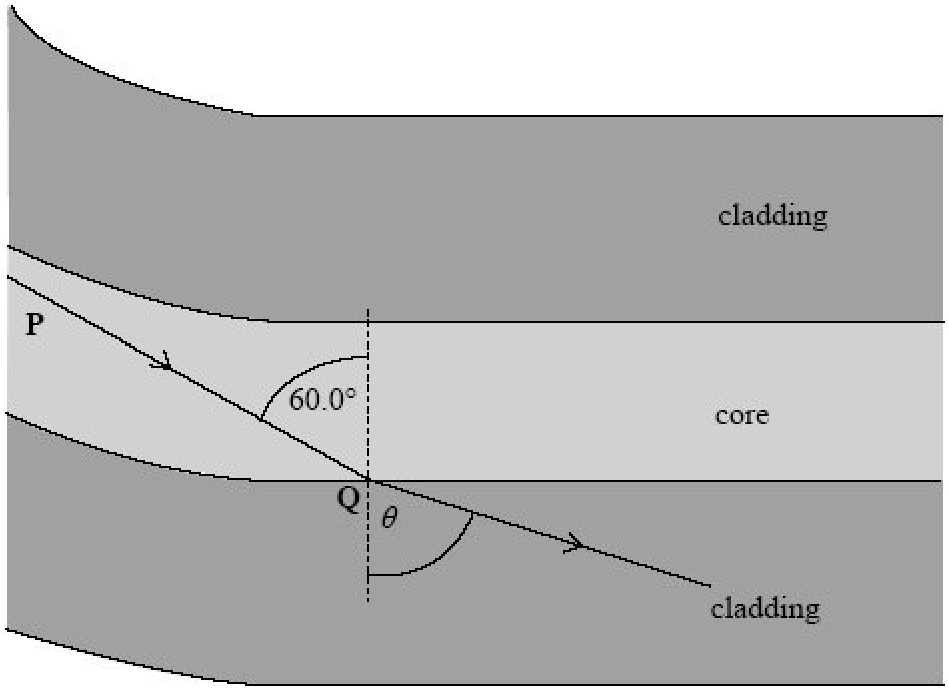
____

____

(1)

(Total 9 marks)

19 An optical fibre used for communications has a core of refractive index 1.55 which is surrounded by cladding of refractive index 1.45.



(a) The diagram above shows a light ray **P** inside the core of the fibre. The light ray strikes the core-cladding boundary at **Q** at an angle of incidence of 60.0°.

(i) Calculate the critical angle of the core-cladding boundary.

answer ____________________ degrees

(3)

(ii) State why the light ray enters the cladding at **Q**.

____

____

(1)

(iii) Calculate the angle of refraction, θ, at **Q**.

answer ____________________ degrees

(3)

(b) Explain why optical fibres used for communications need to have cladding.

____

____

____

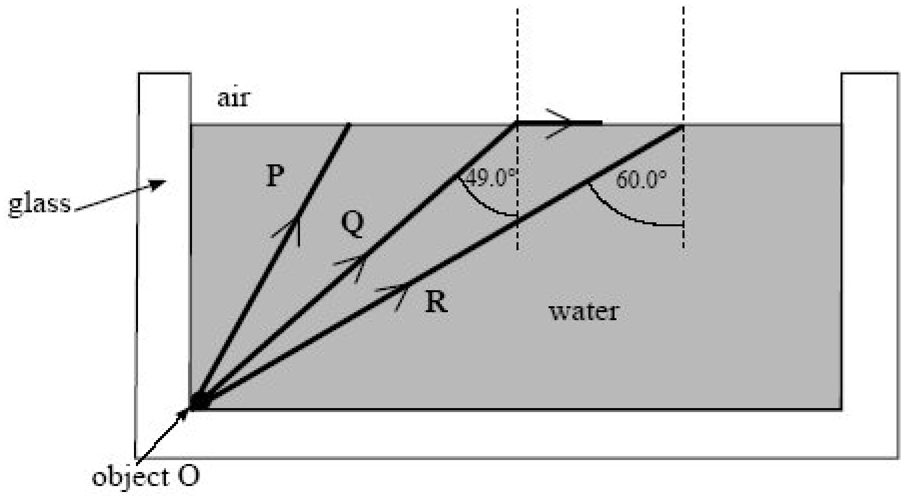
____

____

____

(2)
(Total 9 marks)

20 The diagram below shows a rectangular glass fish tank containing water. Three light rays, **P**, **Q** and **R** from the same point on a small object O at the bottom of the tank are shown.



(a) (i) Light ray **Q** is refracted along the water-air surface. The angle of incidence of light ray **Q** at the water surface is 49.0°. Calculate the refractive index of the water. Give your answer to an appropriate number of significant figures.

Answer ____________________

(1)

(ii) Draw on the diagram above the path of light ray **P** from the water-air surface.

(3)

(b) In the diagram above, the angle of incidence of light ray **R** at the water-air surface is 60.0°.

(i) Explain why this light ray is totally internally reflected at the water surface.

____

____

(2)

(ii) Draw the path of light ray **R** from the water surface and explain whether or not **R** enters the glass at the right-hand side of the tank.

the refractive index of the glass = 1.50

____

____

____

____

____

____

____

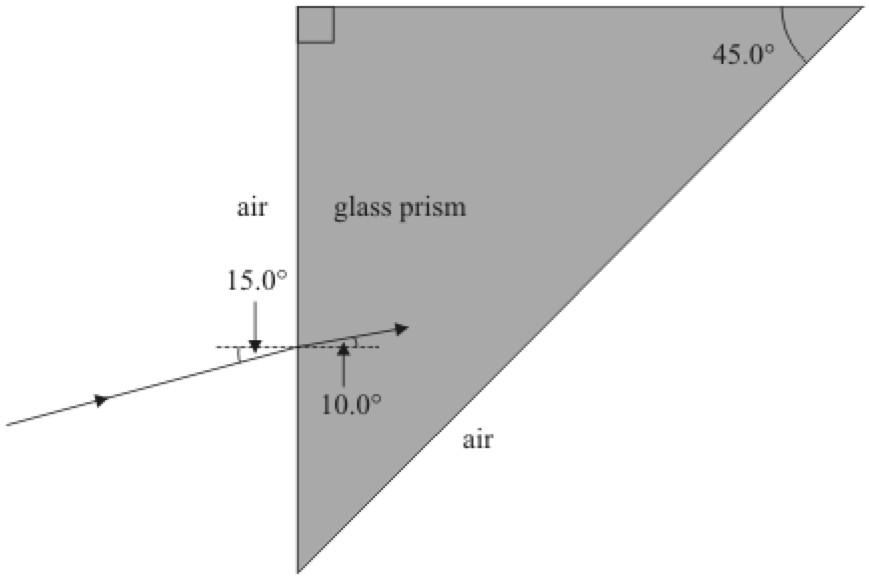
____

(4)

(Total 10 marks)

21 A ray of light passes from air into a glass prism as shown in **Figure 1**.

Figure 1



(a) Confirm, by calculation, that the refractive index of the glass from which the prism was made is 1.49.

___

___

___

___

(1)

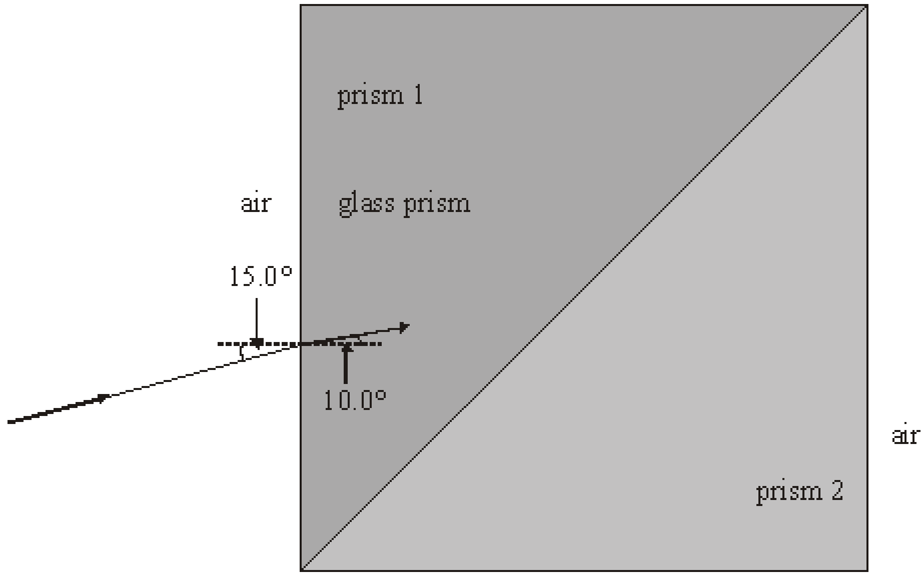
(b) On **Figure 1**, draw the continuation of the path of the ray of light until it emerges back into the air. Write on **Figure 1** the values of the angles between the ray and any normals you have drawn.

the critical angle from glass to air is less than 45°

(2)

(c) A second prism, prism 2, made from transparent material of refractive index 1.37 is placed firmly against the original prism, prism 1, to form a cube as shown in **Figure 2**.

Figure 2



(i) The ray strikes the boundary between the prisms. Calculate the angle of refraction of the ray in prism 2.

____

____

____

____

____

____

(ii) Calculate the speed of light in prism 2.

____

____

____

(iii) Draw a path the ray could follow to emerge from prism 2 into the air.

(7)

(Total 10 marks)

22 **Figure 1** shows a cross-section through a rectangular light-emitting diode (LED). When current passes through the LED, light is emitted from the semiconductor material at P and passes through the transparent material and into the air at Q.

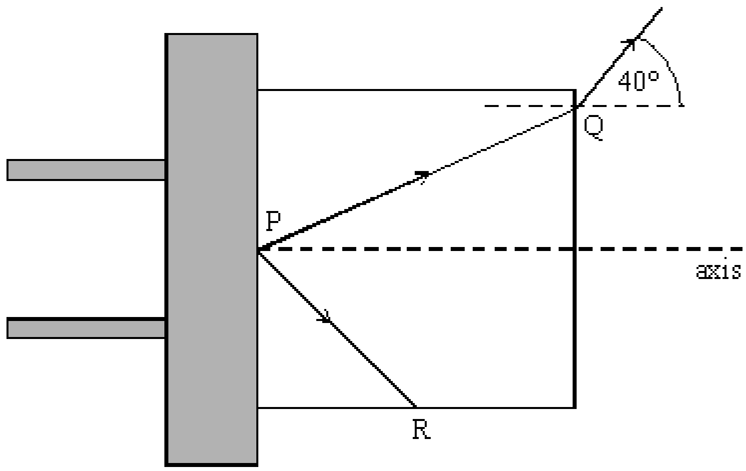


Figure 1

(a) (i) The refractive index of the transparent material of the LED is 1.5. Calculate the critical angle of this material when the LED is in air.

____

____

____

(ii) **Figure 1** shows a light ray PQ incident on the surface at Q. Calculate the angle of incidence of this light ray at Q if the angle of refraction is 40°.

____

____

____

____

(iii) **Figure 1** also shows a second light ray PR incident at R at an angle of incidence of 45°. Use **Figure 1** to explain why this light ray cannot escape into the air.

____

____

____

(7)

(b) The LED in part (a) is used to send pulses of light down two straight optical fibres of the same refractive index as the transparent material of the LED. The fibres are placed end-on with the LED, as shown in **Figure 2**. Optical fibre 1 is positioned at Q and the other at S directly opposite P.

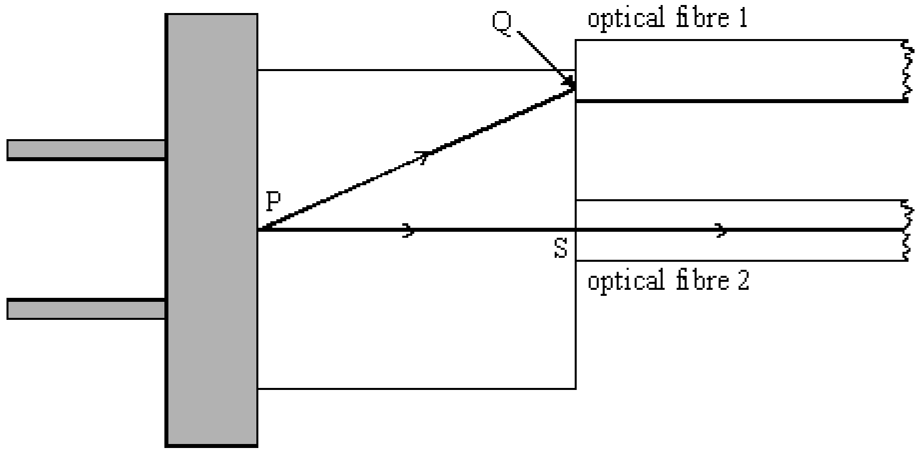


Figure 2

(i) Continue the path of the light ray PQ into and along the optical fibre.

(ii) Compare the times taken for pulses of light to travel along the same length of each fibre.

Give a reason for your answer.

____

____

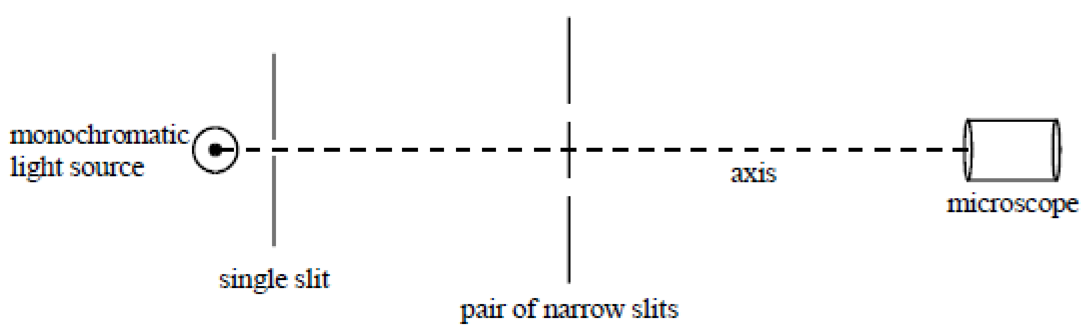
____

____

(3)

(Total 10 marks)

23 The diagram shows two closely spaced narrow slits illuminated by light from a single slit in front of a monochromatic light source. A microscope is used to view the pattern of bright and dark fringes formed by light from the two slits.

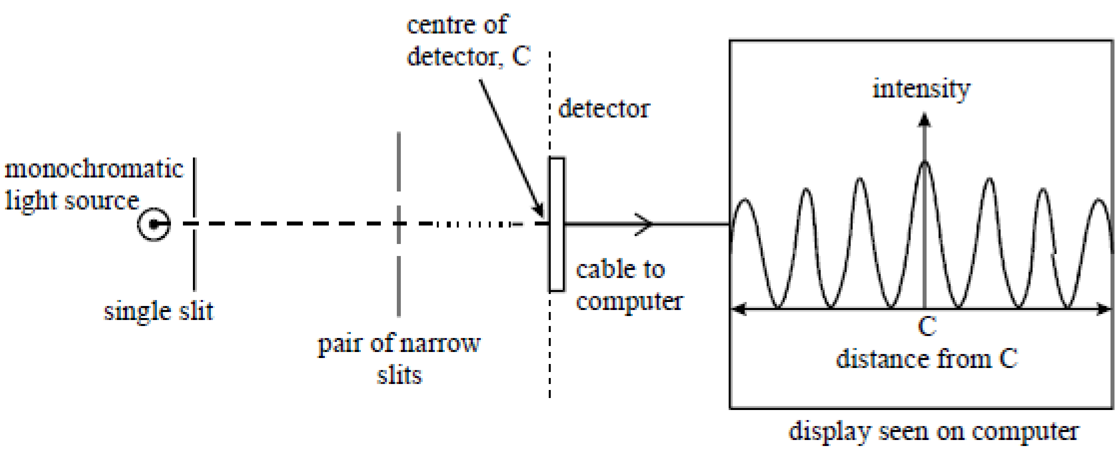


(a) (i) Explain qualitatively why these fringes are formed.

(ii) Describe what is observed if one of the narrow slits is covered by an opaque object.

(8)

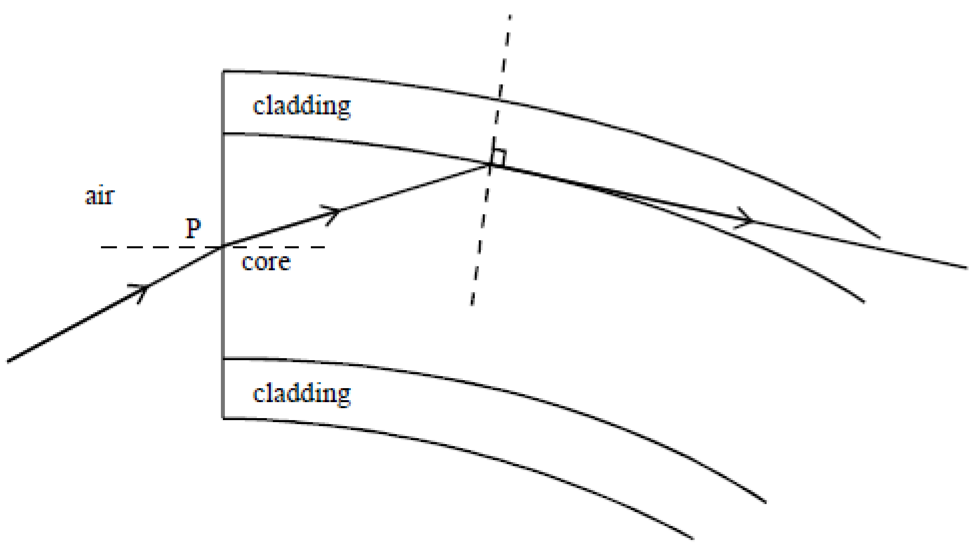
(b) The microscope is replaced by a fibre-optic detector linked to a computer. The detector consists of the flat end of many optical fibres fixed together along a line. The other end of each optical fibre is attached to a light-sensitive diode in a circuit connected to a computer. The signal to the computer from each diode is in proportion to the intensity of light incident on the diode. The computer display shows how the intensity of light at the detector varies along the line of the detector when both of the narrow slits are open.



(i) Describe and explain how the pattern on the display would change if the slit separation were increased.

(ii) Each fibre consists of a core of refractive index 1.50 surrounded by cladding of refractive index 1.32. Calculate the critical angle at the core-cladding boundary.

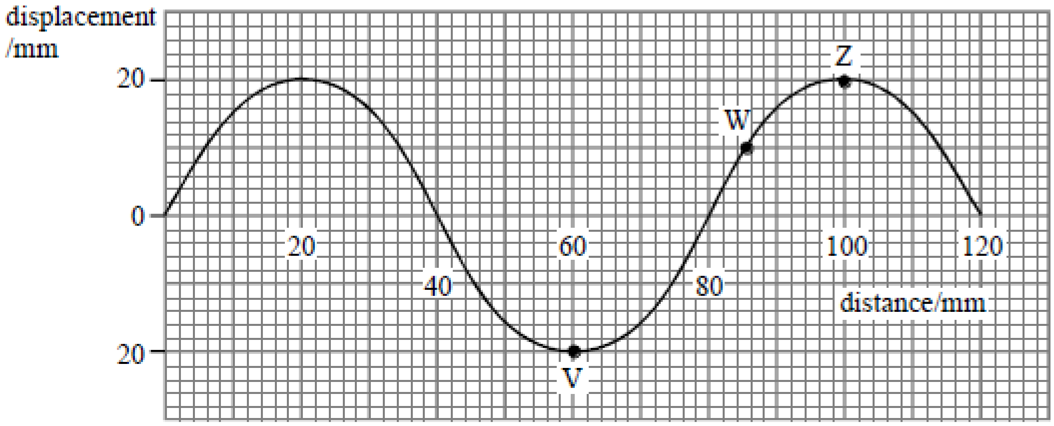
(iii) The diagram below shows a light ray entering an optical fibre at point P on the flat end of the fibre. The angle of incidence of this light ray at the core-cladding boundary is equal to the critical angle. On the diagram, sketch the path of another light ray from air, incident at the same point P, which is totally internally reflected at the core-cladding boundary.



(7)

(Total 15 marks)

24 The graph shows the variation of displacement of the particles with distance along a stationary transverse wave at time t = 0 when the displacement of the particles is greatest. The period of the vibrations causing the wave is 0.040 s.



(a) Using the same axes,

(i) draw the appearance of the wave at t = 0.010 s, labelling this graph B,

(ii) draw the appearance of the wave at t = 0.020 s, labelling this graph C,

(iii) show an antinode labelled A and a node labelled N.

(3)

(b) (i) Describe the motion of the particle at V, giving its frequency and amplitude.

____

____

(ii) State the amplitude of the particle at W and its phase relations with the particle at V and the particle at Z.

____

____

____

(6)

(Total 9 marks)

25 (a) A helium-neon laser produces monochromatic light of wavelength 632.8 nm which falls normally on a diffraction grating. A first order maximum is produced at an angle of 18.5° measured from the normal to the grating.

Calculate

(i) the number of lines per metre on the grating,

____

____

____

(ii) the highest order which is observable.

(6)

(b) When the grating is used with a different monochromatic source, the first order maximum is observed at an angle of 17.2°.

Calculate the wavelength of this second source.

(2)

(Total 8 marks)

26 (a)

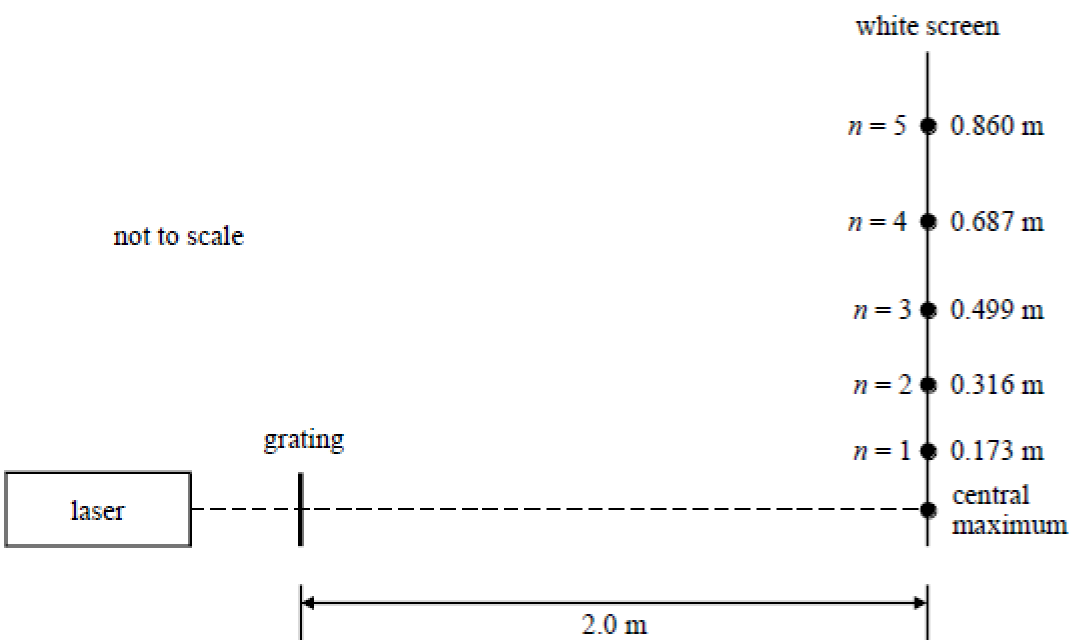


Figure 1

In a laboratory experiment, monochromatic light of wavelength 633 nm from a laser is incident normal to a diffraction grating. The diffracted waves are received on a white screen which is parallel to the plane of the grating and 2.0 m from it. **Figure 1** shows the positions of the diffraction maxima with distances measured from the central maximum.

By means of a graphical method, use all these measurements to determine a mean value for the number of rulings per unit length of the grating.

(6)

(b) Describe and explain the effect, if any, on the appearance of the diffraction pattern of

(i) using a grating which has more rulings per unit length.

___

___

___

(ii) using a laser source which has a shorter wavelength.

___

___

___

(iii) increasing the distance between the grating and the screen.

___

___

___

(6)

(c) **Figure 2**, below, shows the diffracted waves from four narrow slits of a diffraction grating similar to the one described in part (a). The slit separation AB = BC = CD = DE = d and EQ is a line drawn at a tangent to several wavefronts and which makes an angle θ with the grating.

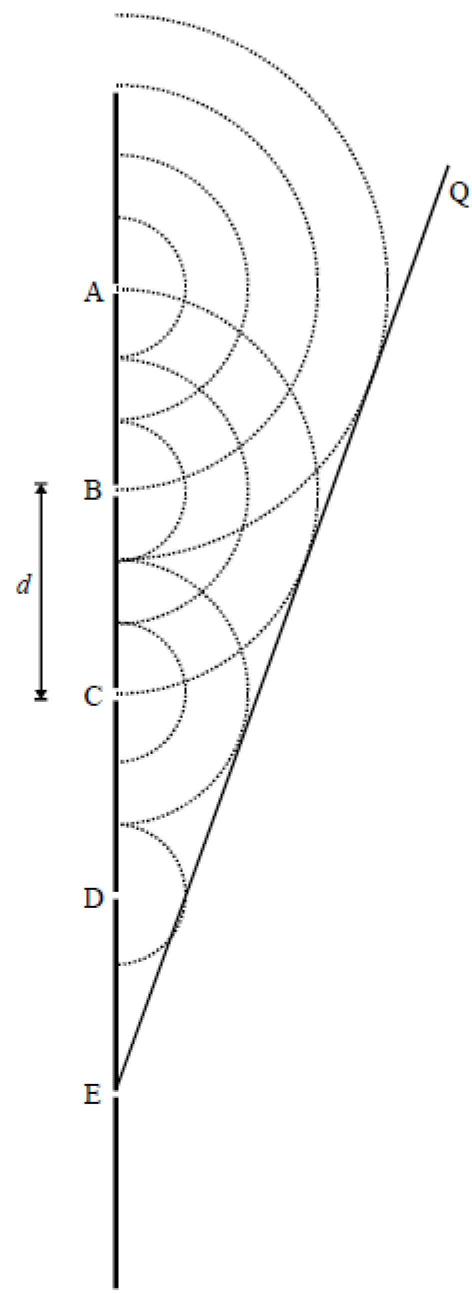


Figure 2

(i) Explain why the waves advancing perpendicular to EQ will reinforce if superposed.

___

___

___

(ii) Show that this will happen when $\sin\theta = \frac{\lambda}{d}$.

____

____

____

(3)
(Total 15 marks)

27 The diagram for this question is drawn to scale and 1 mm on the diagram represents an actual distance of 5 mm.

S_1 and S_2 are identical *coherent* transmitters emitting, in phase, microwaves with a wavelength of 25 mm. They are positioned 250 mm apart on a horizontal surface and a detector can be placed anywhere along the line YY' which is in the same plane as the transmitters and parallel to the line containing S_1 and S_2.

(a) Explain what is meant by *coherent*.

____

____

(2)

(b) By making measurements on the diagram and using the scale, determine the number of wavelengths in the path

(i) S_1R,

____

____

(ii) S_2R.

(iii) Use your answers to (i) and (ii) to determine whether or not you expect the signal received by a detector placed at R to be a maximum. Explain your answer.

(5)

(c) Describe how you would expect the signal strength to vary as the detector is moved from R to P via Q.

(2)

(d) Calculate the frequency of the microwaves.

(1)

(Total 10 marks)

28 (a) Explain how a stationary wave is produced when a stretched string is plucked.

(3)

(b) (i) On **Figure 1**, draw the fundamental mode of vibration of a stretched string. Label any nodes with a letter **N** and any antinodes with a letter **A**.

Figure 1

(2)

(ii) On **Figure 2**, draw the fourth harmonic (third overtone) for the stretched string. Label any nodes with a letter **N** and any antinodes with a letter **A**.

Figure 2

(2)

(c) The fundamental frequency of vibration, f, of a string is given by:

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

where T = the tension in the string
l = the length of the string
μ = the mass per unit length of the string

A string has a tension of 180 N and a length of 0.70 m.

(i) What would need to be done to the length of the string in order to double the frequency?

(1)

(ii) What would need to be done to the tension of the string in order to double the frequency?

(2)
(Total 10 marks)

29 (a) **Figure 1** shows how the displacement *s* of the particles in a medium carrying a pulse of ultrasound varies with distance *d* along the medium at one instant.

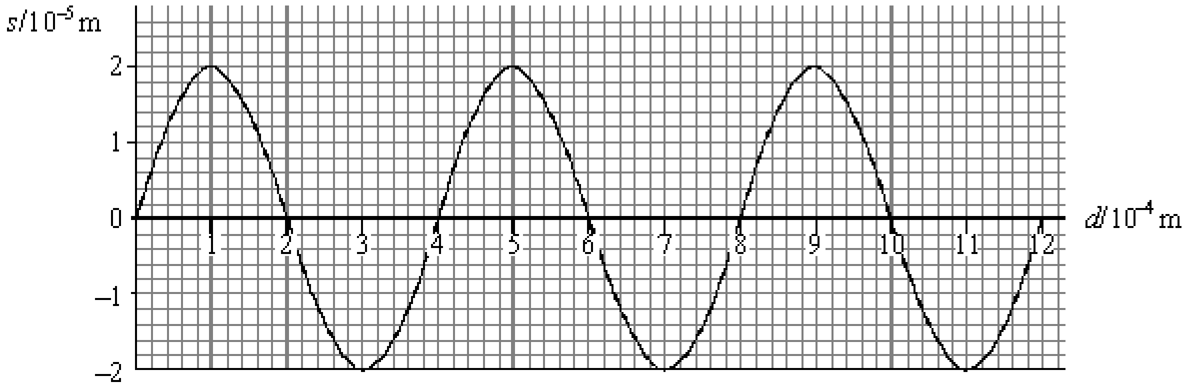


Figure 1

(i) State the amplitude of the wave.

____

(1)

(ii) The speed of the wave is 1200 m s^{-1}. Calculate the frequency of oscillation of the particles of the medium when the ultrasound wave is travelling through it.

Frequency of oscillation ____________________

(3)

(b) An ultrasound transmitter is placed directly on the skin of a patient. **Figure 2** shows the amplitudes of the transmitted pulse and the pulse received after reflection by an organ in the body. amplitude

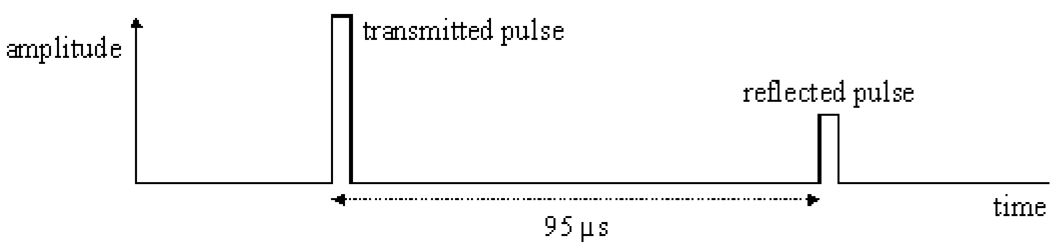


Figure 2

(i) Give **two** possible reasons why the amplitude of the received pulse is lower than that which is transmitted.

Reason 1 ____

____

Reason 2 ____

____

(2)

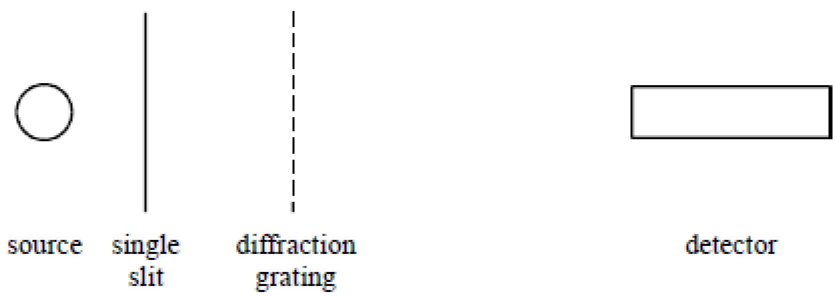
(ii) The speed of ultrasound in body tissue is 1200 m s^{-1}. Calculate the depth of the reflecting surface below the skin.

Depth of reflecting surface ____________________

(2)

(Total 8 marks)

30 The diagram below is an arrangement for analysing the light emitted by a source.



(a) Suggest a light source that would emit a continuous spectrum.

____

(1)

(b) The light source emits a range of wavelengths from 500 nm to 700 nm. The light is incident on a diffraction grating that has 10 000 lines per metre.

(i) Calculate the angle from the straight through direction at which the first order maximum for the 500 nm wavelength is formed.

Angle = ____________________

(3)

(ii) Calculate the angular width of the first order spectrum.

Angular width ____________________

(1)

(iii) The detector is positioned 2.0 m from the grating. Calculate the distance between the extreme ends of the first order spectrum in this position.

Distance = ____________________

(1)

(c) The single slit is initially illuminated by light from a point source that is 0.02 m from the slit.

State and explain how the intensity of light incident on the single slit changes when the light source is moved to a position 0.05 m from the slit.

____

____

____

____

____

(4)

(Total 10 marks)

Mark schemes

1 (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]

2 (a) Answer D ✓ (violet)

1

(b) (light from each slit) superpose
light from adjacent slits have a path difference of one wavelength
(at this angle all) the waves are in phase
constructive interference / peaks coincide / (positively) reinforce

any 3 points ✓ ✓ ✓ max 3

Ignore reference to nodes or antinodes

If general statements are made only give marks for parts related to 'Bright line' or 'First order' which appears in the question.

3

(c) (i) use of $\sin\theta = \lambda / d = 5.3 \times 10^{-7} / 1.8 \times 10^{-6}$ ✓ (= 0.294)
$\theta = 17°$ ✓ (17.1°)

Answer alone scores both marks

2

(ii) (use of $n = d \sin\theta / \lambda$) $n_{max} = (d \sin 90° / \lambda) = d / \lambda =$ ✓
$= 1.8 \times 10^{-6} / 5.3 \times 10^{-7} = 3.4$ ✓
max order = 3 ✓

Showing that n=4 is not possible is not answering the question but the first mark (equation mark) can be gained this way

Max order is an independent mark from reducing a calculated value for n to the next lowest integer.

3

[9]

3 (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

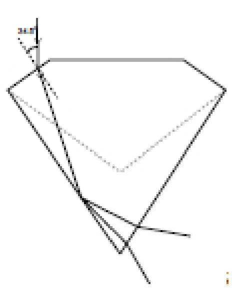
(ii) $\sin\theta_{dia} = \sin\theta_{air} / n = \sin 50.2 / 2.42$ ✓ (= 0.317)
$\theta_{dia} = 18.5°$ ✓ (allow 2 or more sig figs)

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]

4 (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]

5 The marking scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question.

Descriptor – an answer will be expected to meet most of the criteria in the level descriptor.

Level 3 – good

-claims supported by an appropriate range of evidence

-good use of information or ideas about physics, going beyond those given in the question

-argument well structured with minimal repetition or irrelevant points

-accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling

Level 2 – modest

-claims partly supported by evidence,

-good use of information or ideas about physics given in the question but limited beyond this the argument shows some attempt at structure

-the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling

Level 1 – limited

-valid points but not clearly linked to an argument structure

-limited use of information about physics

-unstructured

-errors in spelling, punctuation and grammar or lack of fluency

Level 0

-incorrect, inappropriate or no response

Level 3
Response will give a sensible diagram, suggestion of length of string and sensible range details of range of tension, the procedure to obtain data and the analysis of the data. The response may include a calculation of *f* for the chosen apparatus.

Level 2
All bullet points will be addressed but may lack essential detail. The response will include a sensible diagram and procedure but the procedure may be poorly explained. It should include how the data is analysed to demonstrate the relationship.

Level 1
Attempt will contain some relevant detail of a sensible experiment. The diagram may be poorly drawn. The range for the tension may be given but not be sensible. Their procedure and analysis may be only superficially described.

Level 0
Response will contain no relevant information about an appropriate experiment.

Points that may be included

- *Labelled diagram including string , weights, pulley, metre rule,*
- *method using signal generator (calibrated) and magnets to cause oscillation of the string*
- *method using tuning forks*
- *Length 1-2 m*
- *e.g Weights up to 12 N in 2 N increments (range of at least 6)*
- *Frequencies different by detectable amount on sig gen / use of range of tuning forks*
- *Calculation to show approx f value for selected T and l*
- *Method of changing T*
- *How frequency is determined for each T*
- *Graph of f against √T*

[6]

6 (a) Initially the path difference is zero/the two waves are in phase when they meet/the (resultant) displacement is a maximum ✓

Alternative:

Constructive interference occurs when the path difference is a whole number of wavelengths and the waves are in phase

1

As the movable tube is pulled out, the path difference increases and the two waves are no longer in phase, so the displacement and loudness decrease ✓

Destructive interference occurs when the path difference is an odd number of half wavelengths and the waves are in antiphase

1

When the path difference is one half wavelength, the two are in antiphase and sound is at its quietest. ✓

Initially the path difference is zero and the sound is loud

1

As the path difference continues to increase, the two waves become more in phase and the sound gets louder again. ✓

As the pipe is pulled out the path difference gradually increases, changing the phase relationship and hence the loudness of the sound

1

(b) Use of *wavelength = speed / frequency*

The first mark is for calculating the wavelength

1

To give: 340 / 800 = 0.425 m ✓

Path difference = one half wavelength = 0.21 m ✓

The second mark is for relating the wavelength to the path difference

Path difference = 2 ($d_2 - d_1$) = 2 (distance moved by movable tube)

1

Distance moved by movable tube = 0.10 m. ✓

The final mark is for relating this to the distance moved by the tube and working out the final answer.

1

(c) Start with d1 = d2

(Alternative mark scheme involving changing frequency and measuring to first min for each one can gain equal credit)

Measure distance moved by movable tube for each successive minima and maxima✓

Start with d1 = d2

Measure distance moved by movable tube for first minimum.

1

Each change in distance is equal to one quarter wavelength. ✓

Distance is equal to one quarter wavelength

1

Continue until tube is at greatest distance or repeat readings for decreasing distance back to starting point. ✓

Repeat for different measured frequencies.

1

Use speed = frequency x wavelength ✓

Use speed = frequency x wavelength)

1

[11]

7 (a) 2.9% ✓

Allow 3%

1

(b) $\frac{1}{3.5 \times 10^3}$ seen ✓

1

0.29 mm or 2.9×10^{-4} m✓ must see 2 sf **only**

1

(c) ± 0.01 mm ✓

1

(d) Clear indication that at least 10 spaces have been measured to give a spacing = 5.24 mm✓

spacing from at least 10 spaces
Allow answer within range ±0.05

1

(e) Substitution in $d\ sin\theta = n\lambda$✓

The 25 spaces could appear here as n with sin θ as 0.135 / 2.5

1

$d = 0.300 \times 10^{-3}$ m so
number of lines = 3.34×10^3✓

Condone error in powers of 10 in substitution

Allow ecf from 1-4 value of spacing

1

(f) Calculates % difference (4.6%) ✓

1

and makes judgement concerning agreement ✓

Allow ecf from 1-5 value

1

(g) care not to look directly into the laser beam✓
OR
care to avoid possibility of reflected laser beam ✓
OR
warning signs that laser is in use outside the laboratory✓
ANY ONE

1

[10]

8 (a) Core is transmission medium for em waves to progress (by total internal reflection) ✓

Allow credit for points scored on a clear labelled diagram.

1

Cladding provides lower refractive index so that total internal reflection takes place ✓

1

And offers protection of boundary from scratching which could lead to light leaving the core. ✓

1

(b) Blue travels slower than red due to the greater refractive index

Red reaches end before blue, leading to material pulse broadening ✓

The first mark is for discussion of refractive index or for calculation of time difference.

1

Alternative calculations for first mark

Time for blue = $d / v = d / (c / n)$ = 1200 / (3 × 10^8 / 1.467) = 5.87 × 10^{-6} s

Time for red = $d / v = d / (c / n)$ = 1200 / (3 × 10^8 / 1.459) = 5.84 × 10^{-6} s

Time difference = 5.87 × 10^{-6} – 5.84 × 10^{-6} = 3(.2) × 10^{-8} s ✓

The second mark is for the link to material pulse broadening

1

(c) Discussions to include:

Use of monochromatic source so speed of pulse constant

Use of shorter repeaters so that the pulse is reformed before significant pulse broadening has taken place.

Use of monomode fibre to reduce multipath dispersion ✓ ✓

Answer must make clear that candidate understands the distinction between modal and material broadening.

2

[7]

9 (a) uniform width peaks ✓ (accurate to within ± one division)

peaks need to be rounded ie not triangular

the minima do not need to be exactly zero

a collection of peaks of constant amplitude or amplitude decreasing away from central peak ✓

pattern must look symmetrical by eye

condone errors towards the edge of the pattern

double width centre peak total mark = 0

2

(b) (i) constant / fixed / same phase relationship / difference (and same frequency / wavelength) ✓

in phase is not enough for the mark

1

(ii) single slit acts as a point / single source diffracting / spreading light to <u>both slits</u> ✓

OR

the path lengths between the single slit and the double slits are constant / the same / fixed ✓

1

(iii) <u>superposition</u> of waves from two slits ✓

phrase 'constructive superposition' = 2 marks

diffraction (patterns) from both slits overlap (and interfere constructively) ✓ (this mark may come from a diagram)

constructive interference / reinforcement (at bright fringe)
peaks meet peaks / troughs meet troughs ✓ (any reference to antinode will lose this mark)

waves from each slit meet in phase
OR path difference = $n\lambda$ ✓

4 max 3

(c) (i) $D = \frac{ws}{\lambda} = \frac{0.004 \times 5.0\,10^{-5}}{405 \times 10^{-9}}$ ✓ **do not penalise any incorrect powers of ten for this mark**
= 0.5 (m) ✓ (0.4938 m)

numbers can be substituted into the equation using any form

note 0.50 m is wrong because of a rounding error

full marks available for answer only

2

(ii) fringes further apart or fringe / pattern has a greater width / is wider ✓

ignore any incorrect reasoning

changes to green is not enough for mark

1

(iii) increase D ✓
measure across more than 2 maxima ✓

several / few implies more than two

added detail which includes ✓
explaining that when D is increased then w increases
Or
repeat the reading with a changed distance D or using different numbers of fringes or measuring across different pairs of (adjacent) fringes
Or
explaining how either of the first two points improves / reduces the percentage error.

no mark for darkened room

3

[13]

10 (a) (i) sin 60 = 1.47sin θ **OR** sin θ = sin 60 / 1.47 ✓
($\sin^{-1}$ 0.5891) = 36 (°) ✓ (36.0955°) (allow 36.2)

Allow 36.0

2

(ii) <u>sin θ_c = 1.33 / 1.47</u> OR <u>sin θ_c = 0.9(048)</u> ✓

(sin^{-1} 0.9048) = 65 (°) ✓ (64.79)

Allow 64 for use of 0.9 and 66 for use of 0.91

2

(iii) answer consistent with previous answers, e.g.

if aii >ai:

ray refracts at the boundary AND goes to the right of the normal ✓

Angle of refraction > angle of incidence ✓ **this mark depends on the first**

if aii < ai:

TIR ✓

angle of reflection = angle of incidence ✓

ignore the path of the ray beyond water / glass boundary

Approx. equal angles (continuation of the line must touch 'Figure 1' label)

2

(b) for Reason or Explanation:

the angle of refraction should be > angle of incidence when <u>entering the water</u> ✓

water has a lower refractive index than glass \ light is faster in water than in glass ✓

TIR could not happen \ there is no critical angle, when ray travels from water to oil ✓

TIR only occurs when ray travels from higher to lower refractive index \ water has a lower refractive index than oil ✓

Allow 'ray doesn't bend towards normal' (at glass / water)

Allow <u>optical</u> density

Boundary in question must be clearly implied

4

[10]

11 (a) number of (complete) <u>waves</u> (passing a point) <u>in 1 second</u>

OR

number of waves / time (for the waves to pass a point)

OR

(complete number of) oscillations \ vibrations <u>per second</u>

OR

1 / T with T defined as time for 1 (complete) oscillation ✓

Allow: cycles

Allow: unit time

1

(b) For two marks:
oscillation of particles \ medium \ material etc, but not oscillation of wave is parallel to \ in same direction as
the direction wave (travels) ✓ ✓

For one mark:
particles \ material \ medium move(s) \ disturbance \ displacement
parallel to \ in same direction as
the direction wave travels
OR
(oscillations) parallel to direction of wave travel ✓

the one mark answer with:
mention of compressions and rarefactions
OR
(longitudinal waves) cannot be polarised

gets **two** marks
✓

Allow
Vibration
Allow direction of energy transfer \ wave propagation

2

(c) ($f = 1540 / 0.50 \times 10^{-3}$)
= 3 100 000 (Hz) ✓ (3 080 000)
2sf ✓

2

(d) no more than two points from either list (max 3):
Description
- mention of nodes and antinodes
- particles not moving at a node
- maximum displacement at antinode
- particles either side of node in antiphase / between two nodes in phase
- variation of amplitude between nodes

Explanation
- a stationary wave (forms)
- two waves are of equal frequency or wavelength (and amplitude in the same medium)
- reflected and transmitted waves \ waves travelling in opposite directions, pass through each other
- superpose / interference occurs
- constructive interference at antinodes
- destructive interference at nodes

✓ ✓ ✓

Allow 'standing wave'

3

[8]

12 (a) one of:
(spectral) analysis of light from stars
(analyse) composition of stars
chemical analysis
measuring red shift \ rotation of stars ✓

insufficient answers:
'observe spectra', 'spectroscopy', 'view absorption \ emission spectrum', 'compare spectra', 'look at light from stars'.

Allow : measuring wavelength or frequency from a <u>named source</u> of light

Allow any other legitimate application that specifies the source of light. E.g.
absorbtion \ emission spectra in stars,
'observe spectra of materials'

1

(b) (i) first order beam
first order spectrum
first order image
✓

Allow 'n = 1' , '1' , 'one', 1 st

1

(ii) the light at A will appear white (and at B there will be a spectrum)
OR greater intensity at A ✓

1

(c) (d = 1 / (lines per mm × 10^3)
= 6.757×10^{-7} (m) OR 6.757×10^{-4} (mm) ✓

($n\lambda = d \sin\theta$)
= $6.757 \times 10^{-7} \times \sin 51.0$ ✓ ecf **only** for :

- incorrect power of ten in otherwise correct calculation of d
- use of d = 1480, 1.48, 14.8 (etc)
- from incorrect order in bii

= 5.25×10^{-7} (m) ✓ ecf **only** for :

- incorrect power of ten in otherwise correct d
- from incorrect order in bii

Some working required for full marks. Correct answer only gets 2

Power of 10 error in d gets max 2

For use of d in mm, answer =

5.25×10^{-4} gets max 2

n = 2 gets max 2 unless ecf from bii

use of d = 1480 yields wavelength of 1150m

3

(d) n = d (sin90) / λ OR n = $6.757 \times 10^{-7} / 5.25 \times 10^{-7}$ ✓ ecf both numbers from c

= 1.29 so no more beams observed ✓ or answer consistent with their working

OR

2 = d (sinθ) / λ OR sinθ = $2 \times 5.25 \times 10^{-7} / 6.757 \times 10^{-7}$ ✓ ecf both numbers from c

sinθ = 1.55 (so not possible to calculate angle) so no more beams ✓

OR $\sin^{-1}$(2 × (their λ / their d)) ✓
(not possible to calculate) so no more beams ✓ ecf

Accept 1.28, 1.3

Second line gets both marks

Conclusion consistent with working

2

[8]

13 (a) same wavelength / frequency ✓

constant phase relationship ✓ allow 'constant phase difference' but not 'in phase'

2

(b) (i) ($\lambda = \frac{c}{f}$)

Use of speed of sound gets zero

$3.00 \times 10^8 = 9.4\ (10^9)\ \lambda$ OR $\frac{3.00\times10^8}{9.4\times(10^9)}$ ✓

= 3.2×10^{-2} (3.19×10^{-2} m) ✓

Allow 0.03

2

(ii) 3.2×10^{-2} ✓ (m) ecf from bi

Don't allow '1 wavelength', 1λ, etc
Do not accept: zero, 2π, 360 °

1

(c) maximum (at position shown) ✓

allow constructive superposition.
'Addition' is not enough

constructive interference / reinforcement ✓

ecf for 'minimum' or for reference to wrong maximum

(the waves meet) 'in step' / peak meets peak / trough meets trough / path difference is (n) λ / in phase ✓

3

(d) $s = \frac{\lambda D}{w}$

Don't allow use of the diagram shown as a scale diagram

$= \frac{0.0319 \times 0.42}{0.11}$ ✓ ecf bi

Do not penalise s and w symbols wrong way round in working if answer is correct.

= 0.12 (0.1218 m) ✓

Correct answer gains first two marks.

= **any <u>2sf</u>** number ✓

*Independent sf mark for **any** 2 sf number*

3

(e) a maximum ✓

Candidates stating ' minimum ' can get second mark only

(f × 2 results in) $\lambda/2$ ✓

path difference is an even number of multiples of the new wavelength ($2n\lambda_{new}$) ✓

allow 'path difference is $n\lambda$' / any even number of multiples of the new λ quoted e.g. 'path difference is now 2 λ'

3

[14]

14 (a) use of c/c_s = n (condone inversion of c and c_s)

C1

1.9×10^8 (m s^{-1})

A1

2

(b) (i) path difference = 120 m or 0.12 km/finds two times and subtracts

(allow incorrect speed with working) (condone power of ten error)

C1

(penalise use of different speeds)

6.4×10^{-7}s (ecf from (a))

A1

2

(ii) refractive index varies across (graded-index) core/refractive index maximum at **centre** of core

B1

ray travels slower in centre/rays travel faster at edge/ray B travels faster/ray A travels slower

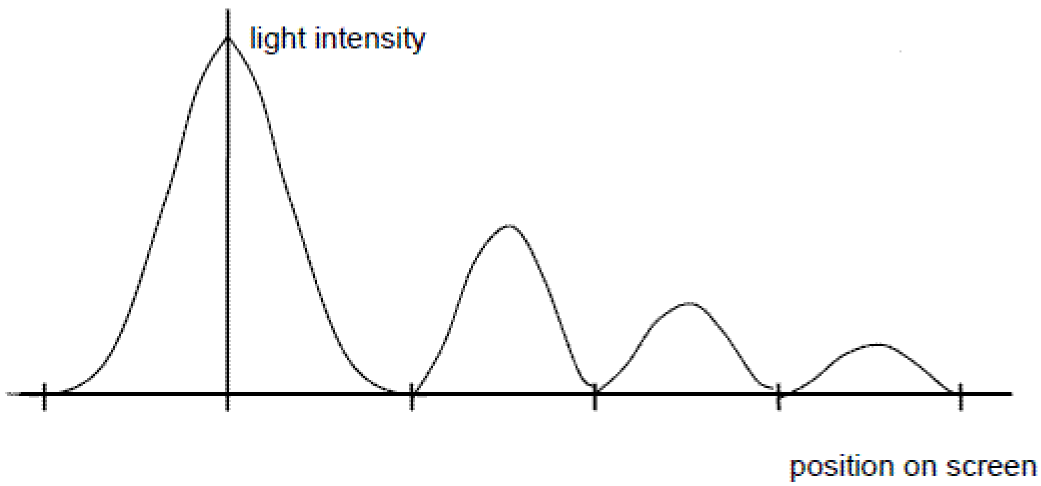
B1

2

[6]

15 (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]

16 (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

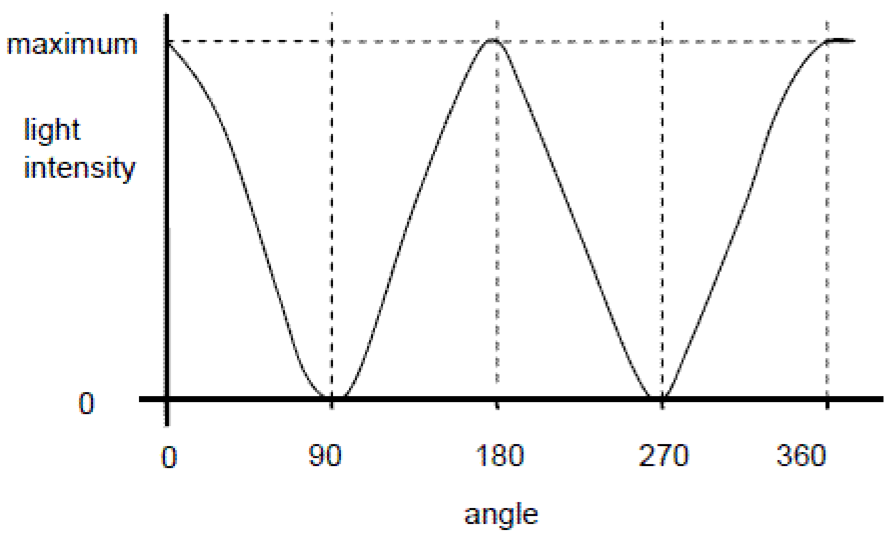
or **all** longitudinal require a medium **(1)**

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/ windscreens	to reduce glare
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]

17

(a) (i) rearrangement of $f = \frac{1}{2l}\sqrt{\frac{T}{u}}$ to give $l = \frac{1}{2f}\sqrt{\frac{T}{u}}$ C1

correct subs $l = \frac{1}{2 \times 92.5}\sqrt{\frac{681}{1.87 \times 10^{-2}}}$ or 92.5 = $\frac{1}{2f}\sqrt{\frac{681}{1.87 \times 10^{-2}}}$

C1

1.0(3) (m) condone sf

A1

3

(ii) 2 loops roughly equal

B1

1

(iii) (lightly) stop (in centre) B1

pluck or bow B1 2

(b) keeps tension or mass per unit length constant

B1

way of measuring frequency or producing vibration of known *f*

B1

way of measuring length (at resonance)

B1

use of suitable graph (*f vs 1/l* or *l vs 1/f)* to display results

B1

marks may be awarded for information seen on diagram

4

[10]

18 (a) (i) one 'loop' (accept single line only, accept single dashed line)

+ nodes at each bridge (± length of arrowhead)

+ antinode at centre **(1)**

1

(ii) $\lambda_0 = 2L$ or $\lambda = 0.64 \times 2$ **(1)**

= 1.3 (m) **(1)** (1.28)

2

(iii) ($c = f\lambda$) = 108 × (a)(ii) **(1)**

= 138 to 140(.4) (m s^{-1}) **(1)** ecf from (a) (ii)

2

(b) (i) four antinodes **(1)** (single or double line)

first node on 0.16 m (within width of arrowhead)

+ middle node between the decimal point and the centre of the 'm' in '0.64 m'

+ middle 3 nodes labelled 'N', 'n' or 'node' **(1)**

2

(ii) ($4f_0$ =) 430 (Hz) **(1)** (432)

or use of $f = \frac{v}{\lambda}$ gives 430 to 440 Hz correct answer only, no ecf

1

(c) decrease the length/increase tension/tighten string **(1)**

1

[9]

19 (a) (i) (using $n_1 \sin \theta_1 = n_2 \sin \theta_2$ or $\sin \theta_c = n_2/n_1$ gives)

correct substitution in either equation (eg 1.55 sin c = 1.45 (sin 90) or sin c = 1.45/1.55) **(1)**

= 0.9355 (accept less sf) **(1)**
c = 69.3(°) **(1)** (accept 69.4°, 69° **or** 70°)

(ii) the angle (of incidence) is less than the **critical angle** or values quoted **(1)**

(iii) (using $n_1 \sin \theta_1 = n_2 \sin \theta_2$ gives)

1.55 sin 60 = 1.45 sin θ **(1)**

(sin θ = 1.55 sin 60/1.45 =) 0.9258 or 0.926 or 0.93 **(1)**

θ = 67.8° **(1)** (accept 68° **or** 68.4)

7

(b) any **two** from:

keeps signals secure **(1)**

maintains quality/reduces pulse broadening/smearing (owtte) **(1)**

it keeps (most) light rays in (the core due to total internal reflection at the cladding-core boundary) **(1)**

it prevents scratching **of the core (1)**

(keeps core away from adjacent fibre cores) so helps to prevent crossover of **information/signal/data** to **other** fibres **(1)**

cladding provides (tensile) strength for fibre/prevents breakage **(1)**

given that the core needs to be very thin **(1)**

max 2

[9]

20 (a) (i) (refractive index of water = 1/sin 49.0) = **1.33** (not 1.3 or 1.325) **(1)**

(ii) ray P shown in the air to right of vertical **(1)**

refracted away from the normal in the correct direction **(1)**

correct partial reflection shown **(1)**

4

(b) (i) **critical angle** for water-air boundary = 49.0°
or angle of (incidence of) Q is θ_c **(1)**

the angle of incidence (of R) exceeds the critical angle **(1)**

(ii) the figure shows that R undergoes TIR at water surface and strikes the glass side **(1)**

angle of incidence at glass side = 30° **(1)**

R enters the glass and refracts towards the normal **(1)**

because $n_g > n_w$ **(1)** (or water is optically less dense than glass)

(calculates angle = 26.2° gets last two marks)

6

[10]

21 (a) $n = \left(\frac{\sin\theta_1}{\sin\theta_2}\right) = \frac{\sin 15.0^o}{\sin 10.0^o}$ **(1)** $(= 1.49)$

1

(b) TIR on hypotenuse **and** refraction at top surface **(1)**
55°, 10° and 15° all marked correctly **(1)**

2

(c) (i) use of ${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2}$ *and* ${}_1n_2 = \frac{n_2}{n_1}$

[or $n_1 \sin\theta_1 = n_2 \sin\theta_2$] **(1)**

$1.49 \sin 55^o = 1.37 \sin\theta_2$ **(1)**

$\theta_2 = 63^o$ **(1)**

(ii) (use of $n = \frac{c_1}{c_2}$) gives $1.37 = \frac{3.0 \times 10^8}{c_2}$ **(1)**

$c_2 = 2.2 \times 10^8$ ms^{-1} **(1)**
(2.19×10^8 ms^{-1})

(iii) refraction at boundary between prisms, refracted away from normal **(1)**

emerging ray (r.h. vertical face) refracting away from normal **(1)**

7

[10]

22 (a) (i) $\sin c = \frac{1}{1.5}$ **(1)**

$c = 42°$ **(1)** **(**41.8°)

(ii) $1.5 \sin i = \sin 40$ **(1)**
$i = 25°$ **(1)** **(**25.4°) (use of $c = 41.8°$ gives $i = 26.4°$)

(iii) total internal reflection at R **(1)**
further total internal reflection below Q **(1)**
further total internal reflection **(1)**

7

(b) (i) light ray enters fibre without refraction **(1)**
total internal reflection at fibre/air surface **(1)**

(ii) pulse in fibre 1 takes longer because it travels across the fibre

as well as along it **(1)**

3

[10]

23 (a) (i) fringes formed when light from the two slits overlap (or diffracts) **(1)**
slits emit waves with a constant phase difference (or coherent) **(1)**
bright fringe formed where waves reinforce **(1)**
dark fringe formed where waves cancel **(1)**
[or if 3rd and 4th not scored, waves interfere **(1)**]
path difference from slits to fringe =
whole number of wavelengths for a bright fringe **(1)**
whole number + half a wavelength for a dark fringe **(1)**
[or phase difference is zero (in phase) for a bright fringe **(1)**
and 180° for a dark fringe **(1)**]

(ii) (interference) fringes disappear **(1)**
single slit diffraction pattern observed
[or single slit interference observed] **(1)**
central fringe (of single slit pattern) **(1)**
side fringes narrower than central fringe **(1)**

max 8

(b) (i) fringes closer **(1)**
(because) each fringe must be closer to the centre for the same path difference
[or correct use of formula as explanation] **(1)**

(ii) $\sin\theta_c \left(= \frac{n_2}{n_1}\right) = \frac{1.32}{1.50}$ **(1)** (= 0.88)

$\theta_c = 61.6°$ **(1)**

(iii) for second light ray, diagram to show:
smaller angle of incidence at P than first ray **(1)**
point of incidence at core / cladding boundary to right of first ray **(1)**
total internal reflection drawn correctly or indicated at point of incidence to right of right angle **(1)**

[alternative if ray enters at P from above:
correct refraction at P **(1)**
TIR at boundary if refraction at P is correct **(1)**
angle of incidence visibly ≥ critical angle **(1)**]

7

[15]

24 (a) (i) B line along distance axis **(1)**

(ii) C negative sine wave starting at O **(1)**

(iii) A, N **(1)**

(3)

(b) (i) s.h.m. [or particle stationary] **(1)**
amplitude = 20 mm **(1)**

$f = \frac{1}{T}$ = 25 Hz or s^{-1} **(1)**

(ii) 10 mm **(1)**
W, V phase difference π [or antiphase or 180°] **(1)**
W, Z in phase **(1)**

(6)

[9]

25 (a) (i) (since $d\sin\theta = n\lambda$) $d\sin 18.5° = 632.8 \times 10^{-9}$ **(1)**

$d = 1.99 \times 10^{-6}$ **(1)**

number of lines per metre = $\frac{1}{d}$ = 5.01×10^5 **(1)**

(ii) $n\lambda = 1.99 \times 10^{-6} \sin 90°$ **(1)**

$n = \dfrac{1.99}{0.6328} = 3.1(5)$ **(1)**

hence highest order is third **(1)**

(6)

(b) $\lambda_{new} = \dfrac{632.8 \times 10^{-9} \times \sin 17.2°}{\sin 18.5°}$ [or $1.994 \times 10^{-6} \times \sin 17.2°$] **(1)**

= 590 nm**(1)**

(2)

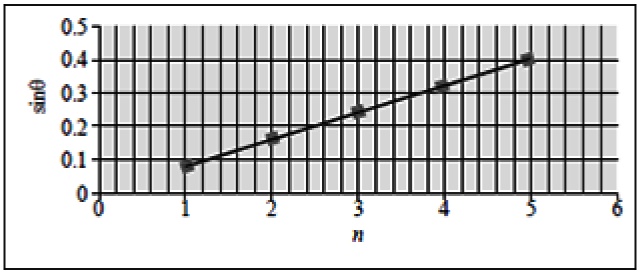
[8]

26 (a)

	x / m	sin θ
1	0.173	0.086
2	0.316	0.156
3	0.499	0.242
4	0.687	0.325
5	0.860	0.395

1

If angles only calculated 1 / 2



at least 4 points plotted correctly **(1)**
best straight line **(1)**
gradient calculated from suitable triangle, 50% of each axis **(1)**
correct value from readings **(1)**
appropriate use of $d \sin \theta = n\lambda$ **(1)**
hence N (rulings per metre) = 1.25×10^{5} m^{-1} (1.1 to 1.4 ok) **(1)**

max 2 / 6 if no graph and more than one data set used <u>correctly</u>, 1 / 6 only one set
if tan calc but plotted as sin, mark as scheme
tan or distance plotted, 0 / 6

max 6

(b) (i) maxima wider spaced [or pattern brighter] **(1)**
sin θ or θ increases with N [or light more concentrated] **(1)**

(ii) maxima spacing less **(1)**
sin θ or θ decreases with λ [or statement] **(1)**

(iii) maxima wider spaced [or pattern less bright] **(1)**
same θ but larger D [or light more spread out] **(1)**

6

(c) (i) waves in phase from **(1)**
any sensible ref to coherence **(1)**
whole number of wavelengths path difference **(1)**

(ii) use of geometry to show that sin $\theta = \frac{\lambda}{d}$

max 3

[15]

27 (a) constant phase relationship **(1)** **(1)**
[or same frequency (wavelength) **(1)** and same phase difference **(1)**]

2

(b) S_1R = 15cm on diagram **(1)** =75cm ∴ 30 waves **(1)**
S_2R = 16cm on diagram (1) = 80cm ∴ 32 waves **(1)**
2 whole waves difference so in phase at R **(1)** maximum **(1)**

max 5

(c) (falls then rises to) maximum at Q **(1)**
(then falls and rises to) maximum at P **(1)**

2

(d) $f\left(=\frac{c}{\lambda}\right) = \frac{3.0\times10^{8}}{25\times10^{-3}}$ = 1.2×10^{10} Hz (or 12 GHz) **(1)**

1

[10]

28 (a) idea that there are waves in opposite directions

B1

because of reflection at end of string

B1

the two waves interfere with each other/superimpose

B1

3

(b) (i) one loop

M1

with **N** at each end and **A** in the middle

A1

2

(ii) 4 approximately even loops

B1

all nodes and antinodes correctly marked for their number of loops

B1

2

(c) (i) length halved/0.35 (m)

B1

1

(ii) tension greater

C1

T = 720 (N)/increased by a factor of 4

A1

2

[10]

29 (a) (i) 2(.0) × 10^{-5} m (i.e. allow 1 sf)

B1

1

(ii) λ = 4(.0) × 10^{-4} (m)

B1

$v = f\lambda$ (condone $c = f\lambda$)

C1

3.0 MHz sf penalty applies
allow e.c.f. for omitting 10^{-4} (300 Hz) but sf penalty applies for e.g. 0.3 kHz)

A1

3

(b) (i) ultrasound/wave/pulse/energy spreads out from the transmitter (beam not uni-directional)

B1

energy is absorbed by(or lost to) the transmitting medium/tissue/body

B1

incident ultrasound/wave/pulse/energy is not all reflected (by the reflecting object)

or some is transmitted /absorbed by the organ
or is reflected at different angles (so does not return to detector)

B1

some ultrasound/wave/pulse/energy reflected by the skin since gel was not used

B1

max2
ANY 2

(ii) distance travelled 1200 × 95 or 114 000 or 0.114 m (i.e. mark for **use of** velocity × time ignoring powers of 10)

C1

0.057 m (allow answers in range 0.055 to 0.057)

A1

2

[8]

30 (a) filament lamp / sun etc.

B1

(1)

(b) (i) $d = 1.0 \times 10^{-4}$ m

C1

use of $\lambda = d\sin\theta$ or substituted values

C1

$\theta_1 = 0.286°$ / 0.29°

A1

(3)

(ii) $\Delta\theta = 0.115°$ (c.a.o.)

B1

(1)

(iii) width = 4.0×10^{-3} m or 3.9×10^{-3} m (e.c.f. for 2 × sin (b(ii)) or 2 × tan (b(ii)); allow 1 s.f.)

B1

(1)

(c) lower intensity

C1

because energy spreads

C1

use or statement of inverse square law

C1

ratio 0.16 or falls by factor of 6.25 c.a.o.

A1

(4)

[10]