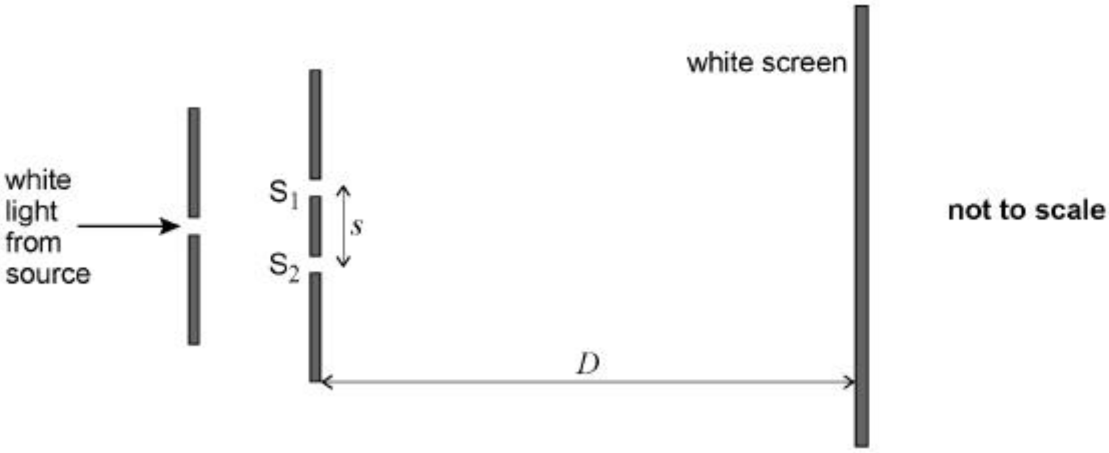
Oscillation and waves

Q1.

The figure below shows a diagram of apparatus used to demonstrate the formation of interference fringes using a white light source in a darkened room. Light from the source passes through a single slit and then through two narrow slits S_1 and S_2.



(a) Describe the interference pattern that is seen on the white screen.

____

____

____

____

____

____

____

____

____

(2)

(b) A filter transmits only green light of wavelength λ and red light of wavelength 1.2λ This filter is placed between the light source and the single slit.

Describe the interference pattern now seen on the white screen.

Use a calculation to support your answer.

(4)

(c) A student decides to use the apparatus shown in the figure to determine the wavelength of red light using a filter that transmits only red light.

The student suggests the following changes:

- decrease slit separation s
- decrease D, the distance between the slits and the screen.

The student decides to make each change independently.

Discuss the effects each independent change has on the interference pattern, and whether this change is likely to reduce uncertainty in the determination of the wavelength.

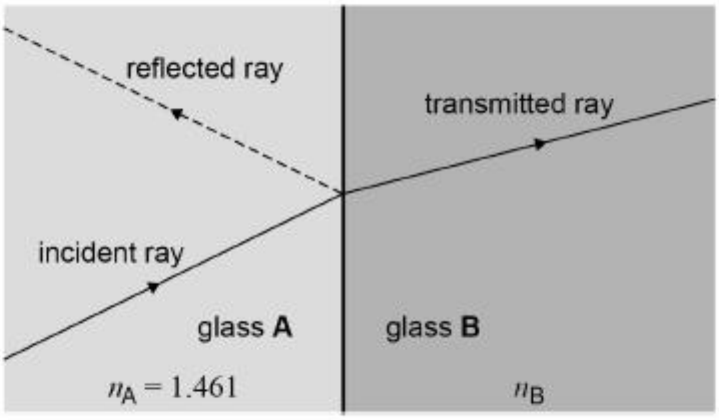
(6)
(Total 12 marks)

Q2.

(a) **Figure 1** shows an incident ray of light being partially reflected at the boundary between glass **A** and glass **B**. The refractive index n_A of glass **A** is 1.461

The speed of light in glass **B** is 3.252% less than the speed of light in glass **A**.

Figure 1



Calculate the refractive index n_B of glass **B**.

Give your answer to an appropriate number of significant figures.

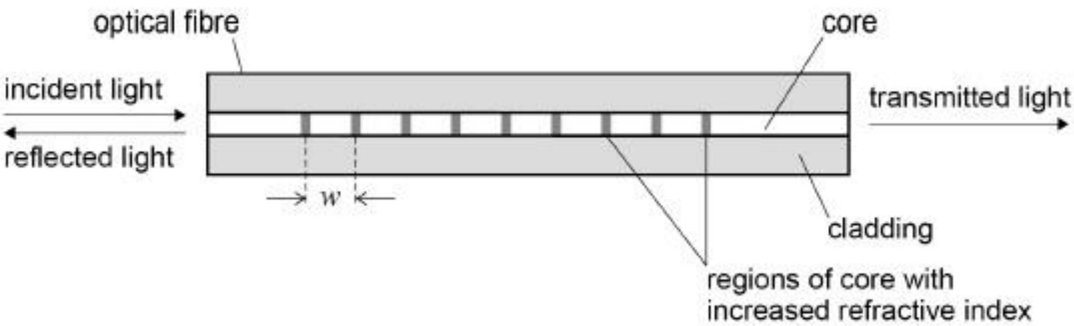
speed of light in a vacuum = 2.998×10^8 m s^{-1}

n_B = ______________________

(3)

(b) **Figure 2** shows a cross-sectional view of an optical fibre strain gauge.

Figure 2

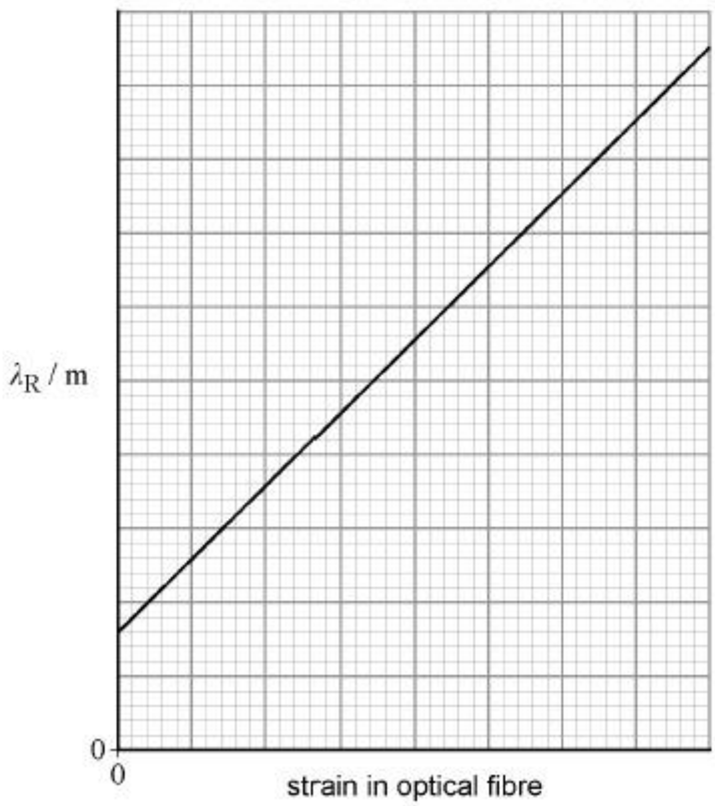


A maximum intensity of the reflected light is produced due to superposition of the light reflected from each of the regions with increased refractive index in the core.

This maximum intensity occurs at a particular wavelength λ_R.

Figure 3 shows the relationship between λ_R and the strain in the optical fibre.

Figure 3



A cable is used to raise and lower a lift. An engineer fixes the optical fibre strain gauge to the cable to monitor changes of the strain in the cable.

The lift is initially at rest and then accelerates downwards for a short time before reaching a constant velocity.

Discuss how the value of λ_R changes.

___

___

___

___

___

___

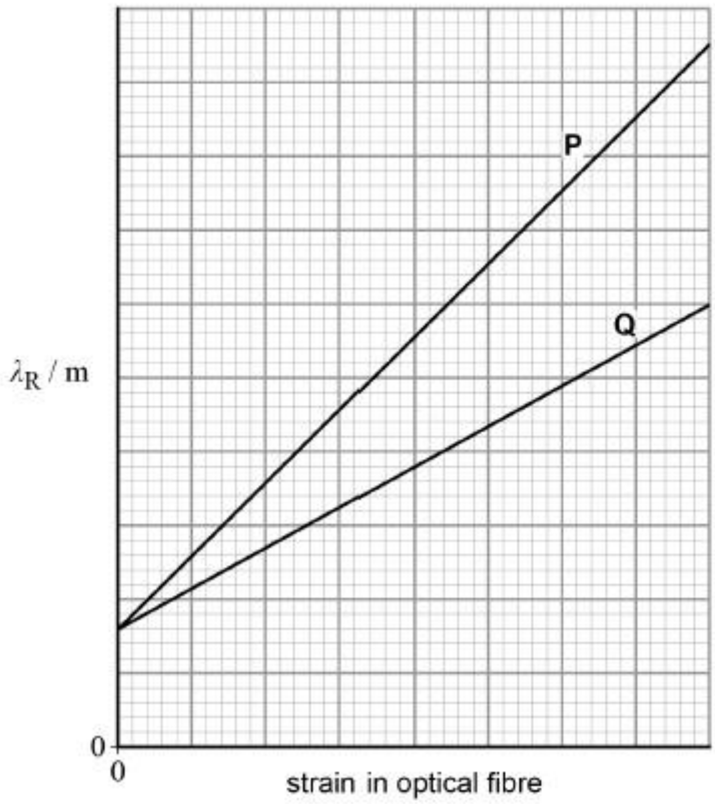
___

___

(3)

(c) **Figure 4** shows the relationship between λ_R and the strain in two optical fibre strain gauges **P** and **Q**. The engineer wishes to measure small accelerations in another lift. She can choose to fix either optical fibre strain gauge **P** or optical fibre strain gauge **Q** to the lift's cable.

Figure 4



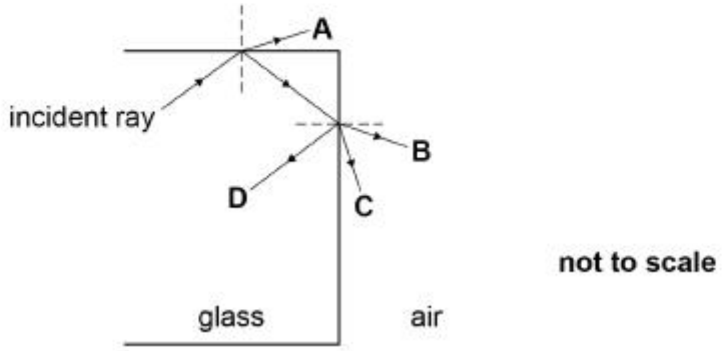
Explain which gauge the engineer should select.

(2)

(Total 8 marks)

Q3.

A ray of light is incident on a glass–air boundary of a rectangular block as shown.



The refractive index of this glass is 1.5
The refractive index of air is 1.0
The angle of incidence of the light at the first glass–air boundary is 44°

What is the path of the ray of light?

A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

Q4.

The fundamental frequency f is the lowest frequency heard when a stretched string is vibrating.

The string is now lightly touched one third of the way along its length.

What is the lowest frequency heard?

A $\frac{f}{3}$ ☐

B $\frac{2f}{3}$ ☐

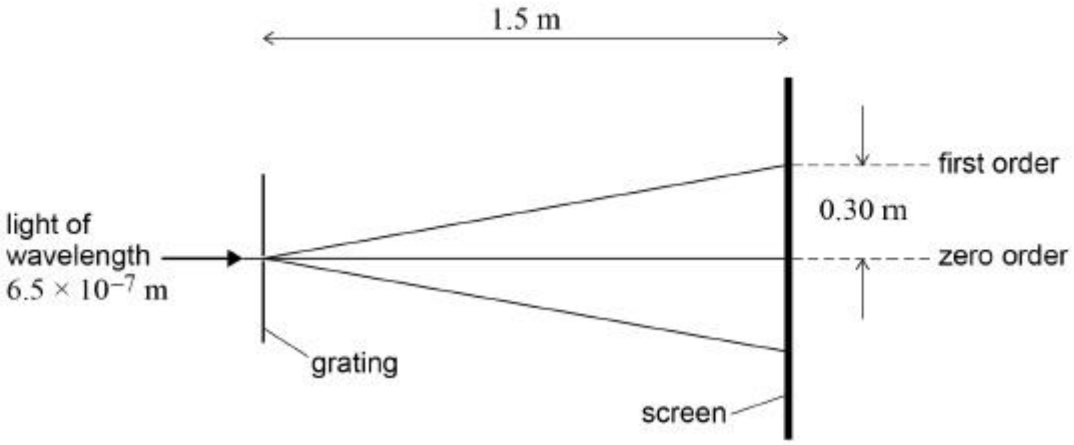
C f ☐

D $3f$ ☐

(Total 1 mark)

Q5.

A diffraction grating is illuminated normally with light of wavelength 6.5×10^{-7} m
When a screen is 1.5 m from the grating, the distance between the zero and first-order maxima on the screen is 0.30 m



What is the number of lines per mm of the diffraction grating?

A 3.3×10^{-6} ○

B 3.3×10^{-3} ○

C 3.0×10^{2} ○

D 3.0×10^{5} ○

(Total 1 mark)

Q6.

Two points on a progressive wave have a phase difference of $\frac{\pi}{6}$ rad
The speed of the wave is 340 m s^{-1}

What is the frequency of the wave when the minimum distance between the two points is 0.12 m?

A 240 Hz ○

B 470 Hz ○

C 1400 Hz ○

D 2800 Hz ○

(Total 1 mark)

Q7.

Figure 1 shows the structure of a violin and **Figure 2** shows a close-up image of the tuning pegs.

Figure 1

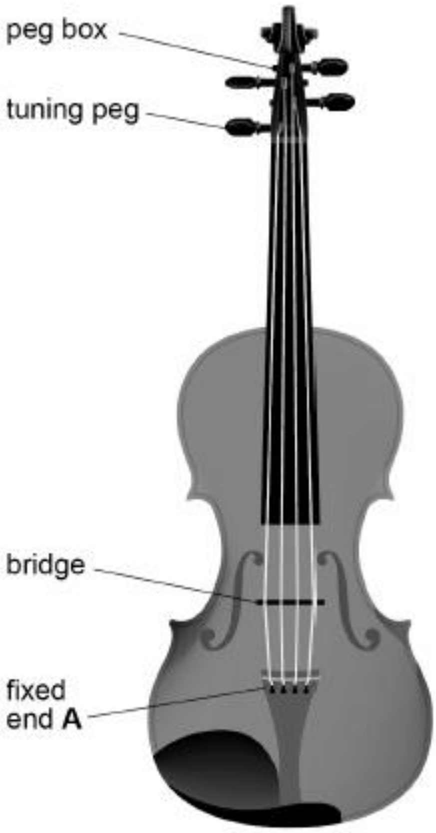
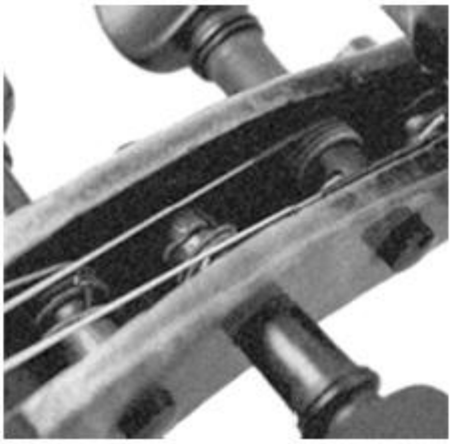


Figure 2



The strings are fixed at end **A**. The strings pass over a bridge and the other ends of the strings are wound around tuning pegs that have a circular cross-section. The tension in the strings can be increased or decreased by rotating the tuning pegs.

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

____

____

____

____

____

____

____

____

(3)

(b) The vibrating length of one of the strings of a violin is 0.33 m
When the tension in the string is 25 N, the string vibrates with a first-harmonic frequency of 370 Hz

Show that the mass of a 1.0 m length of the string is about 4×10^{-4} kg

(2)

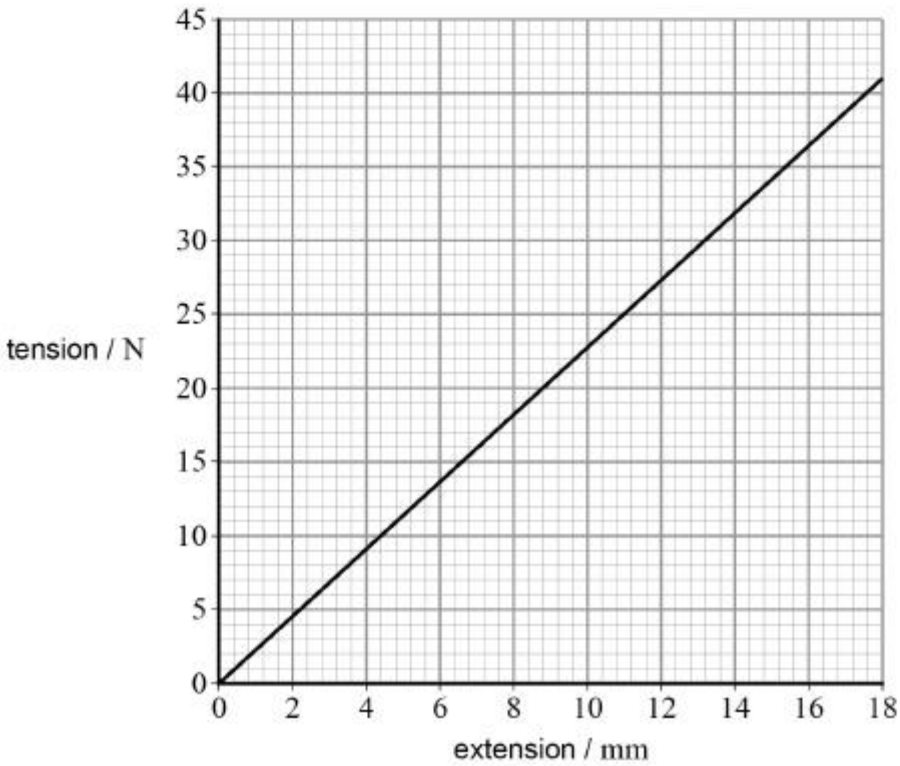
(c) Determine the speed at which waves travel along the string in question **(b)** when it vibrates with a first-harmonic frequency of 370 Hz

speed of waves = ____________________ m s^{-1}

(1)

(d) **Figure 3** shows how the tension in the string in question **(b)** varies with the extension of the string.

Figure 3



The string with its initial tension of 25 N is vibrating at a frequency of 370 Hz
The diameter of the circular peg is 7.02 mm

Determine the higher frequency that is produced when the string is stretched by rotating the tuning peg through an angle of 75°

Assume that there is no change in the diameter of the string.

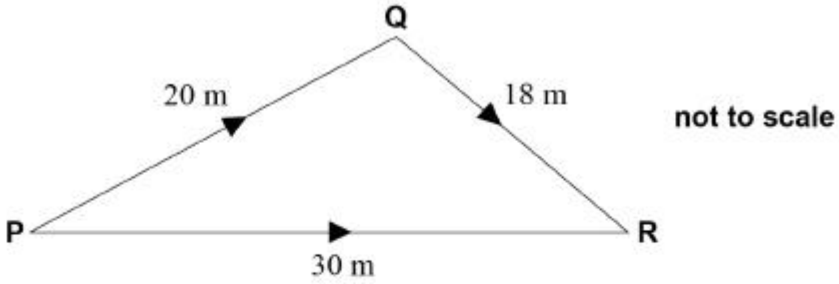
frequency = ____________________ Hz

(4)

(Total 10 marks)

Q8.

In the diagram, **P** is the source of a wave of frequency 50 Hz



The wave travels to **R** by two routes, **P** → **Q** → **R** and **P** → **R**. The speed of the wave is 30 m s−1

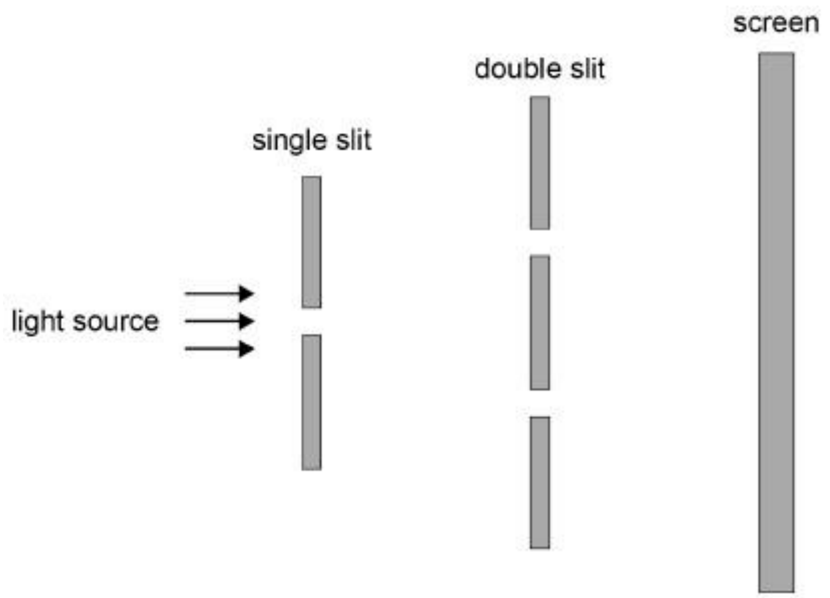
What is the path difference between the two waves at **R** in terms of the wavelength λ of the waves?

A	4.8λ	○
B	8.0λ	○
C	13.3λ	○
D	20.0λ	○

(Total 1 mark)

Q9.

Light from a point source passes through a single slit and is then incident on a double-slit arrangement. An interference pattern is observed on the screen.



What will increase the fringe spacing?

A increasing the separation of the single slit and the double slit

B increasing the width of the single slit

C decreasing the distance between the double slits and the screen

D decreasing the separation of the double slits

(Total 1 mark)

Q10.

A diffraction grating has 500 lines per mm. When monochromatic light is incident normally on the grating the third-order spectral line is formed at an angle of 60° from the normal to the grating.

What is the wavelength of the monochromatic light?

A 220 nm

B 580 nm

C 960 nm

D 1700 nm

(Total 1 mark)

Q11.

An electromagnetic wave enters a fibre-optic cable from air. On entering the cable, the wave slows down to three-fifths of its original speed.

What is the refractive index of the core of the fibre-optic cable?

A 0.67 ☐

B 1.33 ☐

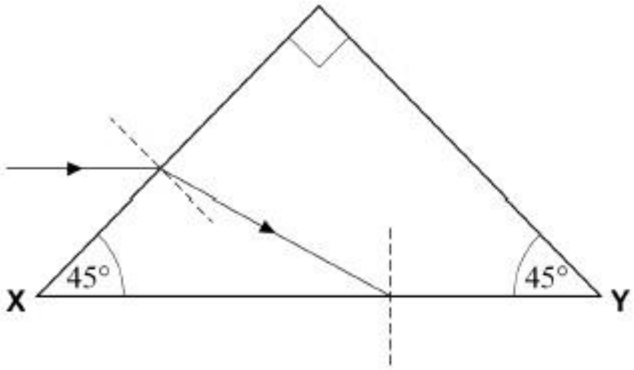
C 1.50 ☐

D 1.67 ☐

(Total 1 mark)

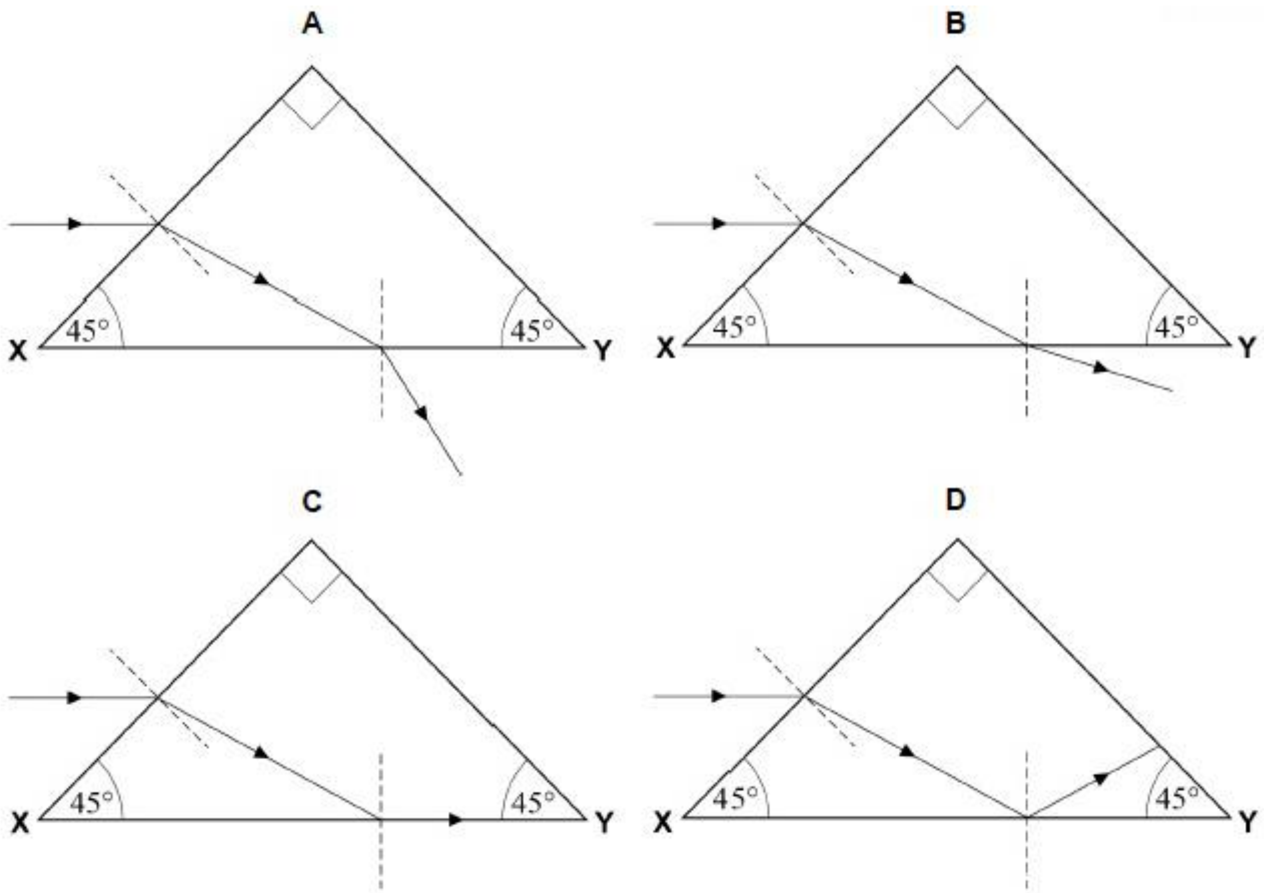
Q12.

The diagram shows part of the path of a ray of light through a right-angled prism.



The prism is made of glass of refractive index 1.5
The incident light ray is parallel to the face **XY**. The ray is refracted towards the face **XY**.

What is the path of the ray after it is incident on face **XY**?



A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q13.

A body performs simple harmonic motion.

What is the phase difference between the variation of displacement with time and the variation of acceleration with time for the body?

A 0 ⬭

B $\frac{\pi}{4}$ rad ⬭

C $\frac{\pi}{2}$ rad ⬭

D π rad ⬭

(Total 1 mark)

Q14.

An object of mass 0.15 kg performs simple harmonic motion. It oscillates with amplitude 55 mm and frequency 0.80 Hz

What is the maximum value of its kinetic energy?

A 5.7×10^{-3} J ☐

B 11×10^{-3} J ☐

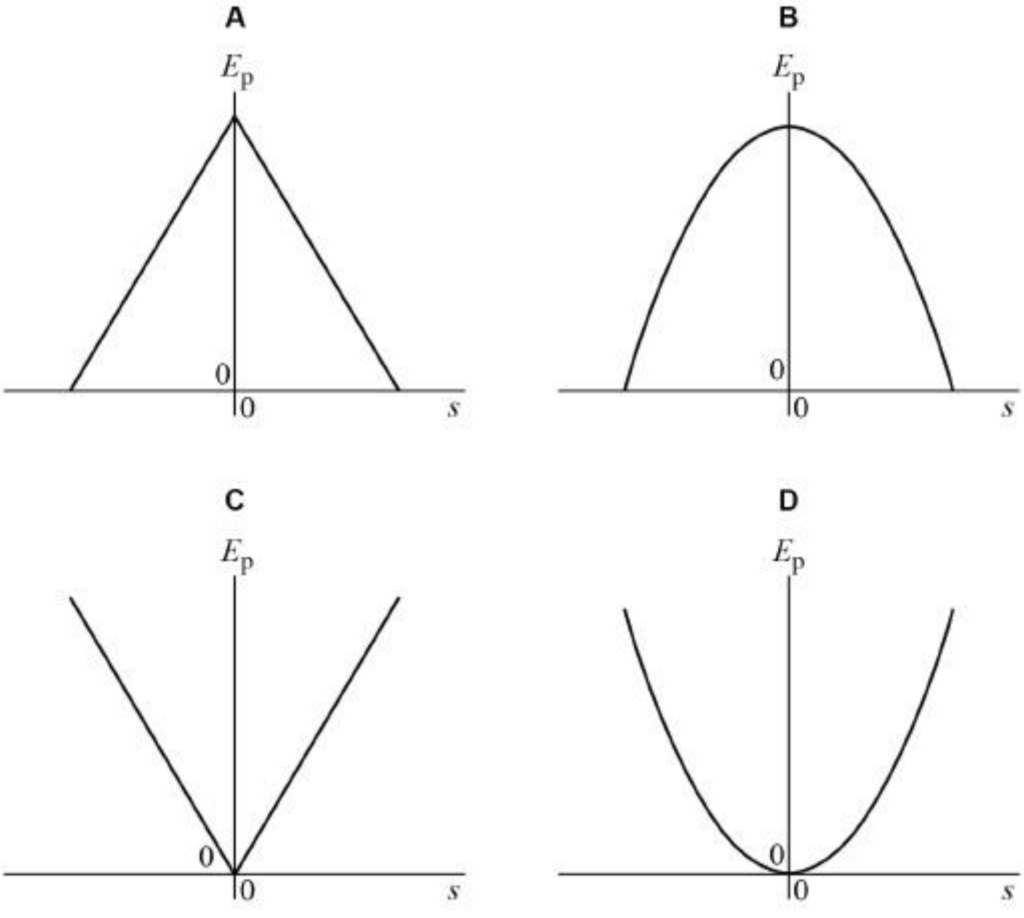
C 0.57 J ☐

D 11 J ☐

(Total 1 mark)

Q15.

Which graph shows how the gravitational potential energy E_p of a simple pendulum varies with displacement s from the equilibrium position?



A ☐

B ☐

C ☐

D ○

(Total 1 mark)

Q16.

Figure 1 shows an arrangement used to investigate double slit interference using microwaves. **Figure 2** shows the view from above.

Figure 1

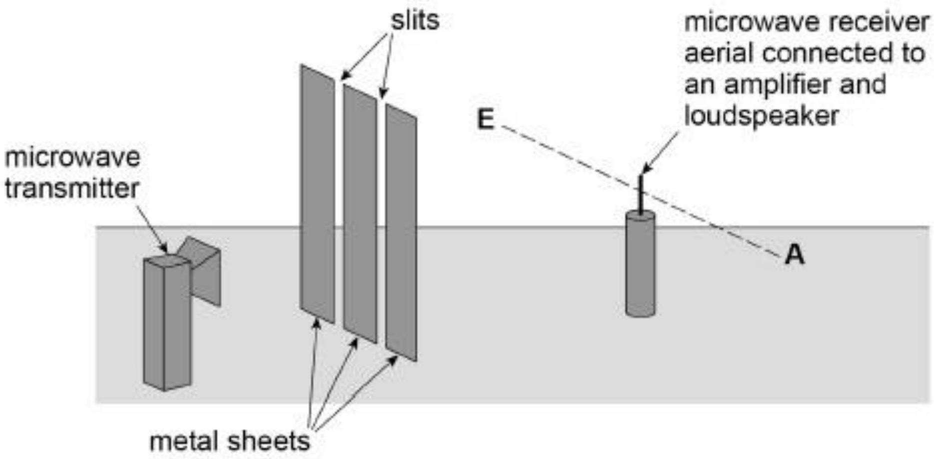
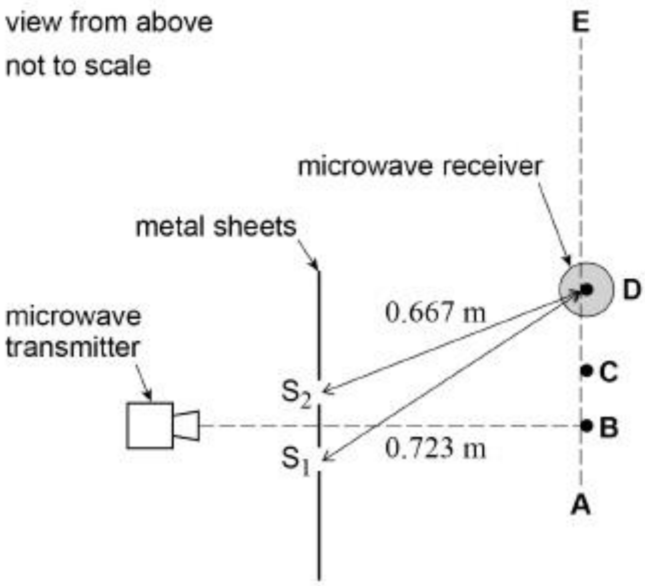


Figure 2



The microwaves from the transmitter are polarised. These waves are detected by the aerial in the microwave receiver (probe). The aerial is a vertical metal rod.

The receiver is moved along the dotted line **AE**. As it is moved, maximum and minimum signals are detected. Maximum signals are first detected at points **B** and **C**. The next maximum signal is detected at the position **D** shown in **Figure 2**.

Figure 2 shows the distances between each of the two slits, S_1 and S_2, and the microwave receiver when the aerial is in position **D**.
S_1D is 0.723 m and S_2D is 0.667 m.

(a) Explain why the signal strength falls to a minimum between **B** and **C**, and between **C** and **D**.

____

____

____

____

____

____

____

____

(3)

(b) Determine the frequency of the microwaves that are transmitted.

frequency = ______________________________ Hz

(3)

(c) The intensity of the waves passing through each slit is the same.

Explain why the minimum intensity between **C** and **D** is not zero.

____

____

____

____

____

____

____

____

(2)

(d) The vertical aerial is placed at position **B** and is rotated slowly through 90° until it lies along the direction **AE**.

State and explain the effect on the signal strength as it is rotated.

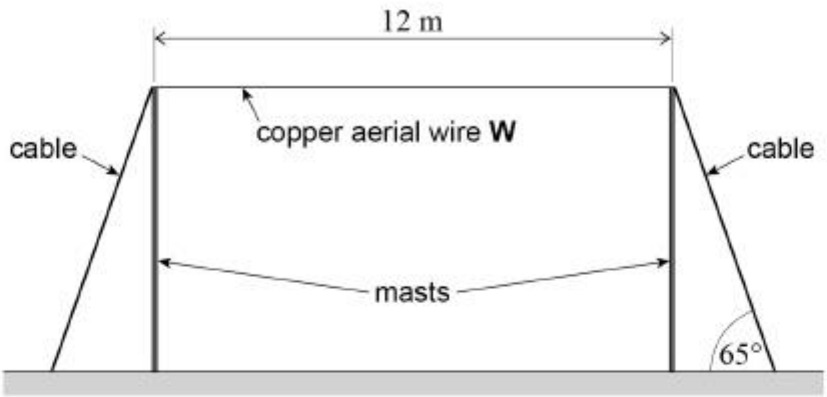
(3)

(Total 11 marks)

Q17.

Figure 1 shows a structure that supports a horizontal copper aerial wire **W** used for transmitting radio signals.

Figure 1



The copper aerial wire is 12 m long and its area of cross-section is 1.6×10^{-5} m^2. The tension in the copper aerial wire is 5.0×10^2 N.

Young modulus of copper = 1.2×10^{11} Pa

(a) Show that the extension produced in a 12 m length of the aerial wire when the tension is 5.0×10^2 N is less than 4 mm.

(2)

(b) The cables that support each mast are at an angle of 65° to the horizontal.

Calculate the tension in each supporting cable so that there is no resultant horizontal force on either mast.

tension = ______________________________ N

(1)

(c) When wind blows, stationary waves can be formed on the aerial wire.

Explain how stationary waves are produced and why only waves of specific frequencies can form on the aerial wire.

____

____

____

____

____

____

____

____

(4)

(d) Calculate the mass of a 1.0 m length of the aerial wire.

Density of copper = 8900 kg m^{-3}

mass = ______________________________ kg

(1)

(e) Calculate the frequency of the wave when the third harmonic is formed on the aerial wire.

frequency = ______________________________ Hz

(2)

(f) Sketch, on **Figure 2**, the standing wave on the wire when the third harmonic is formed.

Figure 2

(1)

(g) High winds produce large amplitudes of vibration of the aerial wire.

Explain why the wire may sag when the high wind stops.

____

____

____

____

(2)
(Total 13 marks)

Q18.

Which row correctly shows electromagnetic radiations in order of decreasing wavelength?

A gamma > ultraviolet > microwave ☐

B ultraviolet > gamma > microwave ☐

C microwave > ultraviolet > gamma ☐

D gamma > microwave > ultraviolet ☐

(Total 1 mark)

Q19.

Which statement is correct about the properties of an unpolarised electromagnetic wave as it passes through a polariser?

A The wave remains unchanged. ☐

B The wave does not pass through the polariser. ☐

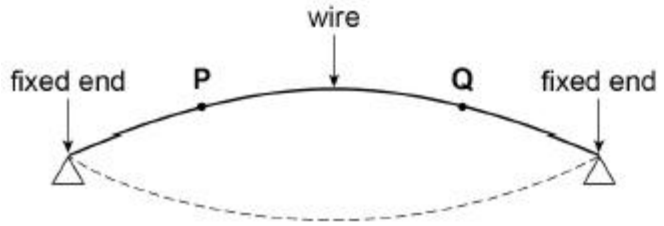
C The wave's electric field oscillates along the direction of travel. ☐

D The intensity of the wave is reduced. ☐

(Total 1 mark)

Q20.

A uniform wire, fixed at both ends, is plucked in the middle so that it vibrates at the first harmonic as shown.



What is the phase difference between the oscillations of the particles at **P** and **Q**?

A zero ☐

B $\frac{\pi}{4}$ rad ☐

C $\frac{\pi}{2}$ rad ☐

D $\frac{3\pi}{4}$ rad ☐

(Total 1 mark)

Q21.

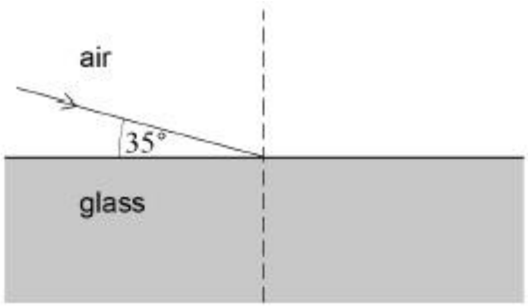
Which row shows the change in velocity, frequency and wavelength of an electromagnetic wave as it travels from an optically less dense to an optically more dense medium?

	Velocity	Frequency	Wavelength	
A	decreases	decreases	unchanged	☐
B	increases	unchanged	increases	☐
C	decreases	unchanged	decreases	☐
D	increases	increases	unchanged	☐

(Total 1 mark)

Q22.

The diagram shows a ray of light travelling in air and incident on a glass block of refractive index 1.5



What is the angle of refraction in the glass?

A 22.5°

B 23.3°

C 33.1°

D 59.4°

(Total 1 mark)

Q23.

Intensity maxima are produced on a screen when a parallel beam of monochromatic light is incident on a diffraction grating. Light of a longer wavelength can be used or the distance from the diffraction grating to the screen can be increased.

Which row gives the change in appearance of the maxima when these changes are made independently?

	Longer wavelength	**Distance from grating to screen increased**	
A	closer together	more widely spaced	⬭
B	more widely spaced	more widely spaced	⬭
C	more widely spaced	closer together	⬭
D	closer together	closer together	⬭

(Total 1 mark)

Q24.

Light of wavelength 500 nm is passed through a diffraction grating which has 400 lines per mm.

What is the angular separation between the two second-order maxima?

A 11.5°

B 23.1°

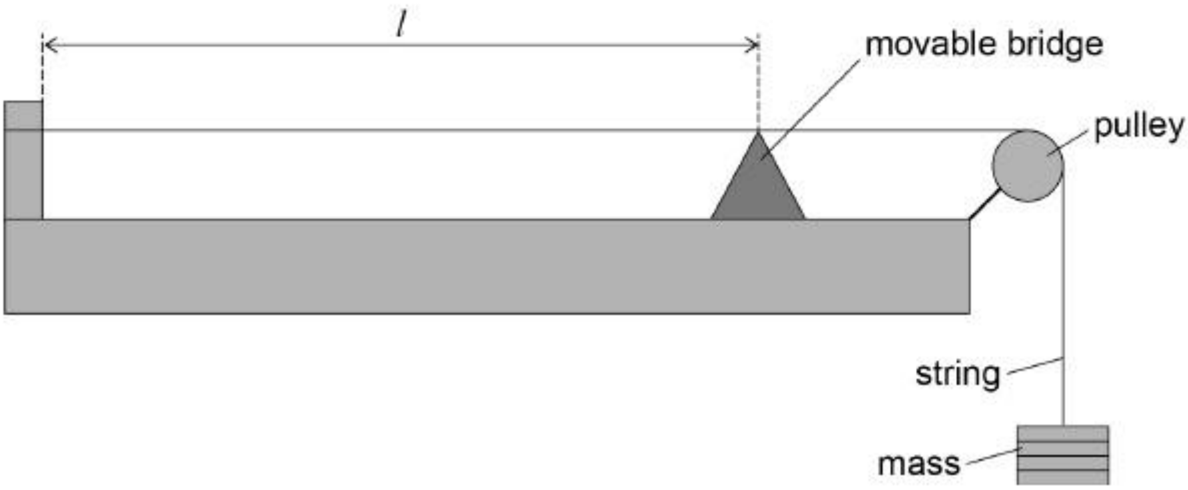
C 23.6° ☐

D 47.2° ☐

(Total 1 mark)

Q25.

The diagram shows an arrangement used by a student to investigate vibrations in a stretched nylon string of fixed length l. He measures how the frequency f of first-harmonic vibrations for the string varies with the mass m suspended from it.



The table shows the results of the experiment.

***m* / kg**	***f* / Hz**
0.50	110
0.80	140
1.20	170

(a) Show that the data in the table are consistent with the relationship

$$f \propto \sqrt{T}$$

where T is the tension in the nylon string.

(2)

(b) The nylon string used has a density of 1150 kg m^{-3} and a uniform diameter of 5.0×10^{-4} m.

Determine the length l of the string used.

l = ____________________ m

(3)

(c) The student uses the relationship in question (a) to predict frequencies for tensions that are much larger than those used in the original experiment.

Explain how the actual frequencies produced would be different from those that the student predicts.

____

____

____

____

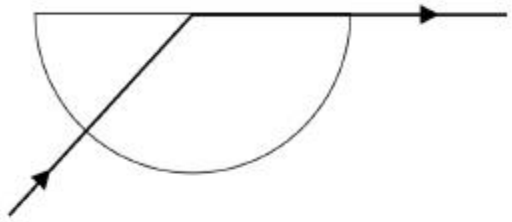
(2)

(Total 7 marks)

Q26.

Figure 1 shows a ray of monochromatic green light incident normally on the curved surface of a semicircular glass block.

Figure 1



(a) The angle of refraction of the ray at the plane surface is 90°.

Refractive index of the glass used = 1.6

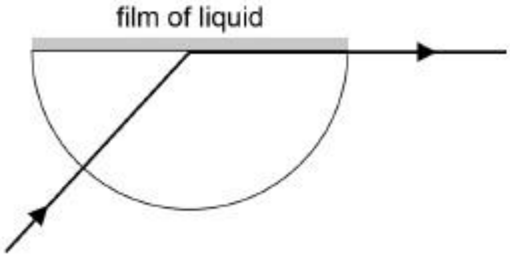
Calculate the angle of incidence of the ray on the flat surface of the block.

angle of incidence = ____________________ degrees

(1)

(b) A thin film of liquid is placed on the flat surface of the glass block as shown in **Figure 2**.

Figure 2



The angle of incidence is changed so that the angle of refraction of the green light ray at the glass-liquid interface is again 90°. The angle of incidence is now 58°.

Calculate the refractive index of the liquid.

refractive index = ____________________

(2)

(c) The source of green light is changed for one that contains only red and blue light. For any material red light has a lower refractive index than green light, and blue light has a higher refractive index than green light. The angle of incidence at the glass-liquid interface remains at 58°.

Describe and explain the paths followed by the red and blue rays immediately after the light is incident on the glass-liquid interface.

____

____

____

____

____

____

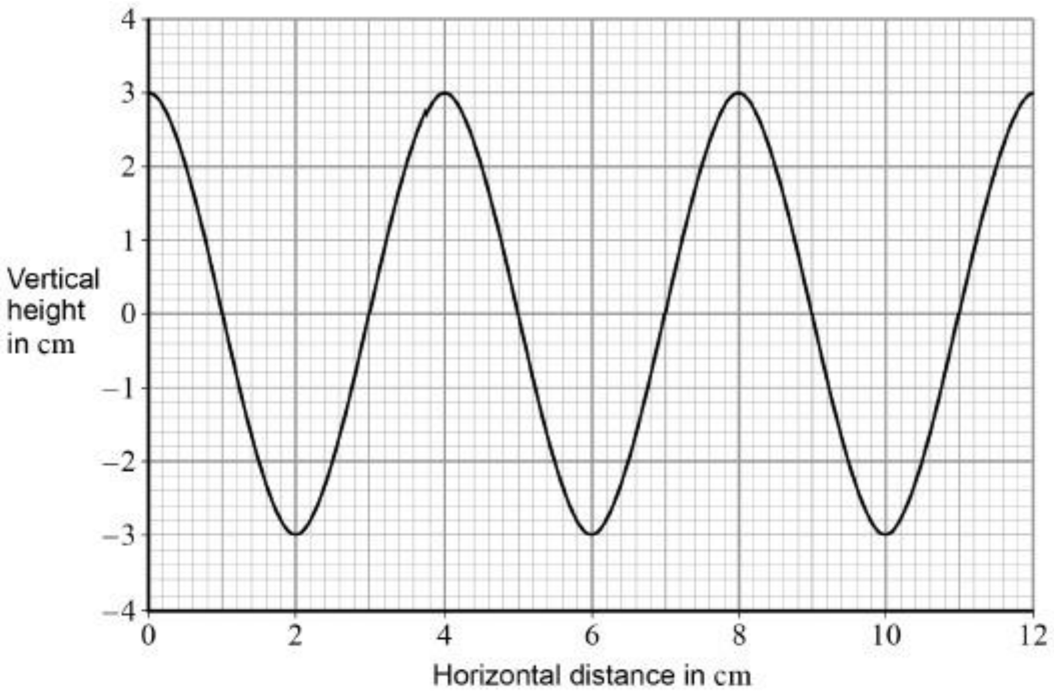
____

(3)

(Total 6 marks)

Q27.

The graph shows how the vertical height of a travelling wave varies with distance along the path of the wave.



The speed of the wave is 20 cm s^{-1}.

What is the period of the wave?

A 0.1 s

B 0.2 s

C 5.0 s

D 10.0 s

(Total 1 mark)

Q28.

Which statement is **not** correct for ultrasound and X-rays?

A Both can be refracted

B Both can be diffracted

C Both can be polarised

D Both can be reflected

(Total 1 mark)

Q29.

A stationary wave is set up on a stretched string of length l and diameter d.
Another stationary wave is also set up on a second string made from the same material and with the same tension as the first.

What length and diameter are required for the second string so that both strings have the same first-harmonic frequency?

	Length of second string	Diameter of second string	
A	$2l$	$2d$	☐
B	l	$2d$	☐
C	$\frac{l}{2}$	$2d$	☐
D	l	$\frac{d}{2}$	☐

(Total 1 mark)

Q30.

When a monochromatic light source is incident on two slits of the same width an interference pattern is produced.

One slit is then covered with opaque black paper.

What is the effect of covering one slit on the resulting interference pattern?

A The intensity of the central maximum will increase ☐

B The width of the central maximum decreases ☐

C Fewer maxima are observed ☐

D The outer maxima become wider ☐

(Total 1 mark)

Q31.

When light of wavelength 5.0×10^{-7} m is incident normally on a diffraction grating the fourth-order maximum is observed at an angle of 30°.

What is the number of lines per mm on the diffraction grating?

A 2.5×10^{2} ☐

B 2.5×10^{5} ☐

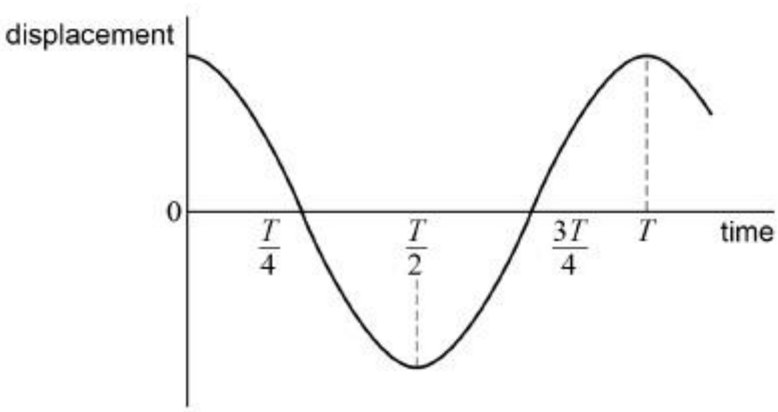
C 1.0×10^{3} ☐

D 1.0×10^{6} ☐

(Total 1 mark)

Q32.

The graph shows how the displacement of a particle performing simple harmonic motion varies with time.



Which statement is **not** correct?

A The speed of the particle is a maximum at time $\frac{T}{4}$ ☐

B The potential energy of the particle is zero at time $\frac{3T}{4}$ ☐

C The acceleration of the particle is a maximum at time $\frac{T}{2}$ ☐

D The restoring force acting on the particle is zero at time T ☐

(Total 1 mark)

Q33.

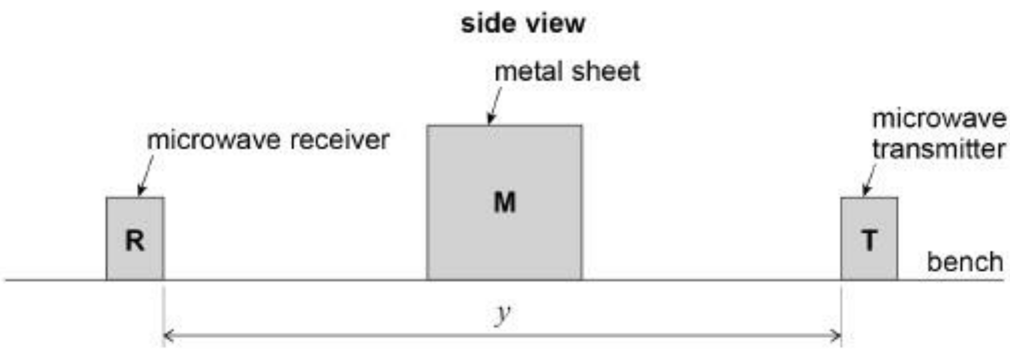
This question is about an experiment to measure the wavelength of microwaves.

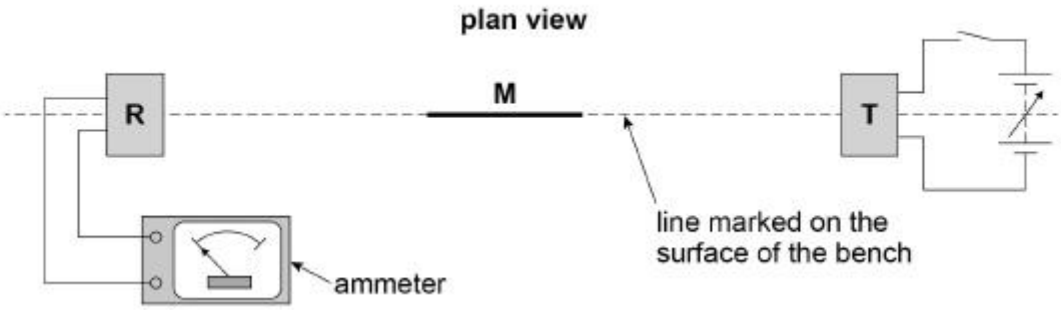
A microwave transmitter **T** and a receiver **R** are arranged on a line marked on the bench.

A metal sheet **M** is placed on the marked line perpendicular to the bench surface.

Figure 1 shows side and plan views of the arrangement.
The circuit connected to **T** and the ammeter connected to **R** are only shown in the plan view.

Figure 1

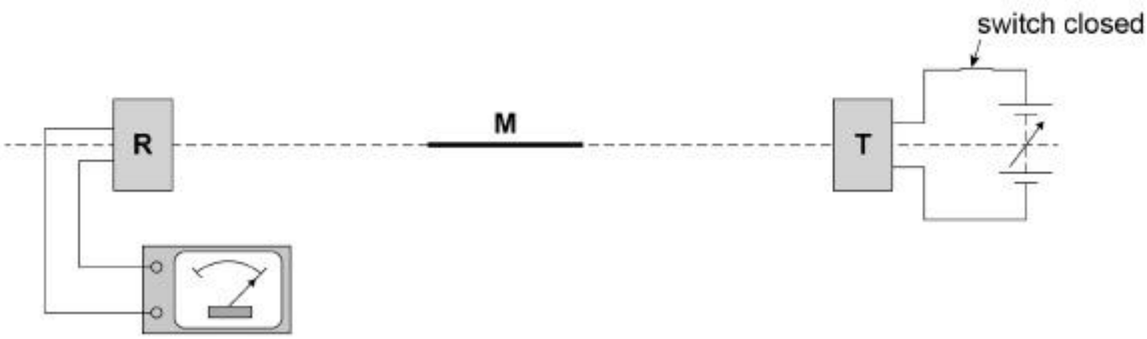




The distance *y* between **T** and **R** is recorded.

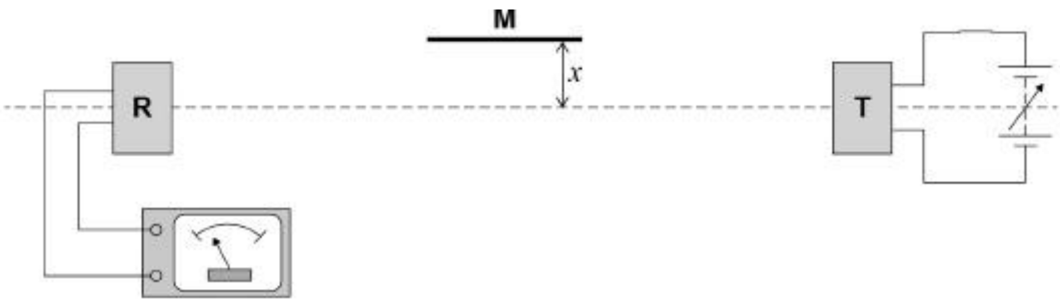
T is switched on and the output from **T** is adjusted so a reading is produced on the ammeter as shown in **Figure 2**.

Figure 2



M is kept parallel to the marked line and moved slowly away as shown in **Figure 3**.

Figure 3



The reading decreases to a minimum reading **which is not zero**.
The perpendicular distance *x* between the marked line and **M** is recorded.

(a) The ammeter reading depends on the superposition of waves travelling directly to **R** and other waves that reach **R** after reflection from **M**.

State the phase difference between the sets of waves superposing at **R** when the ammeter reading is a **minimum**.
Give a suitable unit with your answer.

____

(1)

(b) Explain why the minimum reading is **not** zero when the distance x is measured.

____

____

____

(1)

(c) When **M** is moved further away the reading increases to a maximum then decreases to a minimum.

At the first minimum position, a student labels the minimum $n = 1$ and records the value of x.
The next minimum position is labelled $n = 2$ and the new value of x is recorded.
Several positions of maxima and minima are produced.

Describe a procedure that the student could use to make sure that **M** is parallel to the marked line before measuring each value of x.
You may wish to include a sketch with your answer.

____

____

____

____

____

____

____

____

(2)

(d) It can be shown that

$$n\lambda = \sqrt{4x^2 + y^2} - y$$

where λ is the wavelength of the microwaves and y is the distance defined in **Figure 1**.

The student plots the graph shown in **Figure 4**.

The student estimates the uncertainty in each value of $\sqrt{4x^2 + y^2}$ to be 0.025 m and adds error bars to the graph.

Determine

- the maximum gradient G_{max} of a line that passes through all the error bars
- the minimum gradient G_{min} of a line that passes through all the error bars.

G_{max} = ______________________

G_{min} = ______________________

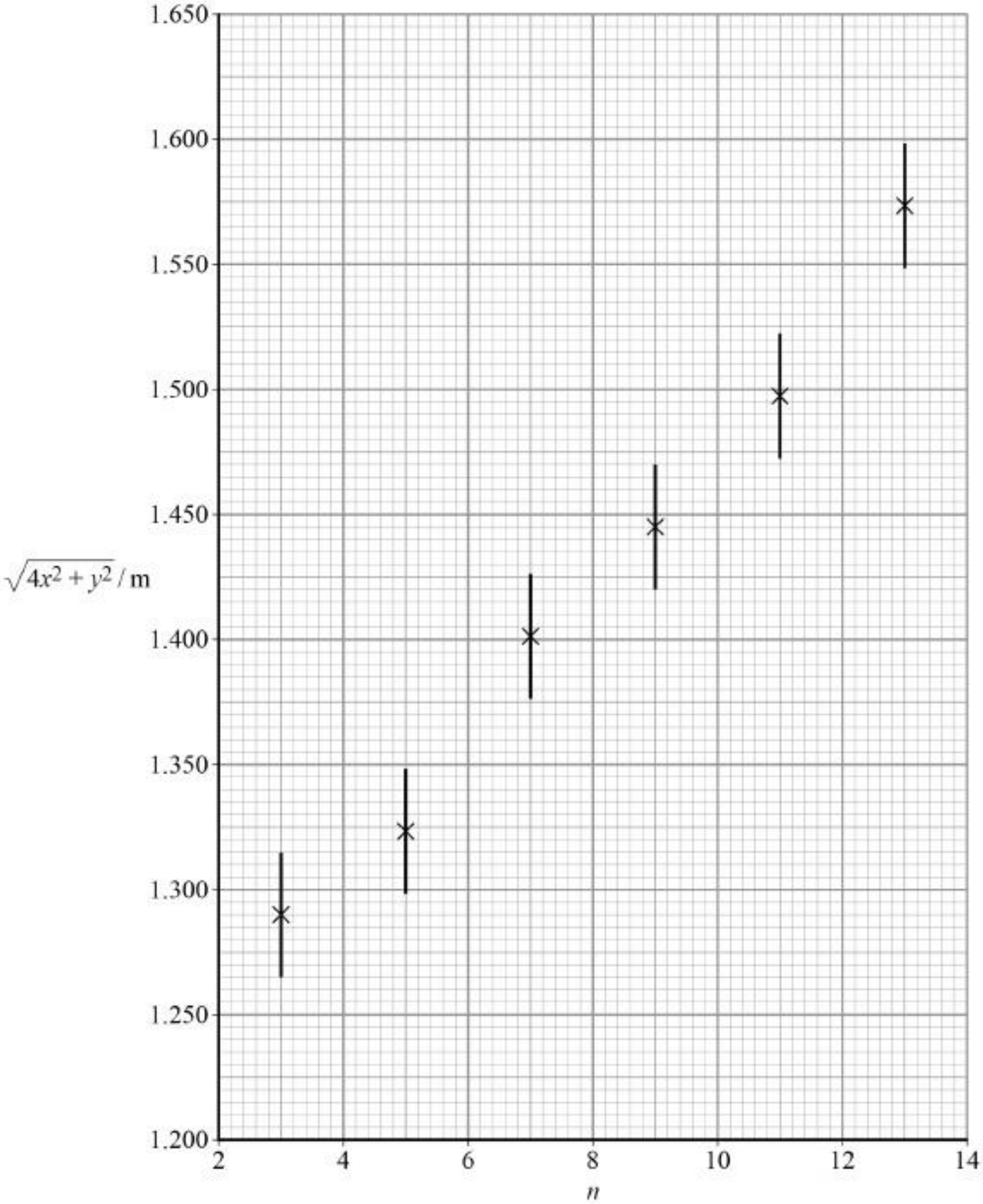
(3)

(e) Determine λ using your results for G_{max} and G_{min}.

λ = ______________________ m

(2)

Figure 4



(f) Determine the percentage uncertainty in your result for λ.

percentage uncertainty in λ = ____________________ %

(3)

(g) Explain how the graph in **Figure 4** can be used to obtain the value of y.
You are **not** required to determine y.

(2)

(h) Suppose that the data for n = 13 had not been plotted on **Figure 4**.

Add a tick (✓) in each row of the table to identify the effect, if any, on the results you would obtain for G_{max}, G_{min}, λ and y.

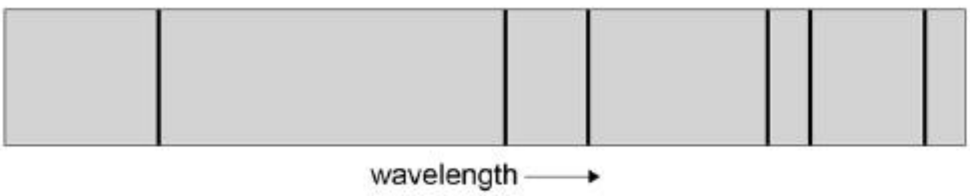
Result	Reduced	Not affected	increased
G_{max}			
G_{min}			
λ			
y			

(4)

(Total 18 marks)

Q34.

The diagram below shows the line spectrum of a gas.



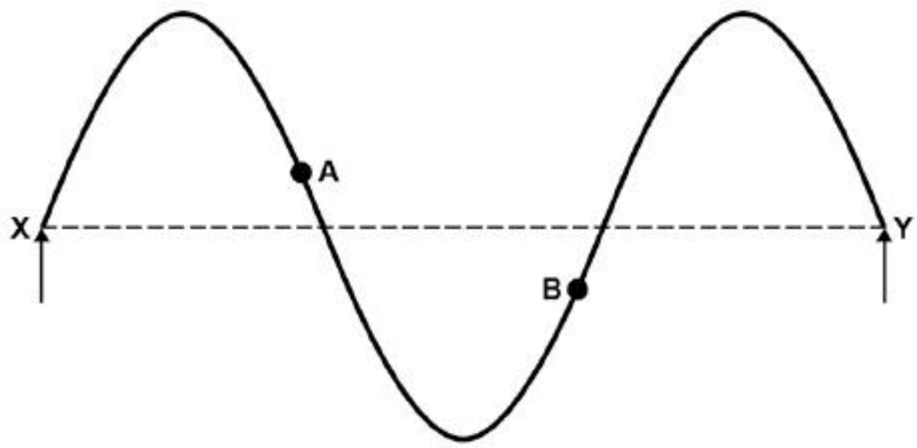
Explain how line spectra are produced. In your answer you should describe:

- how the collisions of charged particles with gas atoms can cause the atoms to emit photons.
- how spectral lines are explained by the concept of discrete energy levels.

(Total 6 marks)

Q35.

The diagram below shows one position of a guitar string stretched between points **X** and **Y**.
The string vibrates at a frequency of 330 Hz.



(a) State the phase relationship between points **A** and **B** on the string.

(1)

(b) Points **X** and **Y** are 0.66 m apart.

Calculate the speed of the wave along the string.

speed = ________________ m s^{-1}

(2)

(c) The total mass of the string is 3.1 g and the total length of the string is 0.91 m.

Show that the tension in the string when it is sounding the harmonic shown in the diagram above is about 70 N.

(3)

(d) The string is fixed at one end and wrapped around a tuning peg of radius 3.0 mm at the other. The tuning peg needs to be turned through 3 complete rotations to increase the tension in the string from 0 to 70 N in part **(c)**.

Discuss, by estimating the energy stored in the string, whether there is a significant risk to the guitar player when the string breaks.

___

___

___

___

___

___

(3)

(Total 9 marks)

Q36.

A progressive wave of frequency 150 Hz travels along a stretched string at a speed of 30 m s^{-1}.

.

What is the phase difference between two points that are 50 mm apart on the string?

A zero ☐

B 90° ☐

C 180° ☐

D 360° ☐

(Total 1 mark)

Q37.

Which of the following statements about the behaviour of waves is **incorrect**?

A	All waves can be diffracted.	⬭
B	All waves can be made to undergo superposition.	⬭
C	All waves can be refracted.	⬭
D	All waves can be polarised.	⬭

(Total 1 mark)

Q38.

Two radio transmitters emit waves at a frequency of 1.4 MHz. A stationary wave is set up between the two transmitters due to the superposition of the radio waves.

What is the minimum distance between two nodes in the stationary wave?

A	107 m	⬭
B	214 m	⬭
C	428 m	⬭
D	857 m	⬭

(Total 1 mark)

Q39.

Two loudspeakers emit sound waves.

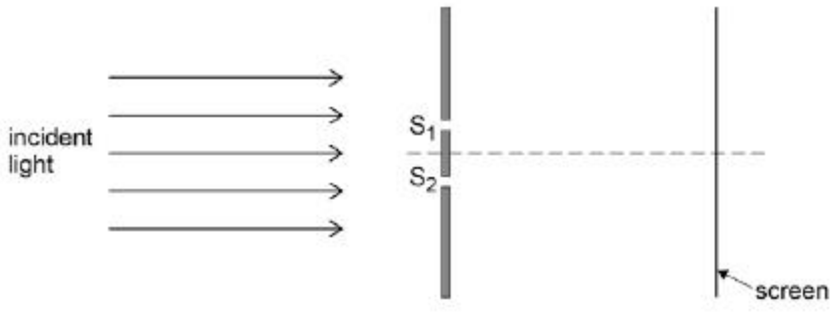
Which line in the table gives the correct frequency condition and the correct phase condition for the waves from the loudspeakers to be coherent?

	Frequency condition	**Phase condition**	
A	same frequency	variable phase difference	⬭
B	constant frequency difference	constant phase difference	⬭
C	constant frequency difference	in phase	⬭
D	same frequency	constant phase difference	⬭

(Total 1 mark)

Q40.

When a parallel beam of monochromatic light is directed at two narrow slits, S_1 and S_2, interference fringes are observed on a screen.



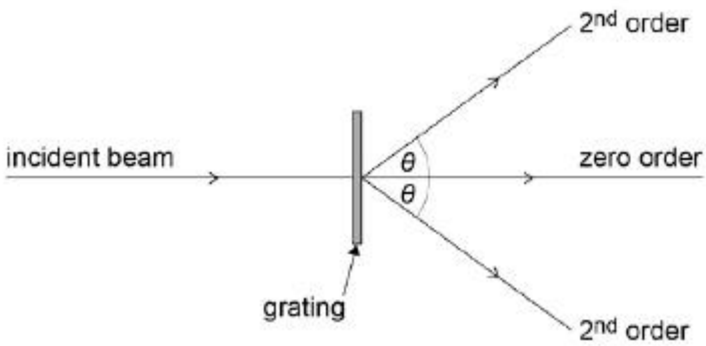
Which line in the table gives the changes that will increase the spacing of the fringes?

	Slit spacing	Distance from slits to screen	
A	halved	halved	☐
B	halved	doubled	☐
C	doubled	halved	☐
D	doubled	doubled	☐

(Total 1 mark)

Q41.

A parallel beam of monochromatic light is directed normally at a plane transmission grating which has N slits per metre. The second order diffracted beam is at angle θ to the zero order transmitted beam.



The grating is then replaced by a plane transmission grating which has $2N$ slits per metre.

Which one of the following statements is correct?

A	With the first grating, the first order beam is at angle 0.5θ to the zero order transmitted beam.	☐
B	With the second grating, the first order beam is at angle 0.5θ to the zero order transmitted beam.	☐

C With the second grating, the first order beam is at angle θ to the zero order transmitted beam. ☐

D With the second grating, the second order beam is at angle θ to the zero order transmitted beam. ☐

(Total 1 mark)

Q42.

A layer of liquid of refractive index 1.6 covers the horizontal flat surface of a glass block of refractive index 1.5. A ray of light strikes the boundary between them at an angle such that it travels along the boundary afterwards.

How does the ray strike the boundary?

A it travels in glass at an angle of 70° to the boundary ☐

B it travels in glass at an angle of 20° to the boundary ☐

C it travels in the liquid at an angle of 70° to the boundary ☐

D it travels in the liquid at an angle of 20° to the boundary ☐

(Total 1 mark)

Q43.

(a) Distinguish between longitudinal and transverse waves.

____

____

____

____

____

(2)

(b) A piano repairer replaces the wire that produces the highest note on a piano. The wire has a vibrating length of 0.050 m. He uses a wire with the following properties:

diameter = 3.5×10^{-4} m
density = 7.8×10^{3} kg m^{-3}
breaking stress = 3.0×10^{9} N m^{-2}

Calculate the tension required for the vibrating wire to produce its correct frequency of 4.1 kHz.

tension = _______________ N

(2)

(c) Evaluate, using the data provided in part **(b)**, whether it is safe to use this wire.

____

____

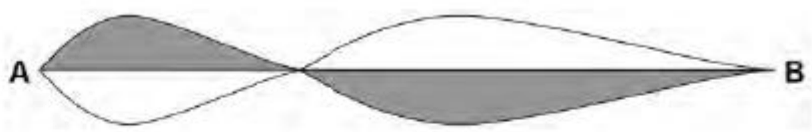
____

____

____

(2)

(d) The repairer uses faulty wire so that the diameter of the wire increases linearly with distance along its length. The profile of the vibration produced when the wire sounds its second harmonic is shown in the diagram below.



The speed c of a transverse progressive wave travelling along a string of mass per unit length μ and under tension T is given by

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

Explain which end of the wire, **A** or **B**, has the greater diameter and why the profile of the stationary wave has the shape shown in the diagram above.

____

____

____

____

____

____

____

(4)

(Total 10 marks)

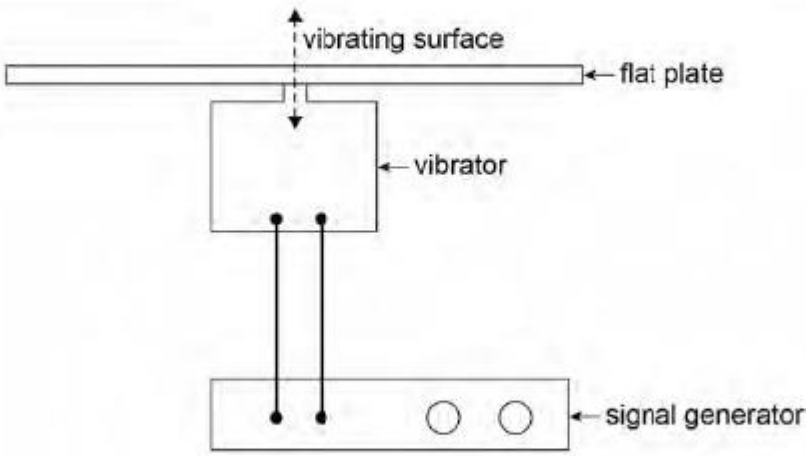
Q44.

(a) State the conditions for simple harmonic motion.

(2)

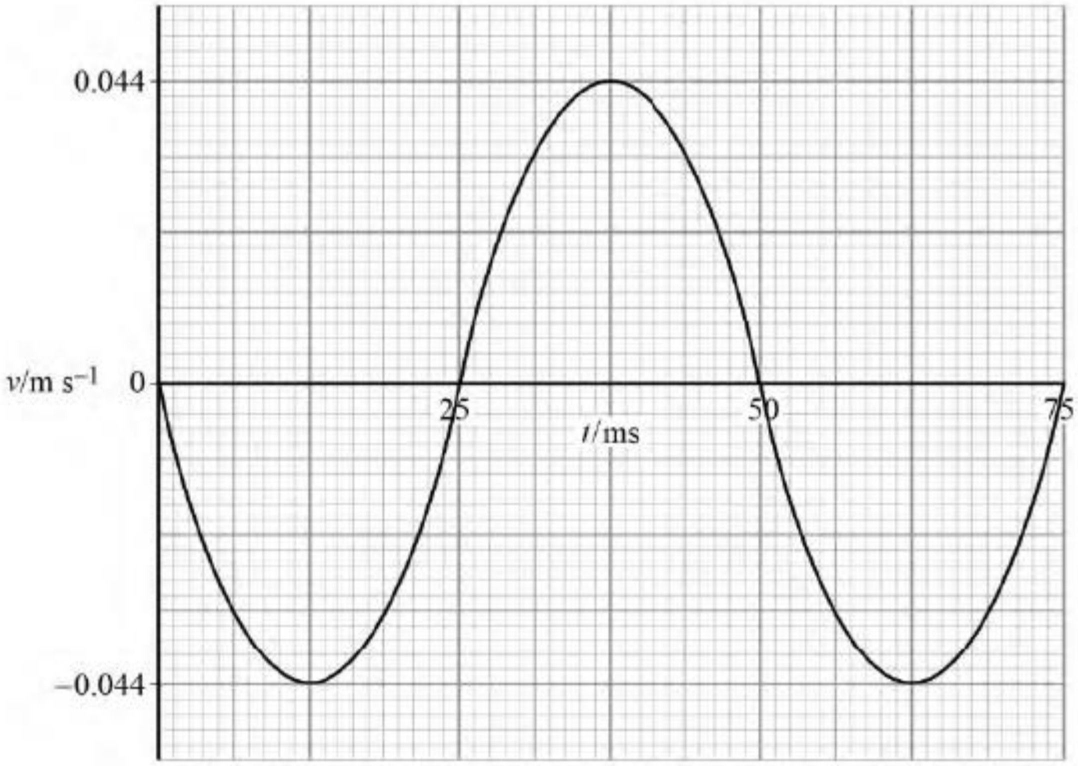
(b) A rigid flat plate is made to vibrate vertically with simple harmonic motion. The frequency of the vibration is controlled by a signal generator as shown in **Figure 1**.

Figure 1



The velocity−time (v−t) graph for the vibrating plate at one frequency is shown in **Figure 2**.

Figure 2

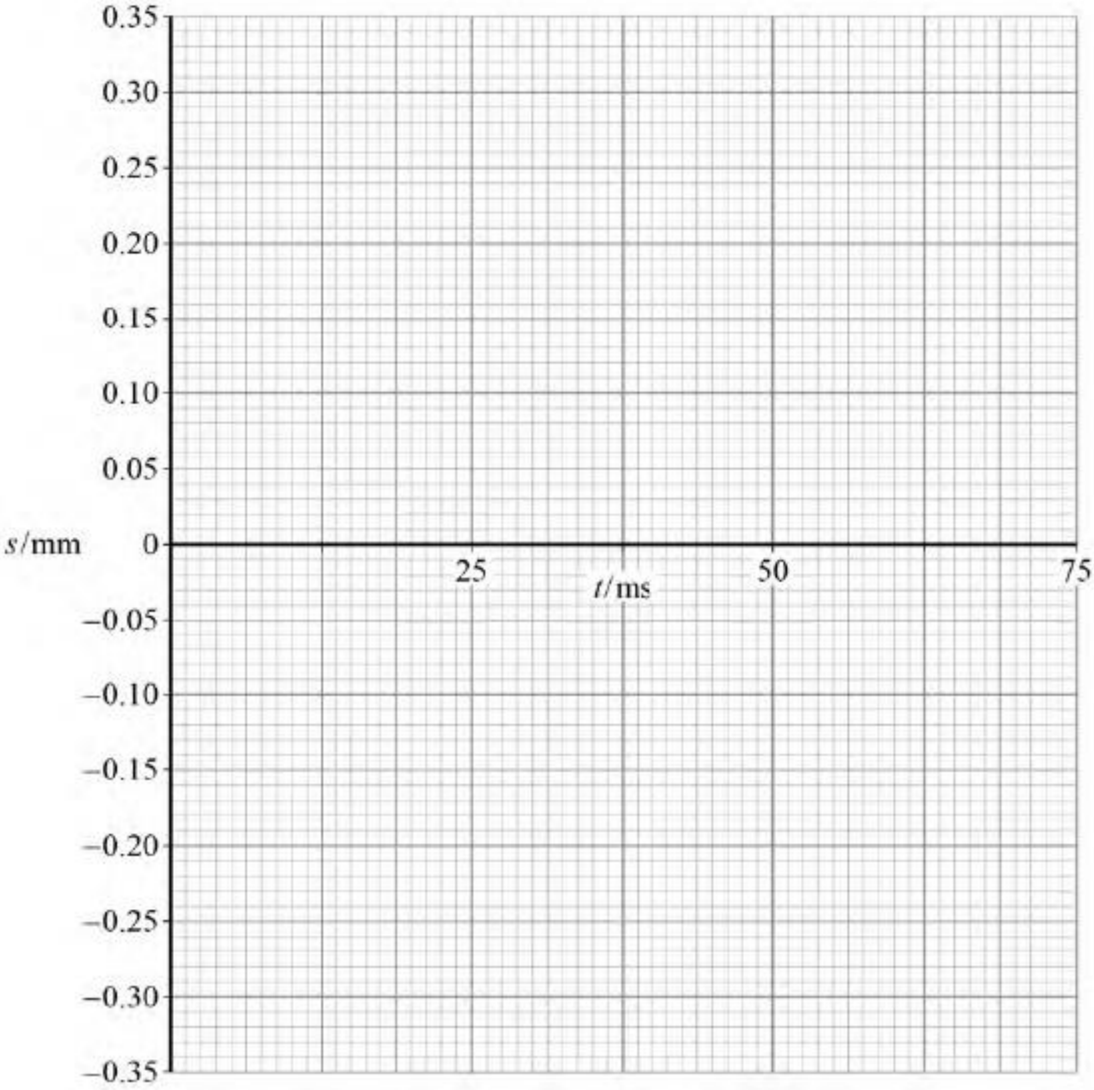


Show that the maximum displacement of the plate is 3.5×10^{-4} m.

(2)

(c) Draw on **Figure 3** the displacement−time (s−t) graph between 0 and 75 ms.

Figure 3



(1)

(d) State **one** time at which the plate has maximum potential energy.

time = ______________________ s

(1)

(e) A small quantity of fine sand is placed onto the surface of the plate. Initially the sand grains stay in contact with the plate as it vibrates. The amplitude of the vibrating surface remains constant at 3.5×10^{-4} m over the full frequency range of the signal generator. Above a particular frequency the sand grains lose contact with the surface.

Explain how and why this happens.

____

(3)

(f) Calculate the lowest frequency at which the sand grains lose contact with the surface of the plate.

frequency = ______________________ Hz

(2)

(Total 11 marks)

Q45.

What is the correct order of increasing photon energy in the electromagnetic spectrum?

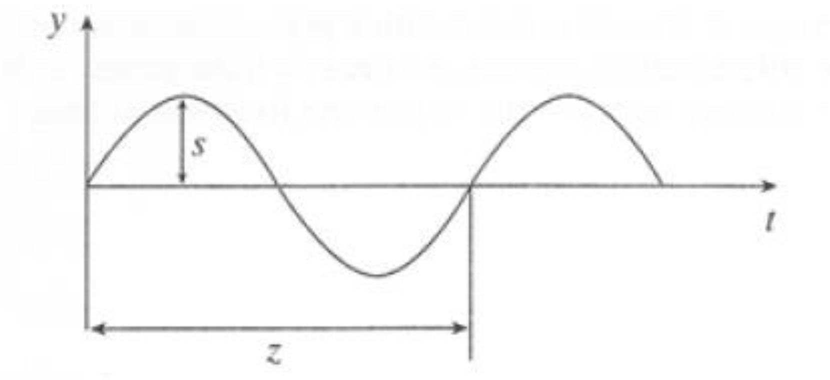
1 is least energy, 4 is greatest energy.

	Radio waves	**γ rays**	**Visible light**	**Infrared**	
A	1	4	3	2	☐
B	4	1	2	3	☐
C	1	4	2	3	☐
D	4	1	3	2	☐

(Total 1 mark)

Q46.

For waves on a water surface, the following graph shows how the displacement *y* of a water particle in the surface varies with the time *t*.



What are the quantities ***z*** and ***s***?

	z	***s***	
A	frequency	amplitude	○
B	period	half-amplitude	○
C	wavelength	half-amplitude	○
D	period	amplitude	○

(Total 1 mark)

Q47.

Monochromatic light of wavelength 600 nm is used to illuminate a pair of slits 0.50 mm apart. The fringes are observed at a distance of 1.50 m from the slits.

What is the separation of the fringes?

A 2.0×10^{-7} mm ○

B 1.8×10^{-3} mm ○

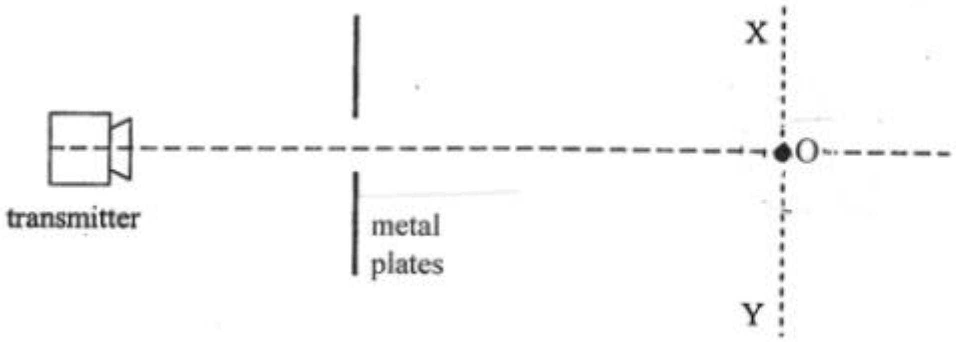
C 5.6×10^{-1} mm ○

D 1.8 mm ○

(Total 1 mark)

Q48.

Microwaves from a transmitter are incident on a gap between two metal plates. The microwaves that pass through the gap are detected by a receiver.



The receiver is placed at O.

What change causes the received signal to decrease and then increase?

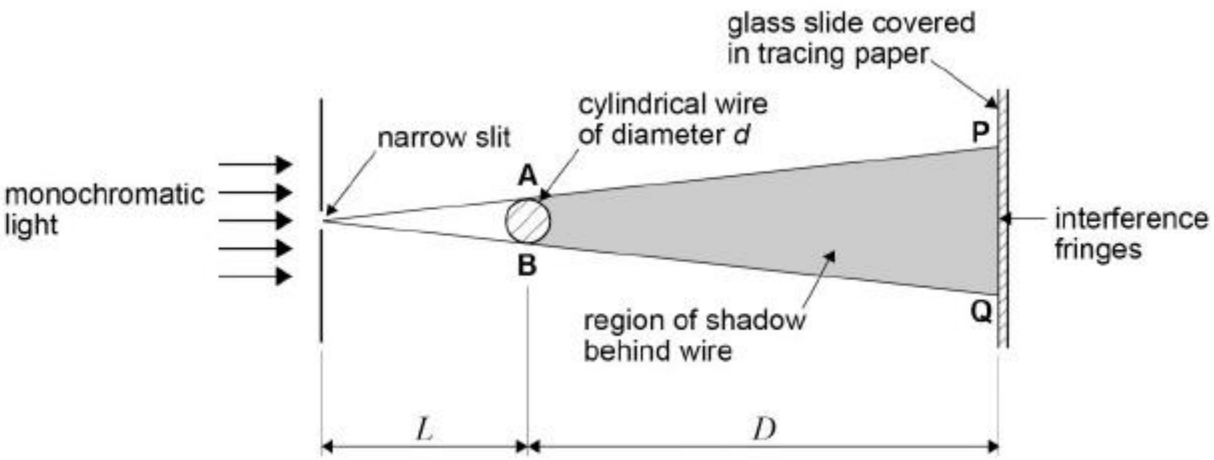
A	make the gap narrower	○
B	move the receiver towards X	○
C	rotate the receiver through 90°	○
D	move the transmitter away from the receiver	○

(Total 1 mark)

Q49.

A student carries out an experiment to determine the diameter of a cylindrical wire based on the theory of Young's double−slit experiment, using the arrangement shown in **Figure 1**.

Figure 1

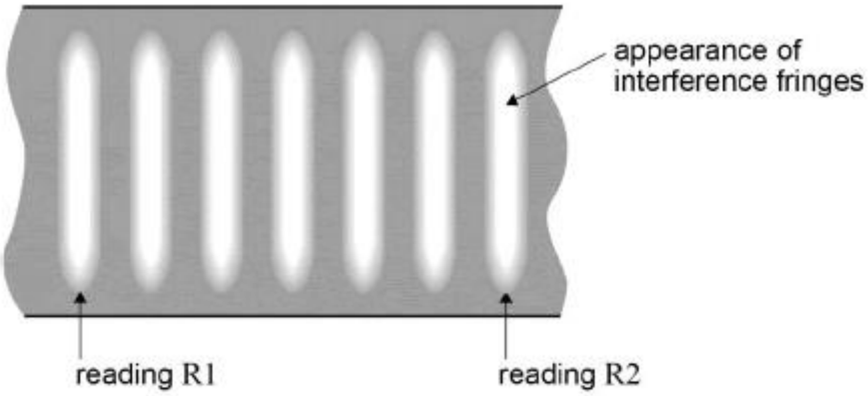


The wire is mounted vertically in front of a single narrow slit which is illuminated by monochromatic light. The wire produces a shadow between points **P** and **Q** on a glass slide covered with tracing paper. The light diffracts as it passes the wire. Points **A** and **B** act as coherent sources causing interference fringes to be seen between **P** and **Q**.

The student uses a metre ruler to measure the distances L and D shown in **Figure 1**.

Figure 2 shows the pattern of interference fringes between **P** and **Q**. The student takes readings from a vernier scale to indicate the positions of the centres of two of the fringes.

Figure 2



The student's measurements are shown in **Table 1**.

Table 1

***L*/mm**	***D*/mm**	**R1/mm**	**R2/mm**
46	395	8.71	11.16

(a) Determine the spacing of the interference fringes w using **Figure 1** and the data in **Table 1**.

Give your answer to an appropriate number of significant figures.

w ____________________ m

(2)

(b) Determine the diameter d of the wire.

wavelength of the monochromatic light = 589.3 nm

d = ____________________ m

(2)

(c) Estimate the number of interference fringes seen between **P** and **Q**.

number of interference fringes = ____________________

(3)

(d) The student uses a micrometer screw gauge to confirm his result for d.

Describe a suitable procedure that the student should carry out before using the micrometer to ensure that the measurements are not affected by systematic error.

___

___

___

___

(2)

(e) To reduce the impact of random error, the student takes several measurements of the diameter at different points along the wire so that he can calculate a mean value for d.

These measurements are shown in **Table 2**.

***d*/mm**
0.572
0.574
0.569
0.571
0.566
0.569

Use the data from **Table 2** to determine the percentage uncertainty in the student's result for d.

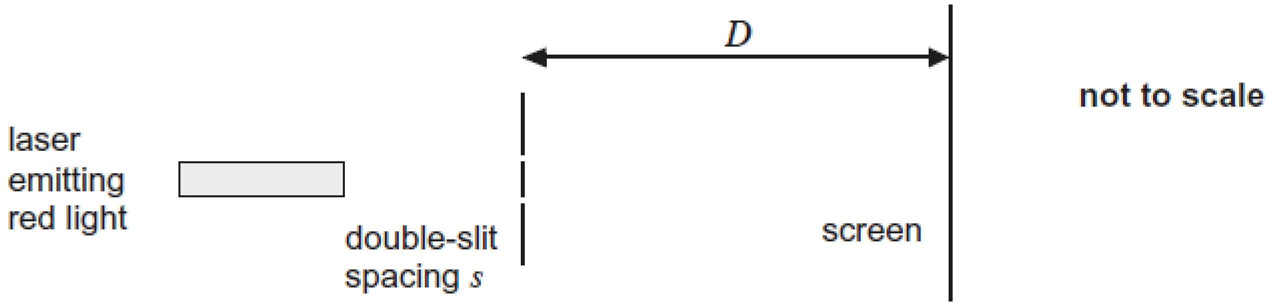
percentage uncertainty = ____________________ %

(2)

(Total 11 marks)

Q71.

The diagram shows the arrangement of apparatus in an experiment to measure the wavelength of red light emitted by a laser. The light is incident on a double-slit so that an interference pattern is produced on the screen.



A student sets up the apparatus and measures the fringe width *w* of the interference pattern and the distance *D* between the double-slit and screen.

The student makes further measurements of *w* using the same laser but with different values of *D* and different slit spacing *s*.

The student's results are shown in the table below

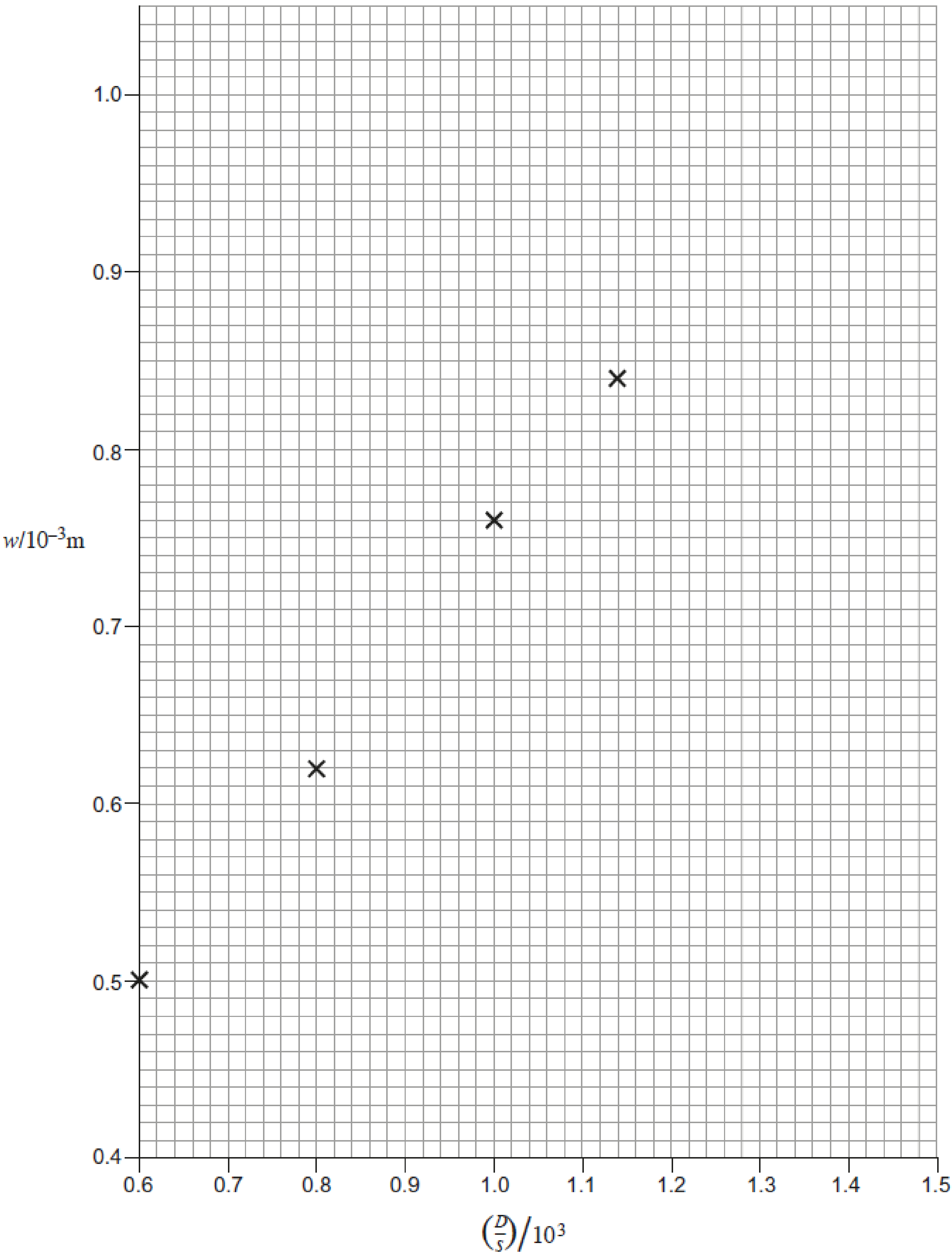
***D*/m**	$S/10^{-3}$ m	$\left(\frac{D}{S}\right)/10^{3}$	$w/10^{-3}$ m
1.000	0.70		1.03
0.900	0.70		0.93
0.800	0.70	1.14	0.84
1.000	1.00	1.00	0.76
0.800	1.00	0.80	0.62
0.600	1.00	0.60	0.50

(a) Complete the table above.

(1)

(b) Complete the graph below by plotting the two remaining points and drawing a best fit straight line.

(2)



(c) (i) Determine the gradient of the graph above.

____

(3)

(ii) Determine the wavelength of the red laser light used in this experiment.

(1)

(d) (i) Theory suggests that the graph above should go through the origin.

State and explain what this suggests about the relationship between *w* and $\frac{D}{S}$.

(2)

(ii) The student discovers that the best fit line drawn in the graph does not go through the origin.

Determine, using information from the graph above, the value of *w* corresponding to $\left(\frac{D}{S}\right) = 0$.

(2)

(iii) The graph suggests a systematic error in a measurement.

Identify the measurement.

(1)

(e) The interference pattern produced on the screen is much brighter in the centre of the screen than at the edges.

State what causes this effect.

___

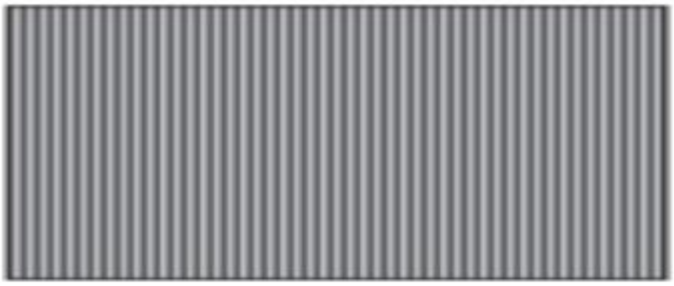
___

(1)

(Total 13 marks)

Q72.

(a) The image below shows a full-size photograph of a double-slit interference pattern, using a laser.



Determine the fringe width w using a ruler to take measurements from the image above.
You may use a hand-lens to help you make this measurement.

___

___

___

___

(3)

(b) Calculate the uncertainty in the value of w measured in part **(a)**.

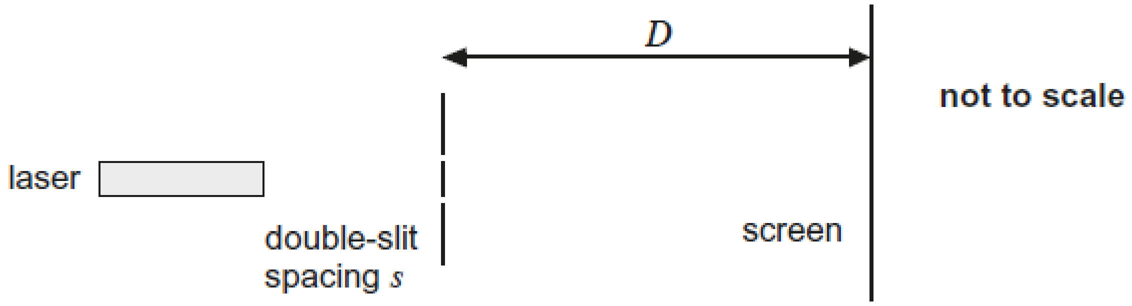
___

___

___

(2)

(c) In the experiment shown in the diagram below, the fringe pattern in the image in part **(a)** is produced.



s = 0.60 ± 0.02 mm
D = 1.500 ± 0.002 m

Using these data and your answers to part **(a)** and part **(b)**, determine

(i) the wavelength of the laser light used

____

____

____

(1)

(ii) the percentage uncertainty in this value of wavelength

____

____

____

(1)

(iii) the absolute uncertainty in this value of wavelength.

____

____

____

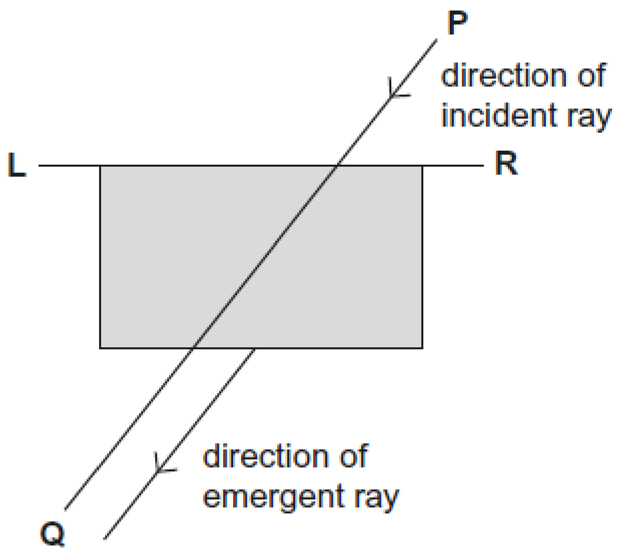
(1)

(Total 8 marks)

Q73.

A student aligns the longer edge of a rectangular glass block along a line **LR**, as shown in **Figure 1**.

Figure 1

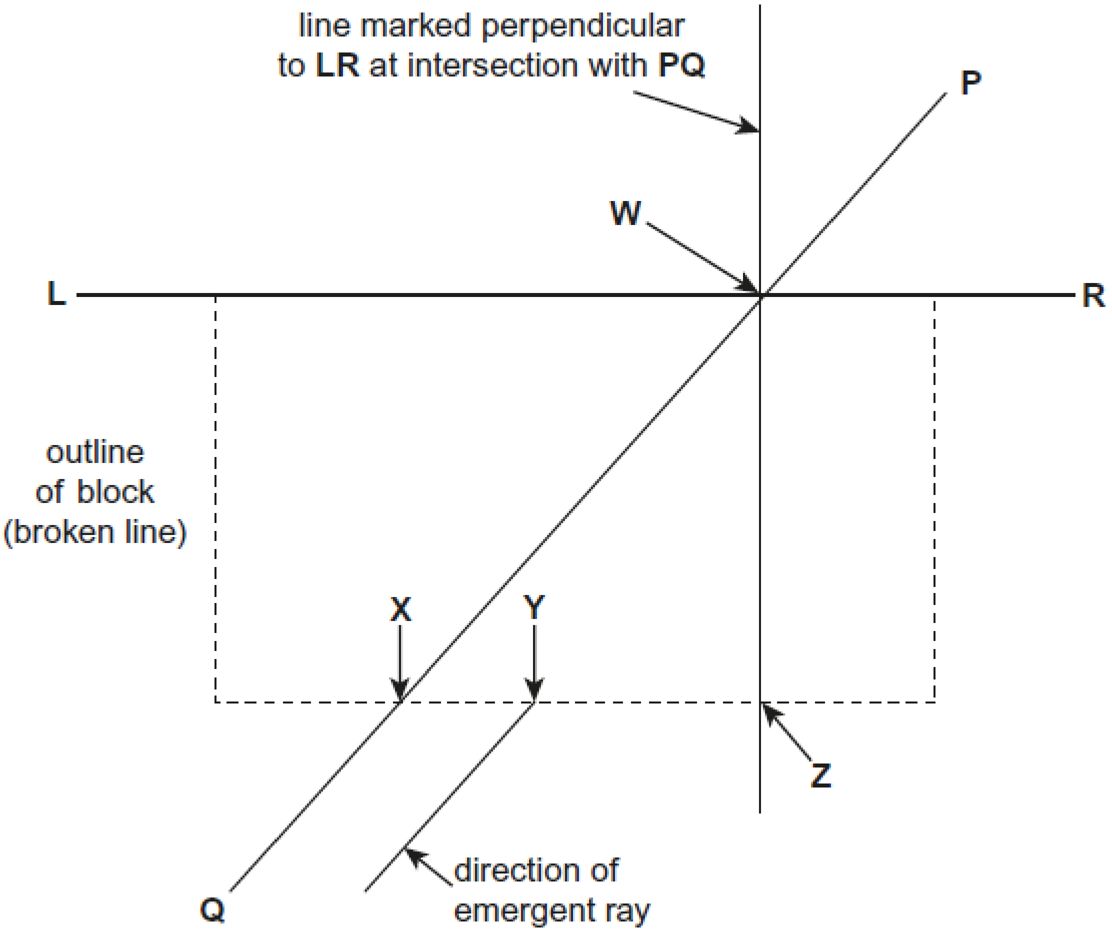


The student marks the outline of the block and directs a ray along **PQ**.

The student marks the direction of the emergent ray then removes the block and marks a line perpendicular to **LR** where **PQ** and **LR** intersect.

The student then marks the points **W**, **X**, **Y** and **Z** that are defined in **Figure 2**.

Figure 2



(a) Show that the refractive index n of the block is given by the equation

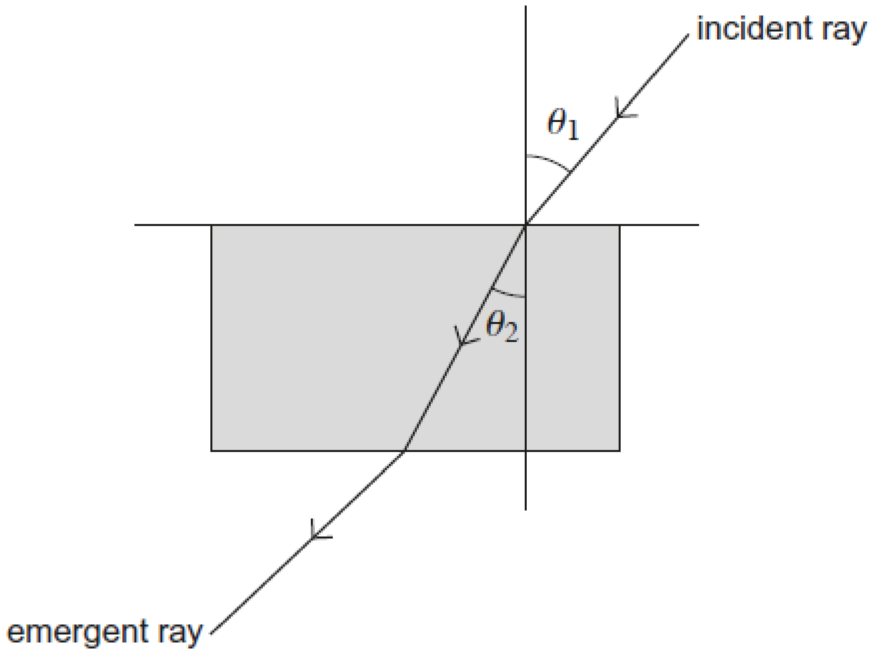
$$n = \frac{XZ \times WY}{YZ \times WX}$$

You may wish to use the equation $n = \dfrac{\sin\theta_1}{\sin\theta_2}$

where θ_1 and θ_2 are the angles shown in **Figure 3**.

You may also wish to illustrate your answer with a diagram.

Figure 3



(2)

(b) The student repeats the procedure for different directions of the incident ray **PQ**. The student measures **XZ**, **WX**, **YZ** and **WY** for each direction of **PQ**.
State and explain how the student can use these results to obtain a value of *n* by a graphical method.

(2)

(c) The student used a block with dimensions 114 mm × 65 mm × 19 mm to perform the experiment.

The student's data are shown in the table below.

WX/mm	WY/mm	XZ/mm	YZ/mm
130	78	113	44
103	75	80	38
90	73	63	33
81	71	49	27
75	69	38	22
67	66	15	10

Explain whether the range of measurements made by the student is suitable.

____

____

____

____

____

____

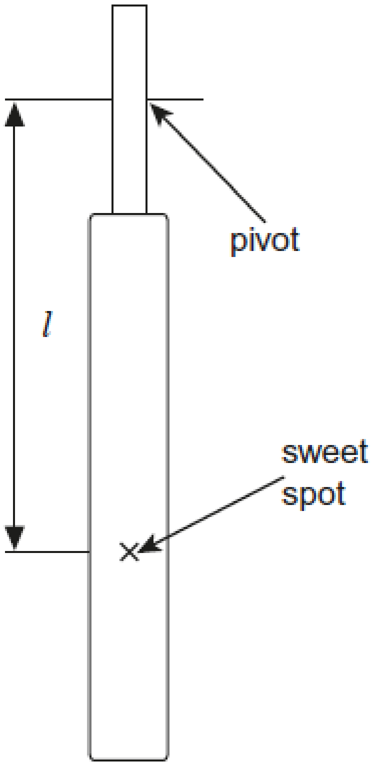
(3)

(Total 7 marks)

Q74.

In a compound pendulum the mass is distributed along its length rather than being a 'point' mass as in a simple pendulum.

When used to strike a ball, a cricket bat behaves like a compound pendulum. The bat has a sweet spot. When the ball hits this spot there is a maximum momentum transfer from the bat to the ball and the bat oscillates in the batsman’s hands.



The diagram above shows a cricket bat pivoted at the point at the centre of the batsman's grip. The position of the sweet spot is also marked on the bat.

It is suggested that the distance l between the pivot and the sweet spot is the same as the length of a simple pendulum with the same period of oscillation as the bat.

Describe how you would use the pivoted bat shown in the diagram to investigate whether the distance from the sweet spot to the pivot is equal to the length of the equivalent simple pendulum.

You should consider the uncertainties in the measurements for the bat and the pendulum in your answer

____

____

____

____

____

____

____

____

____

____

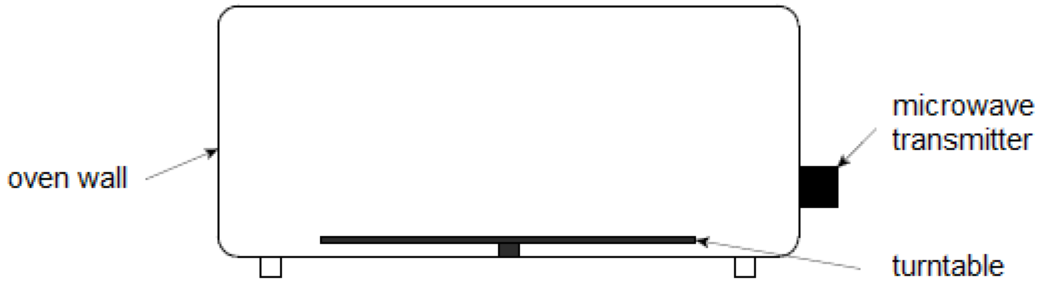
____

(Total 5 marks)

Q75.

Figure 1 is a diagram of a microwave oven.

Figure 1



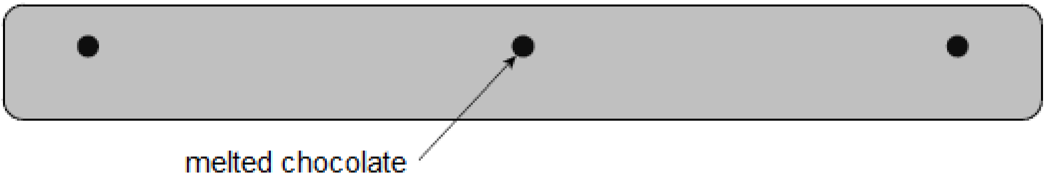
A student wants to use the stationary waves formed in the microwave oven to measure the frequency of the microwaves emitted by the transmitter.

(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.

___

___

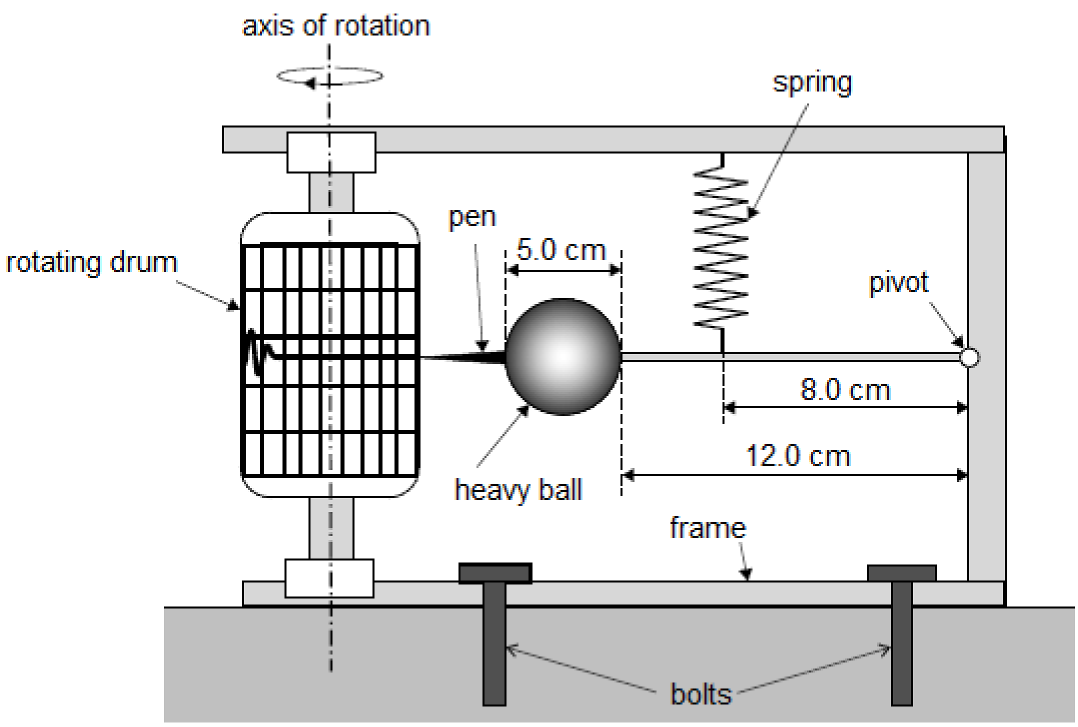
___

(1)

(Total 10 marks)

Q76.

A seismometer is a device that is used to record the movement of the ground during an earthquake. A simple seismometer is shown in the diagram.



A heavy spherical ball is attached to a pivot by a rod so that the rod and ball can move in a vertical plane. The rod is suspended by a spring so that, in equilibrium, the spring is vertical and the rod is horizontal. A pen is attached to the ball. The pen draws a line on graph paper attached to a drum rotating about a vertical axis. Bolts secure the seismometer to the ground so that the frame of the seismometer moves during the earthquake.

(a) The ball is made of steel of density 8030 kg m^{-3} and has a diameter of 5.0 cm.

Show that the weight of the ball is approximately 5 N.

(3)

(b) The distance from the surface of the ball to the pivot is 12.0 cm, as shown in the diagram above.

Calculate the moment of the weight of the ball about the pivot when the rod is horizontal. Give an appropriate unit for your answer.

moment = ____________________ unit = __________

(3)

(c) The spring is attached at a distance of 8.0 cm from the pivot and the spring has a stiffness of 100 N m^{-1}.

Calculate the extension of the spring when the rod is horizontal and the spring is vertical. You may assume the mass of the pen and the mass of the rod are negligible.

extension = ____________________ m

(3)

(d) Before an earthquake occurs, the line being drawn on the graph paper is horizontal.

Explain what happens to the line on the graph paper when an earthquake is detected and the frame of the seismometer accelerates rapidly downwards.

____

____

____

____

____

____

____

(2)

(Total 11 marks)

Q77.

What is the phase difference between two points 0.16 m apart on a progressive sound wave of frequency 256 Hz?

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

A	$\frac{\pi}{8}$	☐
B	$\frac{\pi}{6}$	☐
C	$\frac{\pi}{4}$	☐
D	$\frac{\pi}{3}$	☐

(Total 1 mark)

Q78.

The frequency of the first harmonic of a standing wave on a wire is f. The length of the wire and tension in the wire are both doubled.

What is the frequency of the first harmonic as a result?

A $\frac{f}{\sqrt{2}}$ ☐

B f ☐

C $\sqrt{2}f$ ☐

D $2f$ ☐

(Total 1 mark)

Q79.

In a diffraction-grating experiment the maxima are produced on a screen.

What causes the separation of the maxima of the diffraction pattern to decrease?

A using light with a longer wavelength ☐

B increasing the distance between the screen and grating ☐

C increasing the distance between the source and grating ☐

D using a grating with a greater slit separation ☐

(Total 1 mark)

Q80.

White light passes through a single narrow slit and illuminates a screen.

What is observed on the screen?

A a set of equally spaced white fringes ☐

B a central maximum made up of a spectrum surrounded by white fringes ☐

C a white central maximum surrounded by coloured fringes ☐

D a single narrow white line ☐

(Total 1 mark)

Q81.

Which of the following is correct when total internal reflection occurs?

A the angle of incidence is less than the critical angle ⬭

B the light meets an optically less dense medium ⬭

C the light enters a medium with a higher refractive index ⬭

D the angles that the incident and refracted rays make with the normal are the same ⬭

(Total 1 mark)

Q82.

What is the speed of light in glass of refractive index 1.42?

A 4.26×10^7 m s^{-1} ⬭

B 2.11×10^8 m s^{-1} ⬭

C 3.00×10^8 m s^{-1} ⬭

D 4.73×10^8 m s^{-1} ⬭

(Total 1 mark)

Q83.

(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

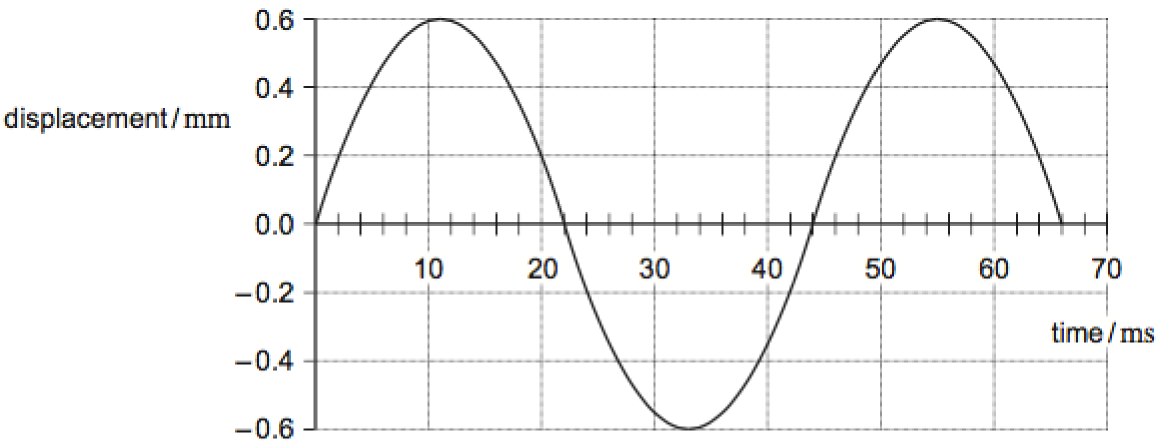
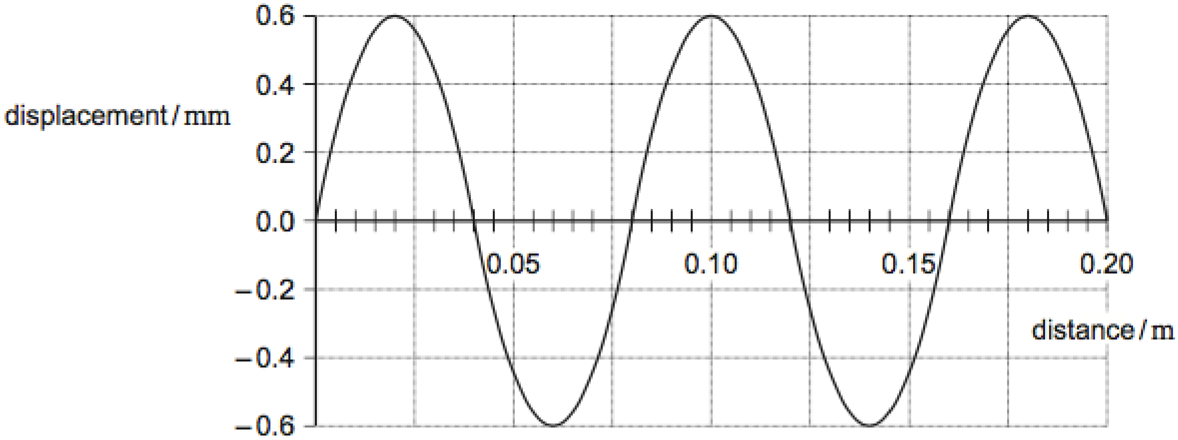


Figure 2 shows the variation of displacement of the same wave with distance.

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	

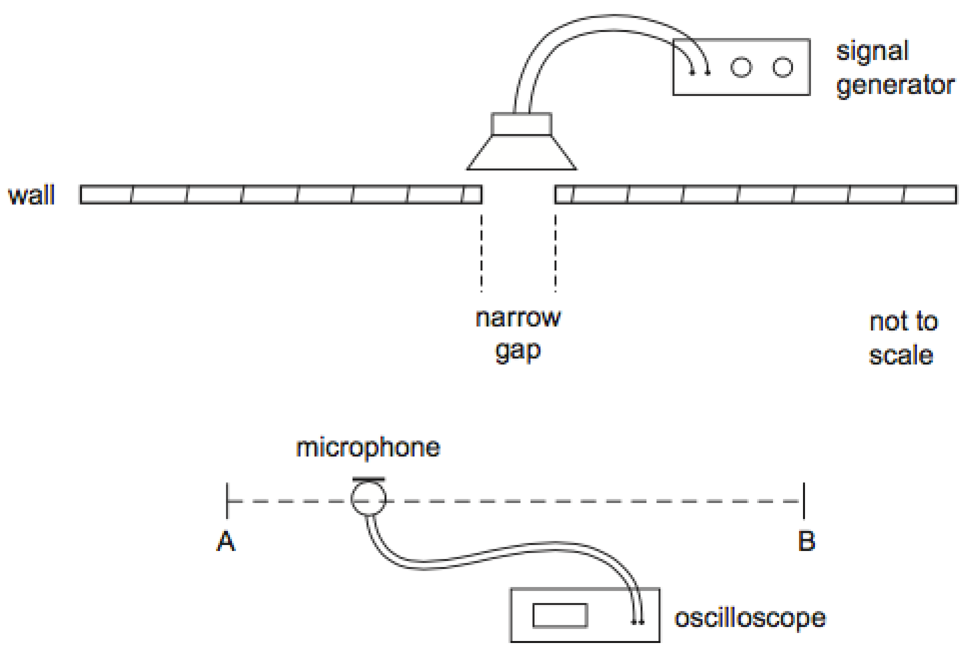
transverse	
sound waves are longitudinal	
sound waves can interfere	
sound waves can be polarised	

(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.

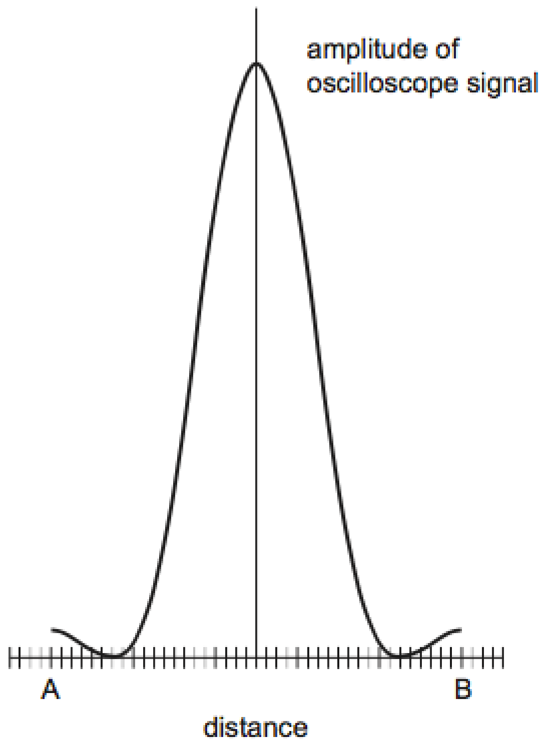
Figure 3



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**.

____

____

____

____

____

____

____

____

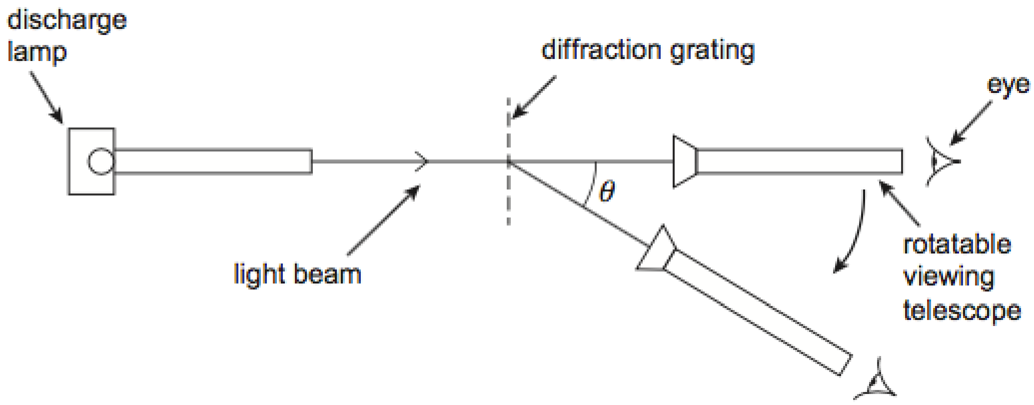
____

____

(3)
(Total 10 marks)

Q84.

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 = ____________________

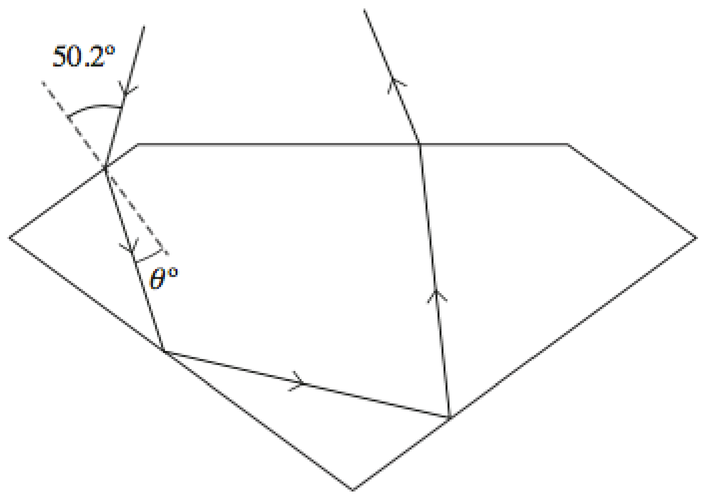
(3)

(Total 9 marks)

Q85.

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)

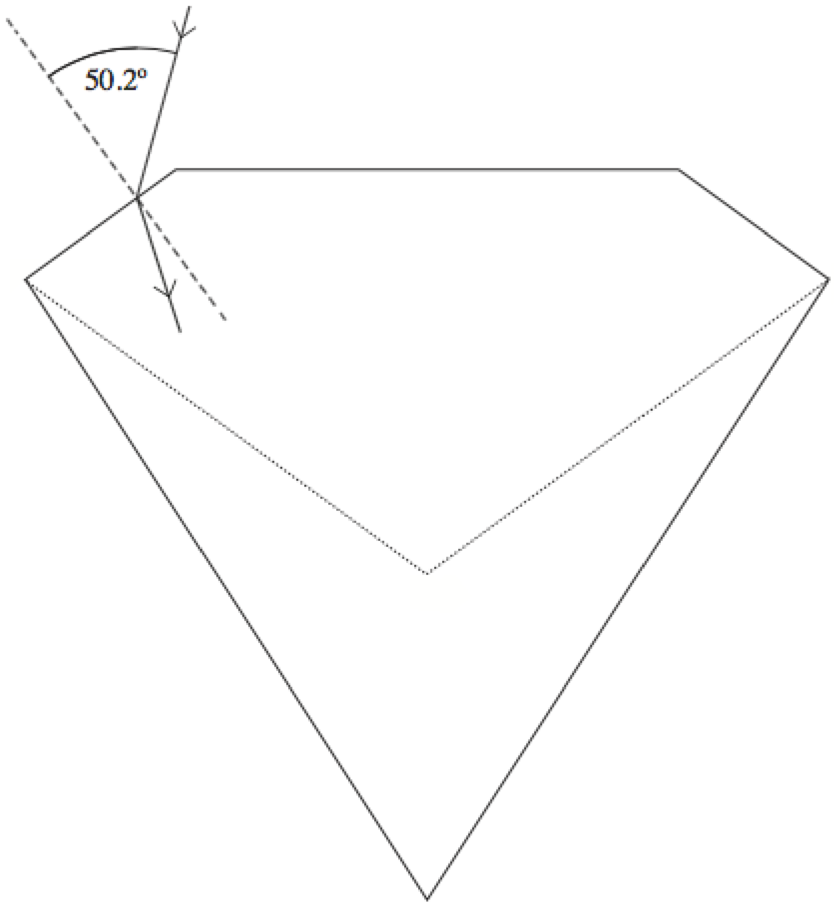
(ii) The ray shown in **Figure 1** enters at an angle of incidence of 50.2°.
Calculate the angle of refraction *θ*.

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.

____

____

____

____

____

____

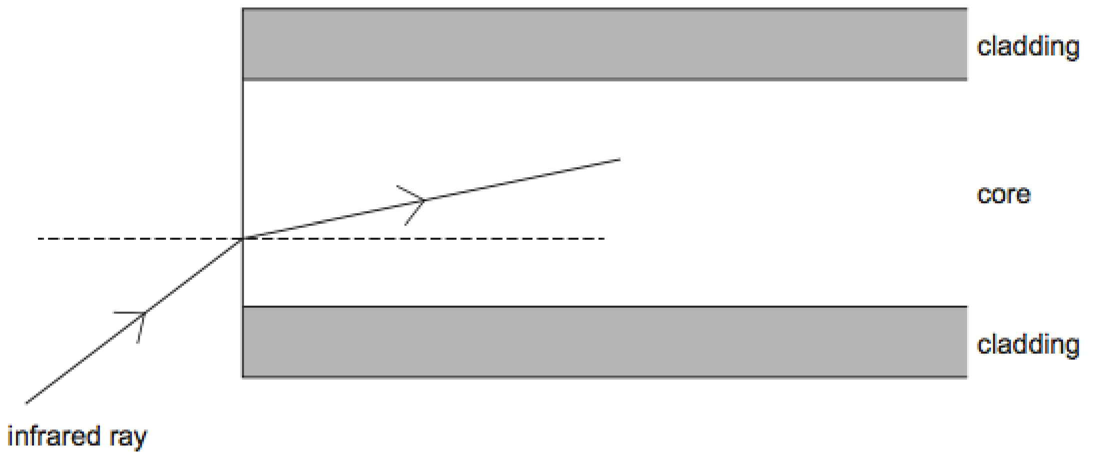
____

____

(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.

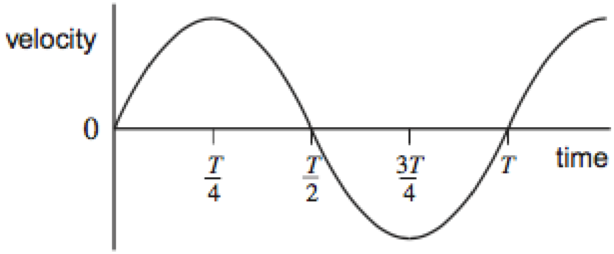
____

____

(1)
(Total 12 marks)

Q86.

The graph shows how velocity changes with time for a simple pendulum moving with simple harmonic motion.



Which one of the following statements related to the motion of the pendulum is **incorrect**?

A The acceleration is a minimum at $\frac{T}{4}$

B The acceleration is a maximum at $\frac{T}{2}$

C The kinetic energy is a maximum at $\frac{T}{2}$

D The restoring force is a minimum at $\frac{3T}{4}$

(Total 1 mark)

Q87.

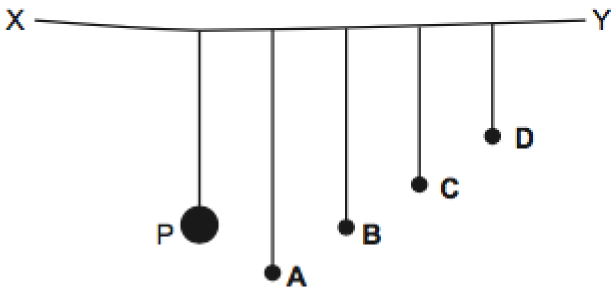
A mass hanging on the end of a spring undergoes vertical simple harmonic motion.
At which point(s) is the magnitude of the resultant force on the mass a minimum?

A at both the top and bottom of the oscillation
B only at the top of the oscillation
C only at the bottom of the oscillation
D at the centre of the oscillation

(Total 1 mark)

Q88.

The diagram shows a string XY supporting a heavy pendulum P and four pendulums **A**, **B**, **C** and **D** of smaller mass.



Pendulum P is set in oscillation perpendicular to the plane of the diagram.

Which one of the pendulums, **A** to **D**, then oscillates with the largest amplitude?

(Total 1 mark)

Q89.

Within certain limits, the bob of a simple pendulum of length l may be considered to move with simple harmonic motion of period T, where

$$T = 2\pi\sqrt{\frac{l}{g}}$$

(a) State **one** limitation that applies to the pendulum when this equation is used.

____

____

(1)

(b) Describe an experiment to determine the value of the Earth's gravitational field strength g using a simple pendulum and any other appropriate apparatus.

In your answer you should:

- describe how you would arrange the apparatus
- indicate how you would make the measurements
- explain how you would calculate the value of g by a graphical method
- state the experimental procedures you would use to ensure that your result was accurate.

You may draw a diagram to help you with your answer.

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

____

____

____

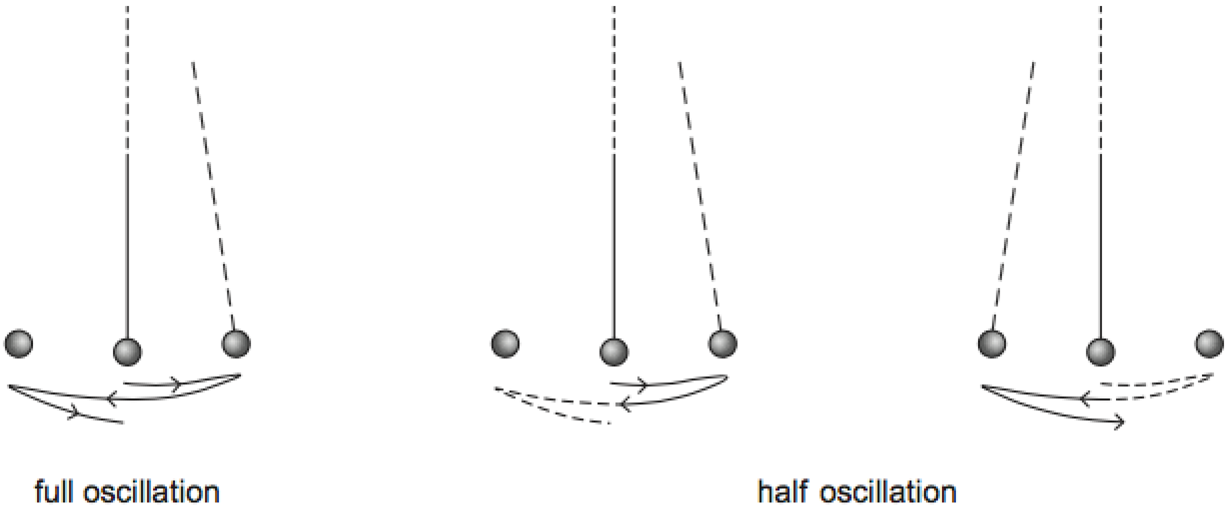
____

____

____

(6)

(c) When carrying out the experiment in part **(b)**, a student measures the time period incorrectly. Mistakenly, the student thinks that the time period is the time taken for half of an oscillation instead of a full oscillation, as illustrated in the diagram.



Deduce the effect this will have on the value of g obtained from the experiment, explaining how you arrive at your answer.

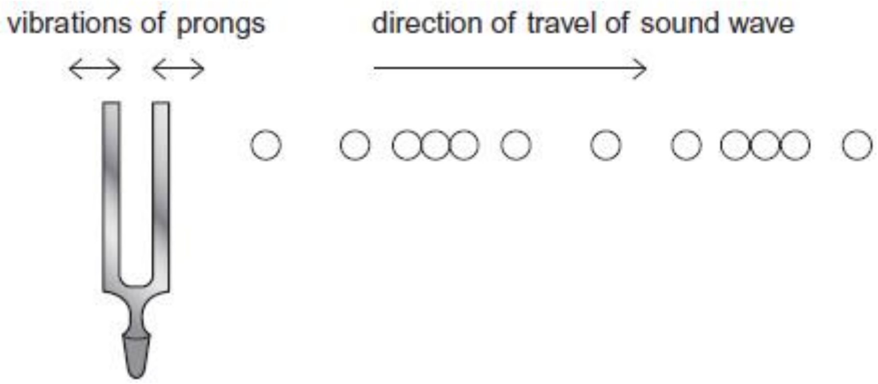
(3)
(Total 10 marks)

Q90.

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}

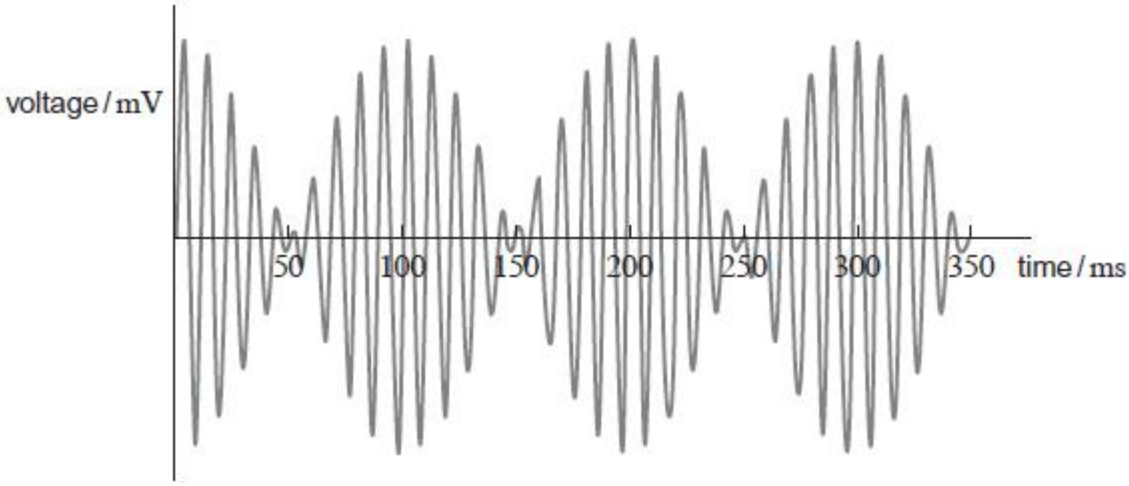
minimum separation ____________________ m

(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.

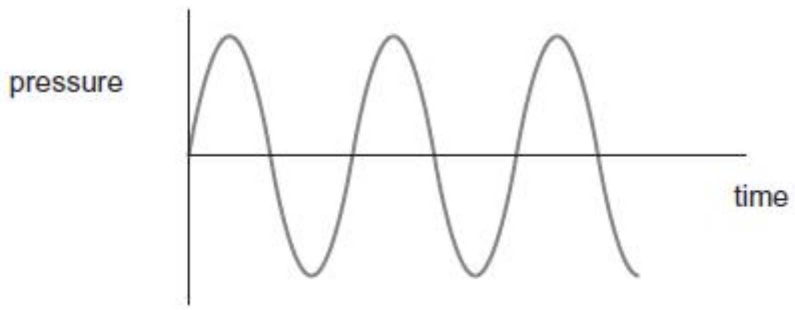
frequency ____________________ Hz

(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)

Q91.

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.

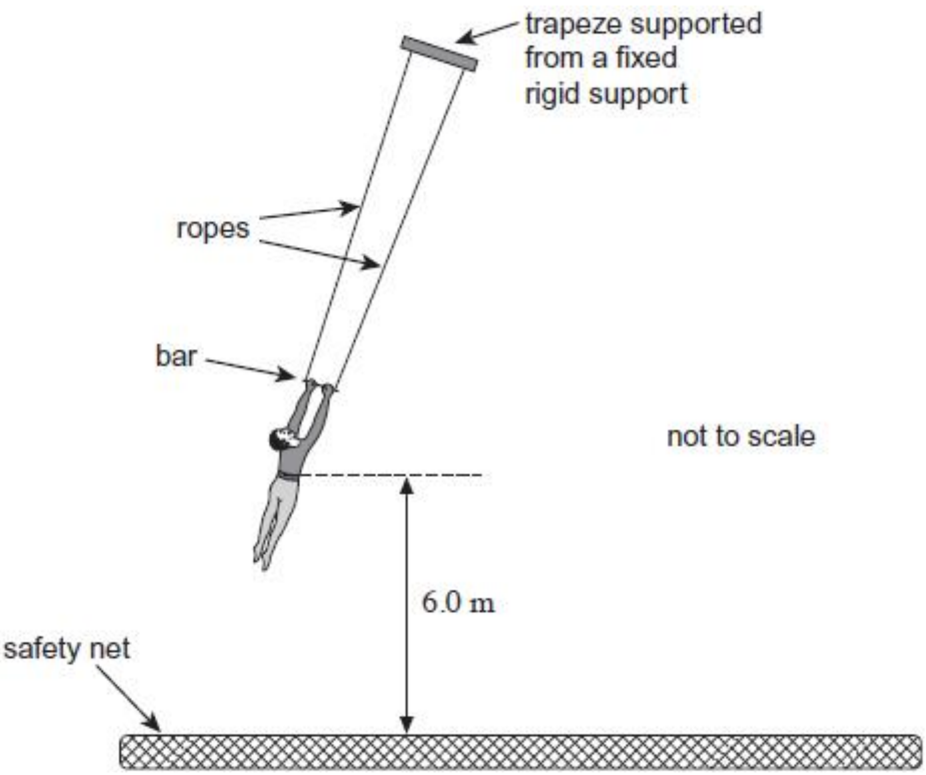
The quality of your written communication will be assessed in your answer.

(Total 6 marks)

Q92.

Figure 1 shows an acrobat swinging on a trapeze.

Figure 1



(a) (i) State and explain how the tension in the ropes of the trapeze varies as the acrobat swings on the trapeze.

___

___

___

___

___

___

___

___

(3)

(ii) The period of the oscillation of the acrobat on the trapeze is 3.8 s.

Calculate the distance between the point of suspension of the trapeze and the centre of mass of the acrobat.

Assume that the acrobat is a point mass and that the system behaves as a simple pendulum.

distance ____________________ m

(2)

(b) At one instant the amplitude of the swing is 1.8 m. The acrobat lets go of the bar of the trapeze at the lowest point of the swing. He lands in a safety net when his centre of mass has fallen 6.0 m.

(i) Calculate the speed of the acrobat when he lets go of the bar.

speed ____________________ m s^{-1}

(3)

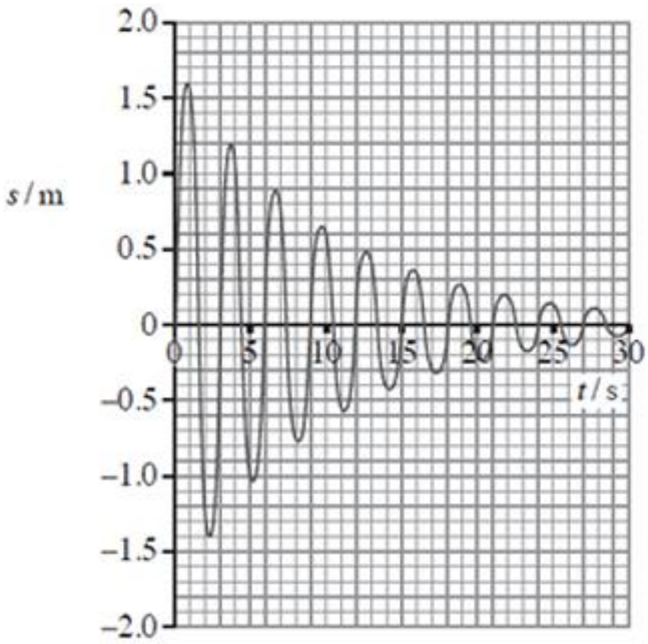
(ii) Calculate the horizontal distance between the point of suspension of the trapeze and the point at which the acrobat lands on the safety net.

horizontal distance ____________________ m

(3)

(c) **Figure 2** shows the displacement−time (*s*–*t*) graph for the bar of the trapeze after the acrobat has let go of the bar.

Figure 2



(i) Show that the amplitude of the oscillations decreases exponentially.

(3)

(ii) Explain why the period of the trapeze changes when the acrobat lets go of the bar.

___

___

___

___

(2)

(Total 16 marks)

Q93.

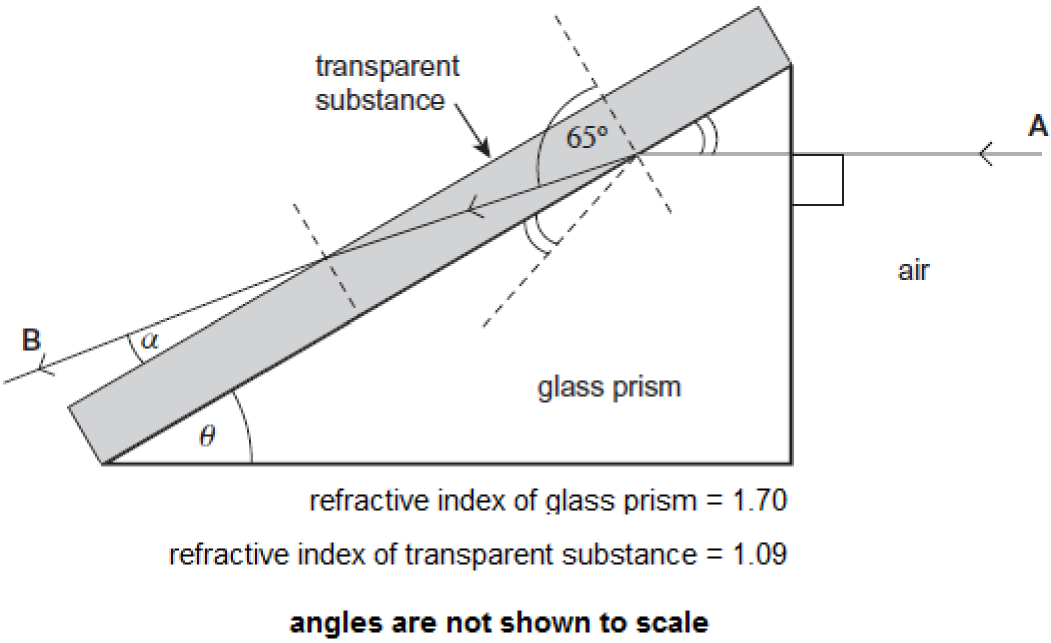
(a) Tick (✓) the appropriate boxes in the table to indicate how the wavelength, frequency and speed of light are affected when a ray of light travels from air into glass.

	Wavelength	**Frequency**	**Speed**
increases			
stays the same			
decreases			

(2)

(b) **Figure 1** shows a right-angled glass prism in contact with a transparent substance on one of the faces. One of the other angles of the prism is θ.

Figure 1



(i) A ray **A** enters perpendicularly to one face of the prism. It is partially refracted and partially reflected at the interface between the glass and the transparent substance. The angle of refraction is 65.0°. The ray eventually leaves at an angle α to the surface of the transparent substance.

Determine the angle α.

angle α = ____________________ degree

(2)

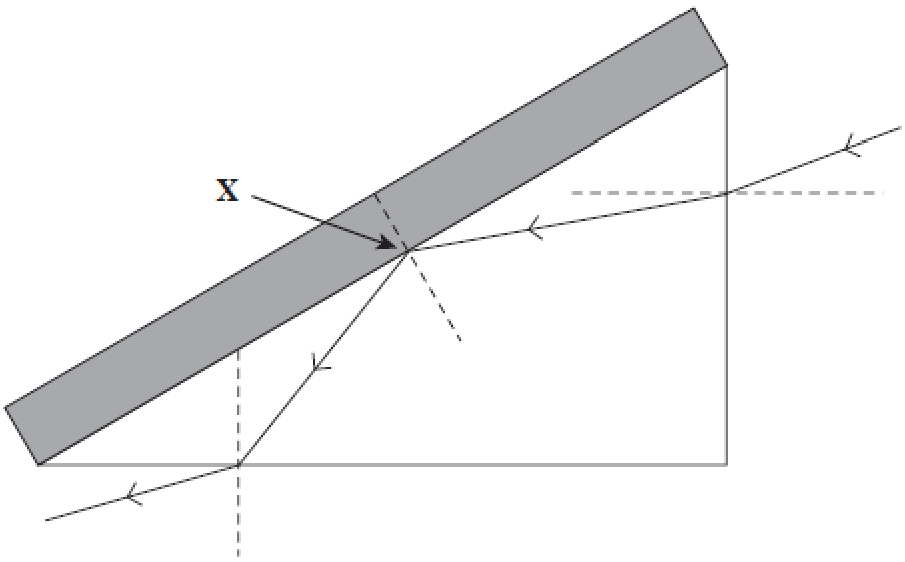
(ii) Determine the angle θ in **Figure 1**.

angle θ = ____________________ degree

(2)

(c) **Figure 2** shows another ray entering the prism.

Figure 2



(i) Identify the effect that takes place at **X** in **Figure 2**.

____

(1)

(ii) Explain, with a diagram, how the effect that occurs at **X** is used to transmit information along an optic fibre.

(3)

(Total 10 marks)

Q94.

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

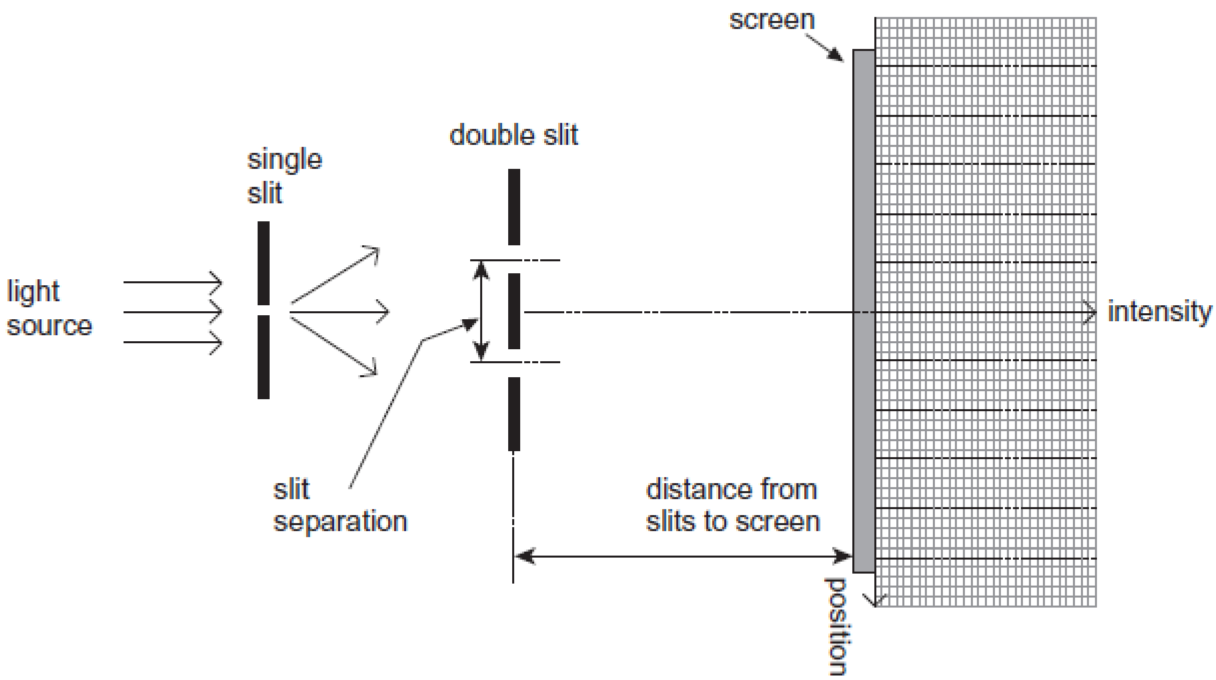
- an explanation of how the stationary wave is formed
- a description of the features of the stationary wave
- a description of the processes that produce these features.

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

(Total 6 marks)

Q95.

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)

Q96.

For a body performing simple harmonic motion, which one of the following statements is correct?

A The maximum kinetic energy is directly proportional to the frequency.

B The time for one oscillation is directly proportional to the frequency.

C The speed at any instant is directly proportional to the displacement.

D The maximum acceleration is directly proportional to the amplitude.

(Total 1 mark)

Q97.

(a) Musical **concert pitch** has a frequency of 440 Hz.
A correctly tuned A-string on a guitar has a first harmonic (fundamental frequency) two octaves below concert pitch.

Determine the first harmonic of the correctly tuned A-string.

frequency ____________________ Hz

(1)

(b) Describe how a note of frequency 440 Hz can be produced using the correctly tuned A-string of a guitar.

___

___

(1)

(c) Describe the effect heard when notes of frequency 440 Hz and 430 Hz of similar amplitude are sounded together.

____

____

____

____

(2)

(Total 4 marks)

Q98.

An optical fibre consists of a core, cladding and an outer sheath.

(a) State the purpose of the outer sheath in an optical fibre.

____

____

(1)

(b) For one fibre, the speed of monochromatic light in the core is 1.97×10^8 m s^{-1} and the speed in the cladding is 2.03×10^8 m s^{-1}.

Calculate the critical angle for this light at the interface between the core and the cladding.

critical angle ______________________ degrees

(2)

(Total 3 marks)

Q1.

(a) TWO FROM:

central white fringe ✓

(fringes either side) showing range of colours/spectrum ✓

with red furthest and blue/violet closest to centre ✓

Allow rainbow for spectrum

Reject different colour fringes

If colours mentioned for last mark must be in right order i.e. red last

1
1
(MAX 2)

(b) FOUR FROM:

central fringe is a mixture of red and green light/two wavelengths ✓

EITHER (1 marks)

(separate) red and green fringes are seen (on either side) ✓

OR (for 2 marks)

spacing of green fringes is less than spacing of red fringe / green fringes closer to middle than red ✓ ✓

OR (for 3 marks)

spacing of red fringes is 20% (or 1.2 times)greater than green fringes ✓ ✓ ✓

6th green fringe overlaps with 5th red fringe ✓

Allow orange/yellow for central fringe

If w used must be identified as fringe spacing for third alternative

1
1
1
1
(MAX 4)

(c) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.**

Mark

Criteria
QoWC

>

Explains how (%) uncertainties combine to determine uncertainty in wavelength OR identify % uncertainty *s* as being the largest
The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear.
The text is legible.

>

Explain how wavelength is determined using $\lambda = \frac{ws}{D}$

>

Explains how second change affects fringe spacing
AND
Comments on how change in fringe spacing affects (%)uncertainty / change in *s* OR *D* affects (%)uncertainty
The student presents relevant information and in a way which assists communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.

>

Explains how second change affects fringe spacing
OR
Comments on how change in fringe spacing affects (%)uncertainty / change in *s* OR *D* affects (%)uncertainty

>

States how one of the changes affects fringe separation (decrease *s* increases fringe separation / decrease *D* decrease fringe separation
The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.

>

States that one of the changes alters fringe separation

>

No correct change identified
The student's presentation, spelling and grammar seriously obstruct understanding.

The following statements may be present for decreasing slit separation s:

Fringe separation increases
Uncertainty in measuring fringe separation will decrease
and as this is needed to measure wavelength, uncertainty in wavelength measurement will decrease

The following statements may be present for smaller D:

Uncertainty in measuring D would increase
Fringe separation would also decrease
so uncertainty in measuring fringe separation would increase
Both are required to find wavelength so uncertainty in finding wavelength would increase

FOR Middle Band ***one*** *of these considered:*

Decrease s
Larger fringe separation so smaller (%) uncertainty (in w)
Smaller s so higher (%) uncertainty in s
Decrease D
Smaller fringe separation so larger (%) uncertainty (in w)
Smaller D so higher (%) uncertainty in D

If explain reverse change correctly (s increase D increase) *no penalty*

6

[12]

Q2.

(a) Use of $n_A = \frac{c}{c_A}$ to make c_A the subject of the equation

Condone truncation without appropriate rounding mid-calculation

OR

speed in glass **A** = 2.05(2) × 10^8 ms^{-1} $_1$✓

Speed in glass **B** = 1.985(3) × 10^8

Condone use of c = 3 × 10^8

But must see answer to 4 sf answer

OR

their speed in glass **A** × 0.96748 (or equivalent) $_2$✓

Values obtained using c = 3×10^8:

- *speed in glass A = 2.05(3)× 10^8 ms^{-1}*
- *speed in glass B = 1.98(7) × 10^8*
- *n = 1.510*

OR

Alternative 1st and 2nd marks

Use of $n_A/n_B = c_B/c_A$ by substitution for n_A $_1$✓

Use of $n_A/n_B = c_B/c_A$ by substitution for n_A and $c_B = c_A \times 0.96748$ $_2$✓

OR

n_B = 1.461 / 0.96748 $_1$✓$_2$✓

Watch for maths errors:

Dividing by 1.03252 ≠ multiplying by 0.96748

Multiplying by 1.03252 ≠ dividing by 0.96748

1.510 cao to 4 sf only $_3$✓

Correct answer to 4 sf obtains all 3 marks

Penalise any unit on final answer

3

(b) **Relationship:**

Increase in tension (or stress) in cable produces increase in strain resulting in increase in λ_R

OR

Decrease in tension (or stress) causes decrease in strain resulting in decrease in λ_R $_1$✓

Variation due to motion:

As the lift accelerates downwards, (the tension is less than the weight in the cable, a decrease in tension results) in λ_R decreasing $_2$✓

At constant velocity (the tension again equals the weight and) λ_R returns to the initial, at rest value $_3$✓

Allow a correct comment on the directional relationship between tension, strain and λ_R independent of the motion of the lift for first mark

3

(c) **P** because it will produce a larger increase in λ_R for the (same) <u>increase</u> in strain

OR

P because it has a larger gradient (must be a sense of larger increase in λ_R for the (same) <u>increase</u> in strain) ✓

Hence <u>smaller accelerations</u> (which produce small changes in strain) can produce <u>measurable changes in λ_R</u>

OR

Hence gauge **P** will have a higher resolution ✓

Selecting Q gains zero marks

Linking steeper gradient to being able to withstand a larger force negates this mark

Allow more accurate measurement of <u>acceleration</u>

Allow more readings of <u>acceleration</u> can be taken (over the range)

More sensitive treat as neutral

2

[8]

Q3.

D

[1]

Q4.

D

[1]

Q5.

C

[1]

Q6.

A

[1]

Q7.

(a) Waves travel to the boundaries and are reflected ✓

Not bounce off ...

1

two waves travelling in opposite directions interfere/superpose ✓

Not superimpose or interferes with itself

1

Fixed boundaries (cannot move so) are nodes ✓

creates nodes and antinodes bland = 0

In some positions the waves always cancel /interfere destructively to give zero amplitude/no vibration/nodes)

OR

interfere constructively to produce positions of maximum amplitude/maximum vibration/antinodes ✓

1

Max 3

(b) Use of $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ ✓

Either rearranges for μ without substitution or substitutes correctly in the formula

1

4.2 (4.19) × 10^{-4} (kg) ✓

1

(c) 240 (244) (m s^{-1})

1

(d) 1 rotation of the peg = 22 mm ✓

Or Reads increase in tension produced by the extra extension (about 10 N) from graph and adds to 25

1

extra extension = 22 × 75/360 = 4.6 mm

(ecf for incorrect circumference) ✓

πd × 75/360 not evaluated =1

1

Total extension = 11 + 4.6 (15.6 mm) so tension 35 - 36N ✓

Inspect their length and their tension in the substitution

1

Calculates frequency **for their tension**

T must be greater than the original 25N

Condone adding or subtracting <u>extra</u> extension to 0.33 m

If 4.0 × 10^{-4} kg used then answer will be in range 448 Hz to 455 Hz

If 4.19 × 10^{-4} used 438 to 444 Hz

1

[10]

Q8.

C

[1]

Q9.

D

[1]

Q10.

B

[1]

Q11.

D

[1]

Q12.

D

[1]

Q13.

D

[1]

Q14.

A

[1]

Q15.

D

[1]

Q16.

(a) path difference for two waves ✓

Allow 'waves travel different distances'

Condone out of phase

gives rise to a phase difference ✓

if phase and path confused only give 1 for first 2 marks

Destructive interference occurs ✓

allow explanation of interference

3

(b) (Path difference =) 0.056 m ✓

Path difference = 2λ or wavelength = 0.028 m ✓e

Use of $f=c/\lambda$ so f = 11(10.7) × 10^9 Hz ✓

Allow 2 max for 5.4 × 10^9 Hz or 2.7 × 10^9 Hz

Allow ecf

3

(c) Intensity decreases with distance ✓

One wave travels further than the other ✓

Amplitudes/intensities of the waves at the minimum points are not equal ✓

Or "do not cancel out"

max 2

(d) The signal decreases/becomes zero ✓

The waves transmitted are polarised ✓

zero when detector at 90° to the transmitting aerial/direction of polarisation of wave ✓

max 3

[11]

Q17.

(a) Substitution of data in $Y = \frac{FL}{A\varepsilon}$

3.1 × 10^{-3} (m) ✓

2 marks can be awarded if 4mm used to show T>500 N provided an explanation is provided, otherwise award zero.

2

(b) (500 = Tcos 65)

T = 1200 N ✓

1

(c) Wind produces a wave / disturbance that travels along the wire ✓

Wave is reflected at each end / waves travel in opposite directions✓

(Incident and reflected) waves interfere / superpose ✓

Only certain frequencies since fixed ends have to be nodes. ✓

4

(d) Mass per m of the wire = 0.14(2) kg ✓

1

(e) Use of $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}} (= 2.47)$ to find fundamental

(or $f = \frac{3}{2l}\sqrt{\frac{T}{\mu}}$)

Third harmonic = 7.4 (Hz) ✓

The second mark is for multiplying the fundamental frequency by 3 – allow ecf

2

(f) Diagram showing three approximately equally spaced loops

Condone single line

1

(g) Copper may be stretched beyond elastic limit / may deform plastically ✓

Permenant deformation / Does not return to original length ✓

Allow 'will remain longer than original' or 'will be permenantly deformed'

2

[13]

Q18.

C

[1]

Q19.

D

[1]

Q20.

A

[1]

Q21.

C

[1]

Q22.

C

[1]

Q23.

B

[1]

Q24.

D

[1]

Q25.

(a) EITHER

calculate value for constant using two calculations ✓

calculate value for constant using three calculations <u>and</u> make a comment that they have same value ✓

need to see table to look for any working

OR

calculate ratio between masses and √T for one pair of values ✓

calculate ratio between masses and √T for two pairs of values <u>and</u> make comment about same value ✓

e.g. 0.5/0.8 = √110/√140

OR

work out constant and use to predict one other frequency or mass ✓

work out constant and use to predict two other frequencies or mass ✓

no comment needed with this alternative

2

(b) $\mu = \rho A = 1150 \times \pi(5.0 \times 10^{-4}/2)^2$

$\mu = 2.258 \times 10^{-4}$ (kg m^{-1}) ✓

use of consistent *m* and *f* Substituted in $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$ including g but condone powers of 10 error ✓

Award second mark if T and f substituted correctly (ignore μ)

0.67 m ✓

If used diameter for radius incorrectly then lose first mark but can get third mark (answer 0.335 m)

3

(c) appreciation of reducing diameter when string is stretched. ✓

lower mass per unit length so (constant of proportionality and hence) frequency is higher (than would be predicted) ✓

2

[7]

Q26.

(a) $i = \sin^{-1}(1/1.6) = 39°$ ✓

1

(b) sin 58 = n/1.6 ✓
n = 1.4 (1.36) ✓

1
1

(c) blue light undergoes TIR ✓
red light refracted ✓
reason i.e. critical angle for red light is more OR critical angle for blue light is less ✓

Allow correct description of refraction. Ignore statements about towards/away from normal

OR
if refractive indices change by same factor ✓
critical angle stays constant ✓
so path followed by red and blue light is the same ✓
OR
don't know if refractive indices change by same factor ✓
so can't predict the effect on critical angle ✓
so can't predict paths of red and blue light ✓

For second two alternatives third mark (i.e. about paths of red and blue) dependent on first mark (i.e. factor of refractive index change)

1
1
1

[6]

Q27.

B

[1]

Q28.

C

[1]

Q29.

C

[1]

Q30.

C

[1]

Q31.

A

[1]

Q32.

D

[1]

Q33.

(a) 180 degrees

accept ° for degrees

OR

π radians ✓

condone ^{c} or 'rad' for radian

reject 'half a cycle'

treat 'π radians in phase' as talk out

1

(b) (idea that) sets of combining waves do not have the same amplitude ✓

condone 'waves do not have same intensity' or 'same energy' or 'some energy is absorbed on reflection' or 'same power' or 'same strength' or idea that non point source or non point receiver would lead to imperfect cancellation

condone the idea that the waves may not be monochromatic

ignore 'some waves travel further' or 'waves do not perfectly cancel out'

reject 'waves may not be 180° out of phase'

1

(c) valid use of a set square or protractor against TR (to ensure perpendicular) $_1$ ✓

measure *x* at two <u>different</u> points [at each end of M] **<u>and</u>** adjust until [make sure] both <u>distances are the same</u> $_2$ ✓

OR

use of set square to align M with the perpendicular line earns

2 ✓

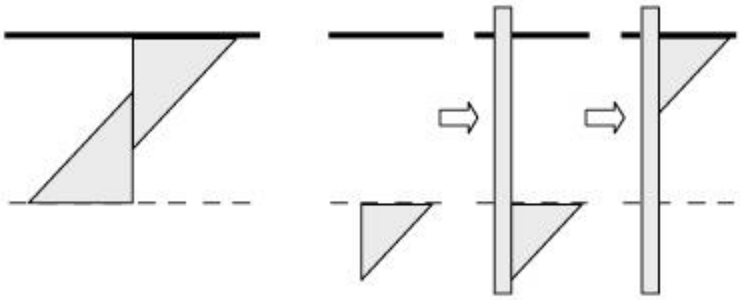
if method used does not allow <u>continuous</u> variation in *x* then award maximum 1 mark

OR

align <u>graph paper</u> with TR 1 ✓

align M with grid lines on graph paper 2 ✓

both marks can be earned for suitable sketch showing a viable procedure involving one or more recognisable set squares or protractors; the sketch may also show a recognisable ruler, eg



allow use of scale on set square to measure the perpendicular distances don't penalise incorrect reference to the set square, eg as 'triangular ruler', as long as the sketch shows a recognisable set square

2

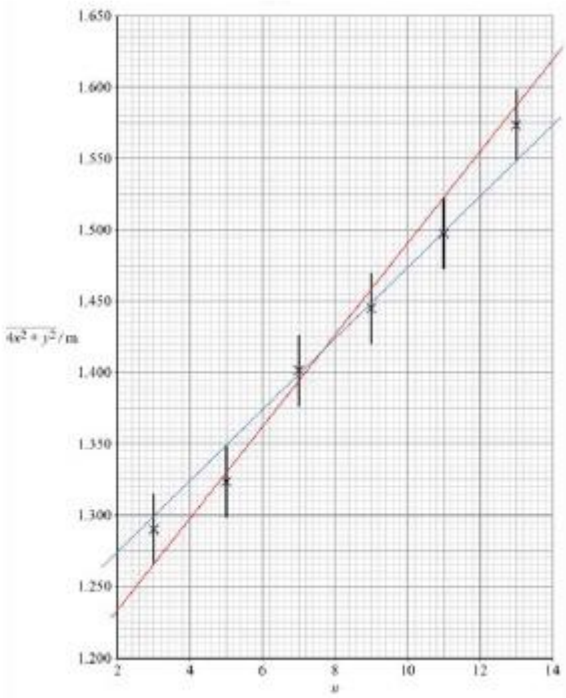
(d) G_{max} line <u>ruled</u> through bottom of *n* = 3 error bar and through top of *n* = 11 error bar 1✓

G_{min} line <u>ruled</u> through top of *n* = 5 error bar and through bottom of *n* = 13 error bar 2 ✓

G_{max} and G_{min} calculated from valid *y* step divided by valid *x* step; <u>both</u> *n* steps ≥ 6 3 ✓

allow 1 mm tolerance when judging intersection of gradient lines with error bars

ignore any unit given with G_{max} or G_{min}; penalise power of ten error in 01.5



12 ✓= 1 MAX if (either) line is thicker than half a grid square or of variable width or not continuous;

expect $G_{max} = 3.2(1) \times 10^{-2}$ and $G_{min} = 2.5\ (2.49) \times 10^{-2}$

3

(e) $\lambda (\text{from } \frac{G_{max} + G_{min}}{2})$

AND

result in range 2.8(0) to 2.9(0) × 10^{-2} (m) 1 ✓ 2 ✓

OR

award one mark for

2.7(0) to 3.0(0) × 10^{-2} (m) 12 ✓

penalise 1 mark for a power of ten error

reject 1 sf 3 × 10^{-2} (m)

if a best fit line is drawn between the G_{max} and G_{min} lines and the gradient of this is calculated award 1 mark for λ in range 2.8(0) to 3.0(0) × 10^{-2}(m)

2

(f) uncertainty in $\lambda = G_{max} - \lambda$

OR

$\lambda - G_{min}$

OR

$\left(\frac{G_{max} - G_{min}}{2}\right)$ 1 ✓

percentage uncertainty = (uncertainty/λ)×100 ₂ ✓

result in range 11(.0) % to 14(.0) % ₃ ✓

₁✓ can be earned by showing a valid uncertainty then dividing by λ

ecf their λ, G_{max} and G_{min} for ₁ ✓ and ₂ ✓

allow λ found from best fit line

accept $\left(\frac{G_{max} - \lambda}{\lambda}\right) \times 100$ or $\left(\frac{G_{max} - G_{min}}{G_{max} + G_{min}}\right) \times 100$ etc for ₁₂ ✓

allow $\left(\frac{\Delta\lambda}{\lambda}\right)$ × *100 where $\Delta\lambda$ is any plausible uncertainty for ₂ ✓*

numerical answer without valid working can only earn ₃ ✓

3

(g) (states) calculate the (vertical) intercept ₁ ✓

OR

outlines a valid calculation method to calculate *y* ₁ ✓

determine the intercept for both lines and calculate average value ₂ ✓

OR

determine the (vertical) intercept of the line of best fit (between G_{max} and G_{min}) ₂ ✓

draw the line of best fit (between G_{max} and G_{min}); perform calculation to find intercept earns ₁₂ ✓

2

(h)

result	reduced	not affected	increased
G_{max}		✓	
G_{min}	✓		
λ	✓		
y			✓

general marker question

allow any distinguishing mark as long as only one per row

for ✓ and X in same row ignore X

for ✓ and ✓ in same row give no mark

ignore any crossed-out response

4

alternative approach: single best fit line drawn on **Figure 4**

(d) *G* calculated from *y* step divided by *x* step;

n step ≥ 6 ₃ ✓

MAX 1

(e) λ in range 2.8(0) to 2.9(0) × 10^{-2} ✓

MAX 1

(f) percentage uncertainty in λ = $\left(\frac{\Delta\lambda}{\lambda}\right)$ × 100

AND

result in range 11(.0) % to 14(.0) % ✓

MAX 1

(g) calculate intercept

OR

outlines a valid calculation method to find *y* ✓

MAX 1

(h) as main scheme

no ecf possible

4

alternative approach: non-crossing lines for G_{max} and G_{min} on **Figure 4**: includes lines that meet but do not cross

(d) G_{max} and G_{min} calculated from *y* step divided by *x* step; both *n* steps ≥ 6 3 ✓

MAX 1

(e) to (h) as main scheme

1

[18]

Q34.

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the '*Mark Scheme Instructions*' document should be used to assist in marking this question.

Level	Criteria	QoWC
L3 5−6 marks	Good discussion of both elements in question with at least 4 points mentioned in each element	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3−4 marks	Good discussion with at least 3 points in one element and 2 points in the other element	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
L1	Discussion of one element	The student presents some

1−2 marks	only incorporating at least two points.	relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
0	Unsupported combination or no relevant analysis	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

Collisions

- *Energy from collision of charged particles transfers to electrons in gas molecules.*
- *Electrons excited to higher energy levels.*
- *The more energy the electrons absorb the higher the energy levels reached.*
- *Electrons are unstable at higher energy levels so will fall back down.*
- *When it falls down it will emit a photon.*

Formation of spectral lines

- *Photon energy = hf/ or photon energy proportional to frequency.*
- *Spectral lines are at specific wavelengths.*
- *Each spectral line corresponds to an electron falling down to a lower energy state.*
- *Energy gap, $\Delta E = hc/\lambda$*
- *Larger energy gap means higher energy photon is emitted so shorter wavelength or vice versa.*

Responses with no mention of photons are likely to receive zero marks.

6

[6]

Q35.

(a) π / 180° out of phase ✓

*Do **not** allow "out of phase".*

1

(b) wavelength = 0.44 m ✓

c (= $f\lambda$) = 145 (m s^{-1}) ✓

2

(c) First harmonic frequency = 110 Hz✓

$T = 4 \times 110^2 \times 0.66^2 \times \left(\frac{3.1\times10^{-8}}{0.91}\right)$ ✓

71.8 N✓

3

(d) Extension of string = $3 \times 2\pi \times 3.0 \times 10^{-3}$ (= 5.65 cm)✓

energy stored = 0.5 × 71.8 × 0.0565 = 2.03 (J)✓

Compares calculated energy quantitatively to another energy and draws correct inference, e.g. wire would be moving at about 80 mph so a risk / 2 J is the equivalent of 1 kg mass dropped through 0.2 m so a risk✓

3

[9]

Q36.

B

[1]

Q37.

D

[1]

Q38.

A

[1]

Q39.

D

[1]

Q40.

B

[1]

Q41.

C

[1]

Q42.

D

[1]

Q43.

(a) Refers to relative direction of oscillations to that of the direction of propagation / transfer of energy ✓

For transverse waves oscillations are at right angles to direction of propagation while in longitudinal waves they are in the same direction ✓

allow direction the wave is travelling in

2

(b) Correct value for μ = (1 ×) $\frac{\pi d^2}{4}$ ρ = 7.5 × 10^{-4} (kg m^{-1}) ✓

$\left(\text{uses } f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}\right)$ ✓

Tension = 126 N (allow 9.7 × 10^5 × their value for μ) ✓

2

(c) Max tension permissible before breaking = 3.0 × 10^9 ×

$\frac{\pi \times (3.5 \times 10^{-4})^2}{4}$ = 288 (289)(290) N ✓

This is greater than required tension so wire is suitable. ✓

OR

stress in operation = $\frac{126 \times 4}{\pi \times (3.5 \times 10^{-4})^2}$ = 1.3 × 10^9 (N m^{-2})✓

which is less than breaking stress ∴ safe to use✓

Allow ecf for incorrect area in 2.2

2

(d) Shows second harmonic λ = $\frac{1}{f}\sqrt{\frac{T}{\mu}}$ ✓

Identify f and T are constant so λ is proportional to $\frac{1}{\sqrt{\mu}}$ ✓

λ increases from A to B ✓

mass per unit length decreases from A to B so A has a greater diameter✓

4

[10]

Q44.

(a) SHM is when

The acceleration is proportional to the displacement ✓

the acceleration is in opposite direction to displacement✓

2

(b) f = 1/T =1/0.05=20 Hz ✓

($(v_{max} = 2\pi f A)$

$A = \frac{0.044}{2\pi \times 20}$ ✓ (=3.5 × 10^{-4} m)

2

(c) Cosine shape drawn, maximum at *t*= 0, amplitude 3.5 × 10^{-4} m ✓

1

(d) (any of the following when the velocity is zero) 0.00s, 0.025s,0.050s or 0.075s ✓

1

(e) when the vibrating surface accelerates <u>down</u> with an acceleration less than the acceleration of free fall the sand stays in contact. ✓

above a particular frequency, the acceleration is greater than *g* ✓

there is no contact force on the sand ***OR***

sand no longer in contact when downwards acceleration of plate is greater than acceleration of sand due to gravity ✓

3

(f) (when the surface acceleration is the same as free fall)

$g = r\,\varpi^2 = A\,(2\,\pi f)^2$ ✓

$f = \sqrt{(g / A4\,\pi^2)} = (9.81/(3.5 \times 10^{-4} \times 4\,\pi^2))^{1/2} = 26.6(7)$ Hz ✓

2

[11]

Q45.

A

[1]

Q46.

D

[1]

Q47.

D

[1]

Q48.

B

[1]

Q49.

(a) w from $\frac{R2 - R1}{6} = 0.408\text{mm} = 4.08 \times 10^{-4}\text{m}$ ✓

3 sf answer ✓

2

(b) double slit formula rearranged to give $d = \frac{\lambda \times D}{w}$ 1✓

$d = \frac{589.3 \times 10^{-9} \times 0.395}{0.408 \times 10^{-3}} = 5.7(1) \times 10^{-4}\text{m}$ 2✓

allow ecf in 2✓ for wrong w but not for POT error

2

(c) use of $PQ = \frac{d \times (D + L)}{L} = 5.46 \times 10^{-3}\text{m}$ 1 ✓

allow ecf for wrong d in 1 ✓

number of fringes seen $= \frac{PQ}{w} = \frac{5.46}{0.41}$ 2 ✓

number of fringes seen = 13 (integer only) 3 ✓

allow 12 or 14 fringes

3

(d) close jaws using ratchet ✓

confirm that instrument reads zero ✓

2

(e) mean = 0.57(0) mm; uncertainty = 0.5 × range ✓

percentage uncertainty $= 100 \times \frac{0.5 \times (0.574 - 0.566)}{0.570} = 0.70(2)\%$ ✓

2

[11]

Q71.

(a) 1.43, 1.29

1

(b) Both plotted points to nearest mm ✓

Best line of fit to points ✓

The line should be a straight line with approximately an equal number of points on either side of the line.

2

(c) (i) Large triangle drawn (at least 8 cm × 8 cm) ✓

Correct values read from graph ✓

Gradient value in range (0.618 to 0.652) × 10^{-6} to 2 or 3 sf ✓

Allow the 2nd mark for incorrect numerical values read

ignoring incorrect power of 10.
Incorrect power of 10 is penalised in gradient value.

3

(ii) Same figure quoted for gradient but with correct unit

1

(d) (i) Straight line (through origin) ✓

(directly) proportional ✓

2

(ii) Evidence of substituting data from the table / graph into *w* = m*D*/s + c (from *y* = m*x* + c) ✓

Computation of correct value for c (i.e. value of *w* when *D/s* = 0) with correct unit.

Should be approximately 0.1×10^{-3} m, depending on the exact lobf drawn.

2

(iii) *w*

1

(e) Any reference to **either** width of slits **OR** single slit diffraction ✓

1

[13]

Q72.

(a) Measurement of at least 30 fringe widths
(check that candidate has not miscounted) e.g. 30 fringe widths = 40 mm or 41 mm.

Correct answer of 1.3 or 1.4 mm quoted to 2sf with unit ✓(one mark)
OR
Correct answer 1.33 – 1.37 mm to 3sf with correct unit ✓✓ (two marks).

If candidate quotes value in range 1.33 – 1.37 mm to 3sf they achieve both the 2nd and 3rd marks (A quote to 3sf is justified in terms of uncertainty if a large number of fringe widths have been measured).

For 2nd & 3rd marks allow ecf from incorrect measurement in 1st mark.

If the printing process in your centre alters the scale of this diagram, measure the values on your printed question papers and mark the scripts accordingly. Send details to the moderator.

If a candidate is visually impaired and using a modified paper that alters the scale of this diagram, measure the values on the printed question paper and mark the script accordingly.

3

(b) 1 mark for intermediate step where candidate doesn't get correct final answer. i.e. calculating % uncertainty of total measurement (i.e. % uncertainty in *w*) ✓

OR for both marks:

Uncertainty in w = ± 0.03 mm ✓✓

(Full 2 marks for correct answer with unit – No unit no mark unless a correct intermediate step has been completed which will have been credited for 1 mark as explained above)

Uncertainty in measurement of multiple fringes is ± 1 mm (precision of ruler used).

E.g. for length 41 mm ± 1 mm % uncertainty = 1/41 x 100 = 2.4 %

Uncertainty in w (single fringe)

= 2.4 x 1.4/100 = ±0.03 mm

Simply quoting 0.03 - ***NO marks***

No penalty for omission of ±

2

(c) (i) (Using w = 1.40 mm)

Wavelength = 5.60 × 10^{-7} m ✓

Allow ecf for value of w from ***(b)***

Consistent unit required for the mark. No sf penalty.

1

(ii) (Intermediate step) % uncertainty = 5.8% ✓

(From %uncty s = 3.3%, w = 2.4%, D = 0.1% % uncertainty in wavelength = 3.3 +2.4+0.1 = 5.8%).

Allow ecf from ***(b)***

1

(iii) (Using wavelength = 5.60 × 10^{-7} m)

Uncertainty in wavelength = ± 3.2 × 10^{-8} (m) ✓ or ± 32 (nm) or ± 3.2 × 10^{-5} (mm)

Allow ecf from ***(c)(i)*** *&* ***(ii)***

No sf penalty

If the value is consistent with the wavelength quoted in ***(c)(i)****,* ***allow the numerical answer without the unit****, otherwise a unit is required.*

1

[8]

Q73.

(a) $\sin\theta_1 = \frac{XZ}{WX}$ and $\sin\theta_2 = \frac{YZ}{WY}$ or $\frac{\sin\theta_1}{\sin\theta_2} = \frac{(XZ)\div(WX)}{(YZ)\div(WY)}$1 ✓

(must see this step either separately or in substitution for $\frac{\sin\theta_1}{\sin\theta_2}$ or 0/2

condone *i* and *r* for θ etc.)

$$n = \frac{(XZ) \div (WX)}{(YZ) \div (WY)} = \frac{XZ}{WX} \times \frac{WY}{YZ} \; _2 \; ✓$$

$$\left(= \frac{(XZ) \times (WY)}{(WX) \times (YZ)} \right)$$

2

(b) idea implied that (XZ) × (WY) = n × (WX) × (YZ) is of form $y = mx$ (+ c);

plot (XZ) × (WY) against (WX) × (YZ) [$\frac{XZ}{WX}$ against $\frac{YZ}{WY}$ etc] or 0/2 $_1$ ✓

calculate gradient to find n (false plot loses both marks) $_2$ ✓

[must mention XZ, WX, YZ and WY for full credit: bland 'plot sin θ_1 against sin θ_2 and calculate gradient to find n'= 1 MAX]

[alternative method is to plot XZ against WX to find G_1 and plot YZ against WY to find G_2 $_1$ ✓; evaluate $\frac{G_1}{G_2}$ to find n $_2$✓]

2

(c) upper limit of (XZ) range [largest value] is suitable $_1$ ✓

largest XZ value ≈ length of block (114)

[largest WX value ≈ diagonal distance (131) across block / used

(approximately) largest value of XZ [WX] available]$_2$✓

lower limit of (XZ or YZ) range [smallest value] is not suitable$_3$✓

smallest YZ [XZ] values have large percentage uncertainty / are unreliable] $_4$✓
(reject idea these values are too close to zero)

smallest WX value ≈ width of block (65)$_5$✓

[statement that range is suitable plus quantitative comment comparing length of block (114) with 98 (the range of XZ data) or covers more than 85% of available range] $_{12}$✓✓

equivalent statement regarding WX: compares available range (131 to 65 = 66) with 63 (the range of WX data) $_{12}$✓✓ = 2 MAX

statement that range is suitable plus simple qualitative comment relating range to the block, e.g. 'a large fraction / part of the available XZ [WX] range is covered' $_{12}$✓
= 1 MAX (bland 'range is large / wide' is not enough)]

MAX 3

[7]

Q74.

(a) Time a minimum of ten oscillations in total including at least one repeat measurement **and then** calculate the mean period of oscillation, *T*, of the bat ✓

(b) Measure the distance, *l*, from the pivot to the sweet spot ✓

(c) Calculate the period, T_c, for a simple pendulum of length *l* using $T_c = 2\pi\sqrt{(l / 9.81)}$ ✓

OR

A clear description of a simple pendulum experiment (length = *l*) to determine T_c ✓

(d) Calculate the uncertainty in *T* from the repeat measurements ✓

(e) The %uncertainty in T_c = 0.5 × the %uncertainty in *l*, if T_c was calculated ✓

OR

Calculate the %uncertainty in T_c from repeat timings, if T_c was found by experiment ✓

(f) Compare *T* with T_c to see whether they agree within the calculated uncertainties. ✓

(g) Allow 1 mark for any experimental detail designed to reduce uncertainties (but not more repeat readings) ✓

Award up to five marks of the 7 that are available.

Annotate the script with a tick and the appropriate code letter (e.g. ✓a) at each point where the candidate's answer matches a marking point.

[5 max]

Q75.

(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 = $3.0 \times 10^8 / 0.118$ ✓

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]

Q76.

(a) use of $V = \frac{4}{3}\pi r^3$ to give $V = \frac{4}{3}\pi(2.5 \times 10^{-2})^3$ ✓ $= 6.5 \times 10^{-5}$ m^3

use of $\rho = \frac{m}{V}$ to give $m = \rho V = 8030 \times 6.5 \times 10^{-5}$ ✓ = 0.53 kg

use of $W = mg$ to give $W = 0.53 \times 9.81 = 5.2$ (N) ✓

the first mark is for making some attempt to calculate the volume; ignore power of ten errors.

the second mark is for the correct substitution or for the calculation of mass

the third mark is for going on to calculate the weight

allow ce for incorrect volume or mass but 2 errors = 0/3

no sf penalty but g = 10 N kg^{-1} loses mark

3

(b) distance of line of action of weight to pivot = (0.120 + 0.025) = 0.145 m ✓

moment = force × distance = 5.2 × 0.145 = 0.75 ✓

unit Nm ✓

the first mark is for identifying that the weight of the ball will act through its centre; use of 0.12 m loses this mark

the second is for correctly calculating the moment; allow ce for wrong distance; condone force = 5 N (which leads to 0.725)

allow suitable unit consistent with calculation, eg N cm

reject 'nm' or 'NM' etc

3

(c) taking moments about the pivot

clockwise moment from spring = anticlockwise moment from ball

$F \times 0.080 = 0.75$ ✓

$F = 9.4$ N ✓

use of $F = kx$ to give $x = \frac{F}{k} = \frac{9.4}{100}$ = 0.094 m ✓

allow ce from (b)

the first mark is for the use of the moment equation

the second mark is for calculating the force on the spring; condone 9.35 and 9.3

the third mark is for calculating the extension; allow calculation in cm

allow ce from the second mark ie use of wrong force; condone 1 sf 0.09 m if (1 sf) 5 N used in (b)

3

(d) the line / pen (initially) moves up; ignore subsequent motion ✓
(the downwards acceleration of the ball is much less than that of the frame and) the ball does not move (very far in the time taken for the frame to move down) ✓

the first mark is for stating the correct direction of the line / pen; allow 'diagonally up', 'up then down' but reject 'up and down'

the second mark is for an explanation which shows some understanding of the relative displacement of the ball and frame; this mark is consequential on the first being correct; condone 'ball has inertia'

2

[11]

Q77.

C

[1]

Q78.

A

[1]

Q79.

D

[1]

Q80.

C

[1]

Q81.

B

[1]

Q82.

B

[1]

Q83.

(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]

Q84.

(a) Answer D ✓ (violet)

1

(b) (light from each slit) <u>superpose</u>
light from adjacent slits have a path difference of <u>one</u> 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]

Q85.

(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)

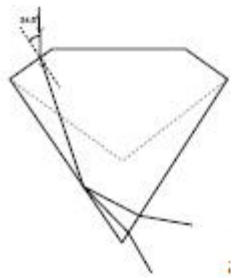
Answer only gains both marks

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 8.4×10^{-7} $\longrightarrow$ 8.7×10^{-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]

Q86.

C

[1]

Q87.

D

[1]

Q88.

B

[1]

Q89.

(a) amplitude (of bob) is small
[**or** (angular) amplitude is less than or = 10°]
[**or** sin $\theta \approx \theta$ with θ explained] ✓

***or** string is inextensible (or of negligible mass)*

or *bob is a point mass*

Ignore references to "air resistance".

1

(b) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

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

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.

The candidate describes the arrangement of the apparatus clearly. They identify correctly the measurements to be made, and indicate how these measurements would be made. They describe a valid method by which a straight line graph may be obtained and show how g would be calculated from their graph. They are also aware of precautions that should be taken during the experiment to ensure that the result is accurate.

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.

The candidate is less clear about the experimental arrangement, gives a reasonable account of the measurements to be made and indicates a valid method by which a straight line graph may be obtained. They are less clear about how the result would be calculated from the graph, and they know the precautions less well.

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.

The candidate gives a superficial account of the experimental arrangement, has some knowledge of the measurements to be made, but has only limited ability to show how a graphical method could be used to calculate the result. Some precautions may be known.

The description expected in a competent answer should include a coherent selection of the following points.

- Diagram or description showing a bob suspended from a fixed point, on which the length l may be labelled correctly.
- Length l of pendulum measured by ruler from fixed point of support to centre of mass of bob.
- Period T measured by stopwatch, by timing a number of oscillations.
- Measurement of T repeated for the same l and a mean value of T calculated.
- Measurements repeated for at least five different values of l.
- Graph of T^2 against l (or any other suitable linear graph) would be plotted.
- Graph is a straight line through origin, gradient is $4\pi 2$/g (or correct expression for g from their graph).

Experimental measures such as the following are likely to be given:

- Small amplitude oscillations.
- Measure l to centre of mass of bob.
- Measure T from a large number of oscillations.
- Repeat timing for each length.
- Begin counting oscillations at nought when $t = 0$.
- Measure complete oscillations.
- Use of fiducial mark at centre of oscillations.
- Pendulum should swing in a vertical plane.
- Avoid very small values of l when repeating the experiment.

Credit may be given for any of these points which are described by reference to an appropriate labelled diagram.

*A **high level** answer must include*

1. a description of the apparatus,

2. a correct statement of the measurements to be made,

3. a correct graph plot,

4. a correct indication of how g would be found from the graph,

5. at least two precautions.

*An **intermediate level** answer must include (at least)*

*1 and 2, **or** 1 and 3, **or** 2 and 3, above and at least one precaution.*

*A **low level** answer must include (at least) any one of 1,2,3,4 above.*

*An inappropriate, irrelevant or physically incorrect answer should be awarded **a mark of zero**.*

*If the experiment described relates to a **compound pendulum**, mark to max 2.*

If a log graph is plotted and explained, it may gain credit.

*If a correct graph is **not** used, then maximum mark awarded is 3.*

max 6

(c) measured value of g will be 4× true value of g ✓

gradient of T^2 against l graph will be ¼ of expected value [**or** reference to g ∞ $1/T^2$ or equivalent] ✓

(T is halved so) T^2 is ¼ of true value ✓

2nd and 3rd marks may be covered by an analysis of the period equation.

3

[10]

Q90.

(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]

Q91.

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* $\sqrt{T}$

[6]

Q92.

(a) (i) Tension minimum at extremities or maximum at middle / bottom

Tension depends on (component of) weight and required centripetal force / velocity

Increases as acrobat moves downwards

Tension at bottom = $mg + mv^2/r$ or Tension = weight + centripetal force

Tension at extremity = $mg/\cos\theta$ (θ is angle between rope and vertical)

Max 3

3

(ii) Use of $T = 2\pi\sqrt{(l/g)}$

3.6 (3.59) (m)

Allow for change of subject for use

2

(b) (i) Frequency of swing = 0.26 Hz

Use of $v = 2\pi fA$

3.0 or 2.97 (m s^{-1})

alternative method

Change in pe = gain in ke

Calculating Δh by geometry from swing = 0.48 m

3.1 or 3.06 (m s^{-1})

3

(ii) Use of $s = ½ at^2$

time to reach safety net = 1.11 s

s = their answer to **(b)(i)** × their time to reach the net = answer

(answer is 3.3 m if all correct)

Allow for change of subject for use

3

(c) (i) Attempt at valid test:

Fractional change in amplitude for same time interval

or use of 'half life' method

or use of exponential formula ($A = A_o e^{-kt}$) to show that k is constant

Correct calculation for one pair of amplitudes

Correct for second pair and conclusion

for half life method must see curve through peaks or other indication to find values between peaks

3

(ii) Period shorter

Centre of mass of trapeze artist was lower than the bar

Effective length of the pendulum is lower

Bar likely to be low mass now have a pendulum with distributed mass / no longer a simple pendulum / centre of mass is half way along suspending rope

Calculates new effective length of the pendulum (2 m)

Max 2

2

[16]

Q93.

(a)

	wavelength	frequency	speed
increases			
stays the same		✓	
decreases	✓		✓

middle column correct ✓
first and third column correct ✓

2

(b) (i) ($n_1\sin\theta_2 = n_2\sin\theta_2$)
(1.09)sin 65.0 = (1.00)sinθ_2 ✓ (giving θ_2 = 81°)

α = 9(°) ✓ (8.93°)

no internal CE

allow 9.0°

2

(ii) 1.09sin65 = 1.70sin*x*
or sin*x* = 0.58
or *x* = 35.5 (°) ✓ (allow 35° or 36°)

[beware an answer close to the correct value can come from n = 1 / sinC]

90 − 35.5 = 54.5(°) ✓ (allow 54° or 55°)
CE for 90° − their value

2

(c) (i) <u>total</u> internal reflection

TIR does not gain the mark

1

(ii) diagram showing core / cladding and light ray TIR at interface at least once with another TIR shown on the diagram or suggested in their explanation ✓

labelling is not required and reflections do not have to be accurate provided they are shown on the correct side of the normal

light fibre consists of core and cladding with lower refractive index / <u>optical</u> density ✓

light (incident) at angle greater than the critical angle (results in TIR) ✓

3

[10]

Q94.

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 superposition [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]

Q95.

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

1

(iii) superposition 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) $D = \frac{ws}{\lambda} = \frac{0.004 \times 5.010^{-5}}{405 \times 10^{-9}}$ ✓ **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]

Q96.

D

[1]

Q97.

(a) 110 Hz

B1
1

(b) (Use finger on the fret so that) a ¼ length of the string is used to sound the note or hold string down on 24th fret

B1
1

(c) Mention or description of beats or description of rising and falling amplitude / louder and quieter

Regular rising and falling of loudness owtte

B1

B1

Beat frequency 10(.0Hz) Allow beat frequency = 430 - 420

2

[4]

Q98.

(a) Prevents (physical) damage to fibre / strengthen the fibre / protect the fibre

Allow named physical damage e.g. scratching

B1

Prevent crosstalk

1

(b) (Relative) refractive index = 1.03
or
Use of sin$c$ = n_2 / n_1

Calculating the refractive indices and rounding before dividing gives 76.8

C1

76.0° or 76.8°

A1
2

[3]

Q1.

This question required students to be familiar with the interference pattern produced by a double slit arrangement. They were also required to explain factors that affect the pattern observed.

(a) A significant proportion of students appreciated that the fringes would exhibit a range of colours. It was, however, less common for them to identify the central fringe as being white. Some students did try to explain the reason for the formation of the fringes when only a description of the pattern seen was required.

(b) This question produced good discrimination. Weaker students were able to identify the fact that red and green fringes would be seen, but then frequently thought that the spacing of green fringes would be greater. Only the best students were then able to explain that the red spacing would be 20% greater than the green spacing. It was also quite rare to see responses that explained that the central fringe would be a mixture of red and green.

(c) This was a ‘levels of response’ question and a high proportion of students did at least get into the middle band because they were able to correctly explain the effect of each change on fringe spacing and give some discussion of the effect these changes have on uncertainties. A disappointing number of students (only 3.5%) reached the top band – this was usually because they did not explain how the change in fringe spacing affected the determination of the wavelength of the light and whether the change reduced the overall uncertainty.

Q2.

(a) There were many good examples of work in this part from higher achieving students. On the other hand, lower achieving students had difficulty in following the question structure with many trying to find 97% of the speed of light in a vacuum rather than 97% of the speed of light in glass **A**. Another common mistake seen was students who simply multiplied $n_a \times 1.03252$. This was another place in the paper where students failed to gain marks due to incorrect use of significant figures. Just over a third of students failed to gain any marks.

(b) Lower achieving students characteristically limited their answers to restating the relationship between λ_R and strain as shown in the graph. They were unable to make the link between the motion of the lift and its effect on strain and λ_R. Where students attempted to explain this connection, they often thought that the tension in the cable increased as the lift accelerated downwards. Only 7.4% of students scored two or three marks.

(c) Many students presented answers that addressed the strength of the cable and its ability to withstand larger stress rather than the ability of the sensor to detect small changes in the acceleration. Two-thirds of students who attempted the question failed to gain any marks here.

Q3.

38.1% of students were able to obtain the correct answer. Both A and C were common wrong answers.

Q4.

Most students selected distractor B as their answer, the logic used being $\frac{2}{3}$ of the length able to vibrate would result in $\frac{2}{3}$ of the frequency. 31.3% of students arrived at the correct answer.

Q5.

Most students selected A as their answer, this being *d* rather than the number of lines per mm as requested. Only 25.5% of students were able to select the correct answer.

Q6.

Just over 40% of students selected the correct answer, with distractor B being the most common incorrect response selected; this answer was obtained by multiplying 0.12 by 6 to find their wavelength rather than realising that a wavelength was separated by 2π rather than π.

Q7.

(a) This was well answered by many students (47.5% gained at least two marks here), but there were also many responses that presented ambiguous or unclear statements. Those students who only referred to reflection of the wave at one of the fixed points had difficulty expressing clearly that there are two waves moving in opposite directions that superpose. The clearest answers referred to the wave produced by plucking travelling to both fixed ends of the string where they are reflected and then superpose, followed by an explanation of the interference ideas that produce nodes and antinodes.

(b) This was answered very well by a great majority (81.1%) of the students.

(c) All the data needed to do this were readily available to substitute in $v = f\lambda$. Determining the correct value for λ (0.33 m and 0.165 m were often seen) led to most incorrect answers.

(d) Most students appeared to appreciate the process that needed to be followed to arrive at an answer and many were able to follow this through to a successful conclusion. In general terms, knowing how to determine circumferences and areas of 2- dimensional objects, and circumference, surface areas and volumes of 3-dimensional objects is fundamental in almost all topics in physics. Those who made little progress did not have this basic understanding. In this question, the circumference of a circle was the basic knowledge needed and how to determine the length of an arc of that circle. The other issue for the first step was to read carefully what information had been provided; in this instance diameter, not radius. In the next step, misreading the scale of the extension axis was a common error. The frequency calculation was then straightforward. Many students did not know what to do about the length, not appreciating that the vibrating length was unchanged when the peg was turned. The extension was added and occasionally subtracted from the length of 0.33 m, but this was condoned as ‘specialist knowledge’.

Q8.

78.0% correct

Q9.

74.9% correct

Q10.

83.2% correct

Q11.

89.2% correct

Q12.

48.8% correct

Q13.

48.0% correct

Q14.

66.6% correct

Q15.

74.3% correct

Q16.

This question placed the idea of double slit interference in the less familiar context of microwave transmission. Students who failed to make the link with interference found it difficult to make much headway in this question. There was evidence of students ignoring the context and writing in terms of sound or visible light.

(a) It was common to see answers referring to a simple line of sight issue related to the three metal plates, despite references to double slit interference in the stem. This may suggest that students fail to read the stem of a question with sufficient care, a problem that may be alleviated if students were in the habit of underlining key words as they read. Students who understood the context often lost marks by confusing path difference and phase difference. Being familiar with the difference, and relationship, between these two is fundamental to an understanding of interference in waves.

(b) This is a fairly demanding multi-step problem that many found difficult. In order to answer this question, students were required to relate the data in the diagram to the path difference of the waves, specifically 2 x the wavelength. They also had to apply the wave equation to the answer they obtained. Those who managed to make some attempt at an answer commonly missed the double wavelength, or made an arithmetical error in the use of speed = frequency x wavelength.

(c) Many students suggested that total destructive interference cannot occur, without relating it to the different amplitudes of the waves due to their different path lengths. This is probably due to the fact that students commonly picture waves of equal amplitude interfering, irrespective of path length. Incorrect answers included suggestions that other sources of microwaves, including the CMBR, were to blame.

(d) Most students were able to make an attempt to link the phenomenon described in this question to the polarisation of the waves. Some students interpreted the line AE as another sequence of slits and suggested that the microwaves were being blocked. Many had difficulties expressing their answer in terms of the orientation of the microwave and aerial, with some stating that the signal would increase as the aerial was aligned with the maxima.

Q17.

This question applied both the idea of standing waves and the behaviour of materials to the context of a radio aerial. Despite this combination of topics, several parts of the question proved to be very accessible.

(a) It is clear from the large proportion of students who obtained both marks for this question that the application of the Young modulus is well understood. This question was made even more accessible by providing the area, and by giving all the data in units that did not require conversion.

(b) This one mark calculation was poorly answered, with few students being able to obtain the correct value for the tension. It may be that many students missed the relevant data or could not picture which forces were needed. It would doubtless have helped some students had they drawn the forces on the diagram provided.

(c) It is clear that many students learn about the formation of standing waves in general terms and answers focusing on this were incomplete in several respects. In particular, many students missed out the initial formation of the wave, and many failed to adequately explain the reason for production of specific frequencies. Consequently it was common to see answers obtaining only 2 of the 4 marks.

(d) This calculation proved to be very accessible with a large majority of students obtaining the single mark for it.

(e) However, this calculation proved to be less accessible despite an error for the mass per unit length in part (d) being carried forward. Credit was also given for students making it clear that the fundamental frequency had to be multiplied by 3.

(f) The drawing of three ‘loops’ was generally awarded the mark, unless the length of each loop was too unequal to be acceptable.

(g) Whilst it was common to see answers that made some attempt to describe what happens to the wire if it is stretched too much, poor use of the correct terminology, such as failure to mention an elastic limit or equivalent, tended to limit the mark awarded to many answers.

Q18.

Just over 60% of students identified the electromagnetic radiations in order of decreasing wavelength. The most common incorrect answer was distractor A. Students need to be encouraged to read questions carefully and take note of the inequality signs.

Q19.

Distractor C was selected by almost 35% of students. This response indicated a limited understanding of what is meant by a transverse wave or an assumption that an option, which suggests some type of restriction, has been phrased correctly.

Q20.

Only 35% of students answered this question correctly. The most popular incorrect response was distractor C. Knowledge of the phase relationship between points on a stationary wave is expected. Students should be familiar with characteristics of a stationary wave, not simply limited to no net energy transfer and node / antinode positions.

Q21.

Approximately 35% of students selected distractor A as their answer. Students need to be able to recall that wavelength decreases as velocity decreases as light enters a more optically dense medium.

Q22.

This question was set up to test the students' ability to spot that 35° was not the angle of incidence. This indeed proved to catch a lot of students out, with almost 60% of students selecting distractor A. Errors of this type can be minimised by completing the ray diagram and marking the angle to be determined. Doing this gives the students a chance to take stock of the information, making it less likely to misinterpret the data.

Q23.

The majority of students selected the correct answer. Of those who got it wrong, most of them chose distractor C (20% of all responses); these students could not determine how increasing the distance between the slits and the screen affected the spacing of the maxima. A quick sketch of the grating and typical pattern of the maxima would certainly have aided students in making this connection.

Q24.

Less than 20% of students selected the correct answer. Nearly 40% of students selected distractor C and in doing so failed to notice that the angle required was double 23.6°. Students need to pay close attention to the wording in questions as this type of extra detail is typical of multiple choice questions.

Q25.

Question (a) required students to analyse the data given and demonstrate that it was consistent with the given relationship. Just over half of students were able to do this. Common errors were confusion between linear and proportional relationships, and attempts to derive the expression algebraically without using the data.

The calculation in question (b) proved to be one of the more challenging in the paper. The main reason for this was a lack of appreciation of how to find the mass per unit length of the nylon string; this did limit them although they were able to pick up a mark for a correct substitution of tension and frequency in the appropriate formula.

The explanation, required in (c), of why the result might be different if much larger masses were used, was not well answered. The majority did not appreciate that the nylon would get thinner and this would reduce the mass per unit length. Common responses tried to invoke Hooke's law notwithstanding the fact that nylon does not obey this law.

Q26.

The first two parts of this question on refraction proved to be straightforward, with three-quarters of students scoring full marks. The third part, which involved a certain amount of judgement, was less well done. Many students mixed up the blue and red light, stating that the red light would undergo total internal reflection. Some did pick up on the fact that if the refractive indices of both media increased by the same proportion then there would be no change and all three rays would follow the same path. This approach received full credit.

Q33.

This question addressed the ideas behind assessed practical activity 2. Some of the graphical techniques described in the Practical Handbook were also tested. The numerical work in questions (d) to (f) (and in the multiple-choice part (h)) was usually where students scored the bulk of their marks.

Questions (a) and (b) exposed poor understanding of superposition. Although there were plenty of correct answers to (a) and very few students forgot to supply any unit (we expected π radians or 180°), there were a variety of unsuccessful alternatives and some students clearly confused path difference with phase difference. Most students seemed to think that the resultant amplitude depended only on the phase difference between the sets of superposing waves, and very few considered the possibility that the waves travelling via M would arrive at R with less amplitude than those travelling directly from T. A small but significant number of students blamed microwave background radiation for the non-zero minimum reading on the ammeter.

Examiners found that many students ‘improvised’ their answer to question (c). Developing strategies for encouraging students to think about the practicalities of arranging apparatus, and challenging their reasoning, would pay dividends in future. A simple approach such as measuring, at different points, the distance between M and the line between T and R, and checking these were equal could earn 1 mark; the sensible use of a set-square earned the second mark. Frequent suggestions that non-standard science equipment, such as tri-squares could be used, perhaps indicated that some students had only had limited opportunities to perform practical work. A common misconception was that the ends of rulers can be assumed to be square; several students stated that aligning the end of the ruler, or the graduations along the edge, with the line between T and R, ensured that perpendicular distances would be measured. One really positive aspect of the work seen was the good standard of sketches students used to illustrate their answers; some of these, by themselves, were sufficient to earn both marks.

Answers to question (d) were much stronger, with many students demonstrating an understanding of how the error bars could be used to establish the maximum and minimum gradients. Most knew they should use large steps for the gradient calculations, and recognised in question (e) that their mean gradient gave λ.

In question (f), many students appeared to have taken a guess, often based on the size of the error bars, about the uncertainty they should use. The better students used a variety of valid ways, based around ‘best gradient − worst gradient’, of judging the uncertainty. However, full credit proved elusive because the final answer was often compromised by the truncation, in (d), of the values for maximum and minimum gradients.

Many students seemed to have rushed question (g), thinking they were being asked to explain that *y* was the vertical intercept. However, examiners wanted to know how Figure 4, which did not allow a direct measurement, should be used. Suggesting a calculation method could earn a mark, but this was denied when any suggested algebra was wrong; otherwise, some consideration of an average of the maximum and minimum intercepts also gained credit.

Question (h) provided some respite for students who found the descriptive writing challenging.

Q71.

(a) Correctly answered by almost all candidates.

(b) As usual in this question a small proportion of candidates failed to accurately plot both points and an even greater proportion were unable to draw an acceptable line of best fit.

(c) (i) A large proportion of candidates ignored the powers of 10 on the graph axes.

(ii) A good discriminator, with only the most able candidates giving the correct unit.

(d) (i) A straightforward question with all but the weakest responses scoring both marks.

(ii) A good discriminator, with only the most able candidates correctly using '$y = mx + c$' and substituting data from the table or graph to find intercept c.

(iii) Only the most able candidates correctly identified the systematic error to be in w.

(e) Not well understood by many candidates, with only a small proportion referring to single slit diffraction.

Q72.

As anticipated this question provided good discrimination.

(a) Most students attempted to count and measure a large number of fringe widths. A common error was to measure from the first to the fiftieth fringe, but count this as 50 fringe widths rather than 49.

(b) Weaker responses were unsure how to calculate the uncertainty in a single fringe width from the uncertainty in the total measurement.

(c) (i),(ii) & (iii) Many candidates failed to score on any part of this question, despite part **(i)** being a straightforward substitution into the formula quoted. The uncertainty calculations in **(ii)** & **(iii)** were only successfully completed by the most able candidates.

Q73.

In part **(a)** most showed that $\sin\theta_1 = \frac{XZ}{WX}$ and $\sin\theta_2 = \frac{YZ}{WY}$ to earn a mark but some missed a key step in the manipulation that followed in arriving at $\frac{(XZ) \times (WY)}{(WX) \times (YZ)}$

In part **(b)** the majority saw we expected a simple application of the $y = mx + c$ idea and gained both marks.

Part **(c)** proved challenging for the candidates, most of whom made only limited progress by making an observation without any supporting explanation, e.g. by comparing the largest XZ value with the length of the block or by computing the diagonal distance across the face of the block and comparing this with the largest WX value. We wanted the candidates to discuss whether the limiting values of the data in the table showed if a suitable range had been used. Clearly the upper limit was ideal but the lower limit raised the question of whether such values could be measured without attracting a significant percentage uncertainty.

Better answers seen compared the range of the XZ data with the length of the block but we saw very few responses that earned full credit.

Several candidates used each row to calculate six values of refractive index and decided on the suitability of the data looking at the spread of results. Others judged the quality of the data based on the intervals between the values in each column. These approaches earned no credit.

Few could score more than 5 out of 7. A/B candidates scored between 3 and 5 while E/U candidates usually scored 1 or 2.

Q74.

As usual in this type of question it discriminated well, with only the more able students scoring four or five marks. It was clear that many students had not fully understood what they were trying to measure or calculate, and consequently were only able to pick up the occasional mark.

Experimental techniques involved were very straightforward, and very specific details were required. E.g. timing multiple oscillation and at least one repeat for one mark.

Q75.

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.

Q76.

This question required students to apply their knowledge and understanding of physics to a simple seismometer. Although the diagram contained a lot of information, and there was a relatively long stem to the question, there was no evidence to suggest that students found the context particularly demanding.

(a) This was a multi-step calculation that most students found fairly straight forward. The common errors seen were wrong substitution of diameter (or use of a wrong formula for volume) and power of ten errors arising from calculation of volume in cm^3. Students who have difficulty converting between cm^3 and m^3 would be better advised to work in m from the outset. Generally "show that" questions are used to provide unsuccessful students the data they would need to complete further parts of the question. Students should be reminded to provide at least 1 sf more than the "show that" value, and they should be discouraged from trying to calculate an answer backwards. Another error is forcing their answer to be near the "show that" value: many students were denied consequential error marks when, having made an error, they attempted to manipulate their answer to obtain a numerical value near 5. For example, students who used 5 cm for the radius could obtain a value of 4.2 kg for the mass. Many would then miss out the step (multiplying by g) to determine the weight, as they had already reached a value near to 5 perhaps. Many modern calculators generate results as fractions or surds. No credit is given for final answers given in such a form or with recurring notation but there is no penalty for this with intermediate results. However students should be discouraged from doing this because it makes the work less transparent and inhibits error-checking. The rounding down of intermediate results compromises the chance of full credit; any rounding down, e.g. to the same significant figures as that of the least accurate data should not be done until the final stage is complete.

(b) There were two potential errors in answers that often led students to lose at least one mark. Many students did not take the centre of mass of the ball into account, and therefore did not include the radius when calculating the distance to the pivot. Some students worked through their answers in cm, but wrote the moment unit as Nm.

(c) Many good answers were seen to this multi-step calculation and this was a good discriminator. Some students were unable to suggest much beyond picking $F = 5\ N$ and rearranging $F = k\Delta l$ (given on the data sheet) to produce $\Delta l = 0.05$ m. Spotting that this was a 3 mark question may have led some of them to realise that a more complicated calculation was needed. Others tried to calculate the extension by dividing turning moment by stiffness or by multiplying distance from the pivot by stiffness. A number of students did not attempt this question.

(d) This was a fairly demanding question that aimed to get students to think about the reason for having the heavy ball in the seismometer. Successful answers were able suggest that, in the very short length of time involved, the ball would barely move and therefore the arm holding the pen would pivot about the ball, causing the upwards line. Many incorrect answers were seen: some students were convinced there was a third law or conservation of momentum explanation while others said the spring, having become compressed, then pulled the arm up. It seemed that many felt that the downwards accelerating seismometer took the ball with it and so the line went downwards. No credit was earned for saying the pen or the arm did not move, likewise any suggestion of an 'up and down' motion of the pen (although 'up then down' could earn a mark).

Q77.

This question required students to work out the wavelength of the sound wave, and then calculate the phase difference of two parts a certain distance apart. 45% of students correctly identified the correct answer. Approximately 35% thought A was correct, using π, rather than 2π, as the phase difference for two points a whole wavelength apart, perhaps.

Q78.

This proved to be one of the more demanding questions on the paper, with 39% of students being correct, despite the equation being in the data booklet. The most popular distractor was C, chosen by students having difficulty dividing √2 by 2 perhaps. Unsurprisingly B was also popular, the answer obtained if the two changes cancelled out.

Q79.

57% of students correctly identified D as the appropriate answer. The other students were split almost evenly between the distractors, with A being slightly more popular.

Q80.

It was pleasing to note that 74% of students were sufficiently familiar with white light single slit diffraction to give the correct answer here. Approximately 10% of students gave the answer D, suggesting that they were unaware that any effect would occur.

Q81.

This question proved to be quite demanding, with 40% of the students giving the correct answer. Nearly 30% chose D, confusing angles of reflection and refraction perhaps.

Q82.

This straightforward calculation proved to be very accessible with 85% of the answers correct. It is worth pointing out that only about 2% of students chose D, an answer greater than the speed of light in a vacuum.

Q83.

(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.

Q84.

(a) Although the correct answer (violet) was the most common response all the alternatives were given in significant numbers.

(b) On the whole the answers were set out well. A majority of students discussed constructive interference as well as superposition. Inevitably some wrote 'superposition as 'superimposition'. It was also common to see an 'in-phase' statement but only a minority made all three statements. The idea that the path difference between light coming from adjacent slits was one wavelength was not seen often. The path difference was normally given as n times the wavelength. Students also failed to gain marks by describing the whole pattern of light and dark fringes in which it was not clear what part of the pattern a reference to 'constructive interference' belonged.

(c) (i) This calculation was performed well and the usual tail of students who have difficulty in using a calculator was not seen.

(ii) Most students performed this calculation as shown in the mark scheme. Other students who chose to show the diffraction angle of each order including the fourth order, which is not possible, could score full marks. However many of those students did not show enough work to justify their answer. For example, showing only that the fourth order is not possible does not exclude the answer 'second order'.

Q85.

(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.

Q86.

This question tested students’ interpretation of a velocity-time graph for simple harmonic motion. The question asked for the *incorrect* statement to be selected; this generally causes problems for students who read the questions too superficially. However on this occasion 70% of them gave the correct answer. Maybe the 13% of students who selected distractor D, which is clearly a *correct* statement, had forgotten the wording of the question by the time they reached it.

Q87.

This was another re-used question from an earlier test paper. Its facility this time was 67%, up from 59% last time. 14% of the students thought the resultant force would be a minimum at both the top and the bottom of the oscillation (distractor A).

Q88.

This question, on coupled pendulums, had appeared in the 2009 examination. The results on that occasion were surprisingly disappointing, with fewer than 40% of correct responses. In 2016 more of the students selected the correct resonant pendulum (B), but it was only 53% of them. One third of the students chose pendulum A, the longest one.

Q89.

In (a), quite apart from the obvious "small angle" limitation that applies when a simple pendulum is moving in simple harmonic motion, other answers which were accepted were an inextensible string, a string of negligible mass, or the bob having to behave as a point mass.

The experiment to determine the value of the Earth's gravitational field strength by the use of a simple pendulum is well known, so in part (b) most students successfully described the experimental procedures they had carried out and the measures they had taken to produce an accurate result. When describing the experiment, some answers fell short of what was expected when describing the arrangement of the apparatus and many were quite obscure about the measurement of the length of the pendulum. Students had to give an acceptable graphical procedure in order to reach a high level assessment (5 or 6 marks). Any graph that would give a straight line through the origin was acceptable, but students had to show how they would arrive at the value of *g* from their graph. A few answers suggested that the time for *one oscillation only* would be found, hardly practical for an accurate result from this system. There were also some references to a pendulum that was clearly a *compound pendulum* rather than a simple pendulum; the maximum mark that could be given for these was 2.

Part (c) produced many good answers, in which it was clearly explained why the value of *g* obtained by the mistaken student would be four times the true value. It had been anticipated that the usual approach to the explanation would be by reference to the effect of the mistake on the gradient of the graph obtained in the experiment. In fact, more students preferred an approach relying on $g \propto 1/T^2$, which was equally acceptable. They usually recognised that T would be halved and that T^2 would be a quarter of its true value.

Q90.

(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.

Q91.

Responses to this part were very disappointing and very few seemed to have conducted or seen such an experiment performed. Diagrams of apparatus were very poor and many were quite inappropriate for the experiment. Descriptions included no way of fixing the tension in the string and those who had some idea usually quoted use of increments of 100 g masses. Many seemed to think the experiment had to be conducted in such a way as to use calculations to determine the tension. A few made sensible suggestions such as the use of a set of tuning forks, microphone and oscilloscope or a stroboscope but most responses gave no method at all or an impractical method such as timing a number of oscillations using a stopwatch. When a vibrating mechanism was suggested this was often stated to be driven by dc and / or moved to produce tension with the other end fixed. Relatively few gave a sensible way of using the data.

Q92.

(a) (i) Although only 3 of 5 possible statements were required for full marks, many students found this question difficult. Some believed that the tension at the lowest point was mg, totally ignoring centripetal force. Some stated the weight acts at different angles as the trapeze swings, and some though the centripetal force was constant.

(ii) A few attempts to change the subject of the formula were incorrect, but most students were awarded full marks.

(b) (i) Correct answers were reached by those who used the formula $V = 2\pi fA$, but those that chose the energy method invariably used the wrong value of height (0.48m)

(ii) Most students had difficulty here. Some used the incorrect formula $x = A\cos(2\pi ft)$ and others used Pythagoras in an attempt to find the horizontal distance. Of those who chose an equation of motion, some chose inappropriately and were unable to find, the time (1.11 s).

(c) (i) Many students had little idea of how to tackle this question. The most straight forward correct method was to calculate the ratio of successive amplitudes. Those who attempted to find the half-life were expected to sketch the curve on the graph on (figure 2). The most difficult and rarely correctly executed method was to calculate k in = $A_o e^{-kt}$.

(ii) Most students completely missed the point that the simple pendulum is effectively shortened and so the period is reduced. Those using $T = 2\pi \sqrt{m/k}$ and others claiming that air resistance affected T gained no marks. There were lots of non-committal answers failing to state whether T increased or decreased.

Q93.

This question showed up a lack of geometrical knowledge in some students but strong students sailed through. In (b)(i) most students knew Snell's Law as applied to the boundary between two media. Unfortunately, many did not choose to use the correct refractive indices or use the correct angles. The use of 25° in place of the correct 65° featured prominently. The students who had problems with (b)(i) also had problems in (b)(ii). There was the potential for an error carried forward mark for students who presented a value for the angle *x* as in the mark scheme. However, only a minority of these students correctly found the answer to this section by subtracting *x* from 90°.

Although (c)(ii) asks for a diagram, weaker students sometimes chose not to give one or when they did it showed an optical fibre without cladding. In this way they failed to gain the first mark. The other two marks were only obtained by stronger students. More students chose to give an answer that involved the critical angle than an answer involving the refractive indices. Only the strongest students scored all three marks.

Q94.

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.

Q95.

This was a discriminating question throughout all its parts. Very few students answered this question without error in some part. A majority of students simply reproduced the single slit diffraction pattern with a double width centre fringe for (a). These students were not awarded any marks. Most of the answers that did score some marks rarely produced graphs that were very smooth with peaks falling in height following the expected profile.

All sorts of sharp edges and cusps were drawn and the spacing between fringes were rarely uniform.

In (b)(i) the answer, ‘in phase’, features just as often as, ‘constant phase difference’. Weaker students did not refer to phase but concentrated on the frequency or wavelength being the same thereby missing the main point. In (b)(ii) a majority of students did not understand the function of the single slit and simply gave an answer that couples together some themes suggested earlier in the question. So a common response was, ‘used to make the light coherent as it has the same wavelength’. Students gave a much better response to (b)(iii) where a majority discussed the waves being in phase and constructive interference, although some had a few issues about how to express a phase difference. Many referred to a phase as being a proportion of a wavelength. As in a previous question the words superposition was confused with superimposition. In the explanation of how the bright fringes are formed, very few explained how the pattern is positioned where the two diffraction patterns of the double slits overlap. The weaker students instead discussed how to set up the apparatus in great detail which must have taken some time in using up half the answer space. In essence they only described what was shown.

In (c)(i) most students knew which equation to use but only half managed to calculate the correct answer. Some used a factor of 2 with the width spacing. Others did not rearrange the equation properly or made errors in powers of 10. Many students seem to make a guess in answering (c)(ii). Just as many students correctly said the pattern or fringes get wider as said they get narrower. Additionally many students explained the change by referring to the wavelength change. However in many cases the explanation contradicted what they gave as their answer.

Students did not do well in the final part of this question, (c)(iii). A majority tried to change the apparatus rather than change how it was used. These students did score some marks by getting a mark for increasing the double slit to screen distance along with a majority of the others. Fewer students scored the other marks available but referring to measuring across more fringes was the next regularly gained mark. Some students failed to gain marks unnecessarily by the way they phrased their answers, an example being, ‘Change D to make it easier to measure’.

Q96.

This question on simple harmonic motion, readily gave the correct answer to students who could apply $a = -(2\pi f)^2 x$: clearly therefore a_{max} is proportional to x_{max}, the amplitude. 78% of the responses were correct. Incorrect answers were fairly evenly distributed amongst the other three distracters.

Q97.

(a) A large majority of the candidates completed this successfully.

(b) Many candidate having completed part (a) successfully then failed to appreciate that to produce four times the frequency, a quarter of the length is needed. Some suggested using a shorter length without making reference to the how much shorter it needed to be. Others incorrectly suggested changing tension / thickness or the mass per unit length.

(c) Those who appreciated that beats would be heard often failed to go on to give value of the beat frequency.

Q98.

(a) Most candidates gave a sensible response usually referring to improved strength or protection for the optical fibre. Those who discussed light leaving or entering the fibre rarely referred to the consequences for the signal in the fibre or the effect on other signals in nearby fibres.

(b) Most completed this straightforward calculation successfully. Some candidates gave answers that suggested that their calculators were set in radian-mode. Others rounded off too early in the calculation when finding the refractive index of the core and cladding first which is inadvisable in any calculation as it can produce answers outside an accepted range.