OCR A Level Physics A (H556) Physics B (H557)
PAG 5: Investigating waves
Practice Exam Questions and Mark Scheme

1. A student makes measurements and calculates the speed of sound as 328.16 m s^{-1}.
The experimental uncertainty is ± 3%.

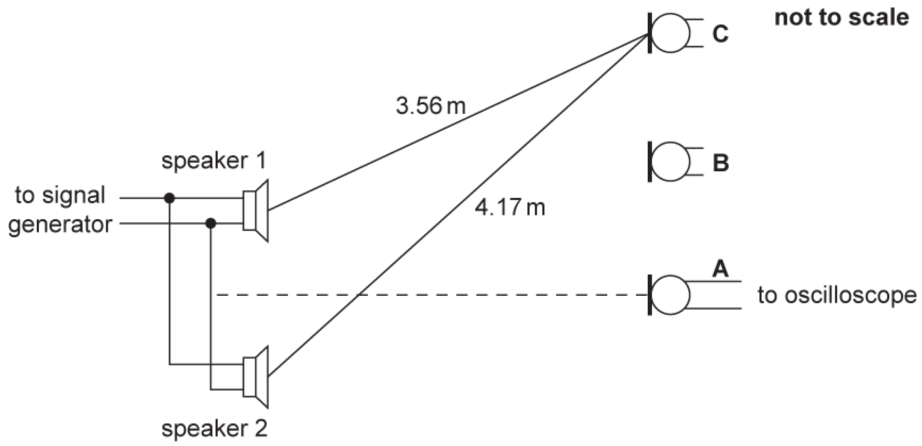
Which of the following expresses the result to an appropriate number of significant figures?

A 300 m s^{-1}
B 330 m s^{-1}
C 328 m s^{-1}
D 328.2 m s^{-1}

Your answer

[1]

2. A student is attempting to measure the wavelength of sound waves using interference.
She sets up the apparatus shown. There are **two** identical loudspeakers connected in parallel to a signal generator and a microphone connected to an oscilloscope.



The student finds that a maximum signal is measured with the microphone at position **A**.
She moves the microphone to position **B** where the signal is a minimum.

Suggest one reason why it would be difficult:

i. to locate position **B** precisely

[1]

ii. to measure the distance between position **A** and the speakers precisely.

[1]

3. An estimation of the speed of electromagnetic waves can be made using the hot spots inside a microwave oven. Microwaves are emitted in all directions inside the metal walls of the oven at a frequency of 2.5×10^9 Hz causing stationary waves to be set up. Fig. 7.1 shows a typical pattern of the centres of the hot spots marked **X** in the central area of the floor of the oven.

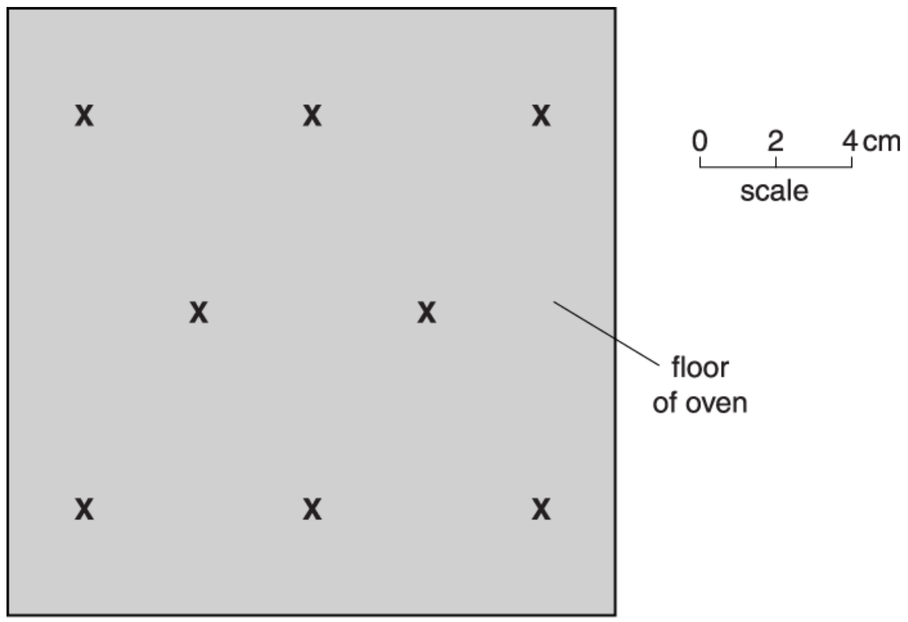


Fig. 7.1

These positions can be located to within a few millimetres by melting small areas in a bar of chocolate placed on the floor of the oven for a few seconds.

Fig. 7.1 is drawn to **half scale**. By using measurements taken from the diagram make an estimate of the speed c of the microwaves. Make your reasoning clear.

c = ... m s^{-1} **[4]**

4.

A loudspeaker mounted on a bench is emitting sound of frequency 1.7 kHz to a microphone. Fig. 5.1 shows an illustration of the bulk movement of the air at one instant of time.

Fig. 4.1

Students are given the equipment in Fig. 4.1 together with a metre rule. They are also given a second loudspeaker connected to the same signal generator at 1.7 kHz. They are asked to design an experiment where they would need to take just **one** measurement and be able to determine the value of the speed of sound.

They set up the experiment in two different ways as shown in Fig. 4.2(a) and (b).

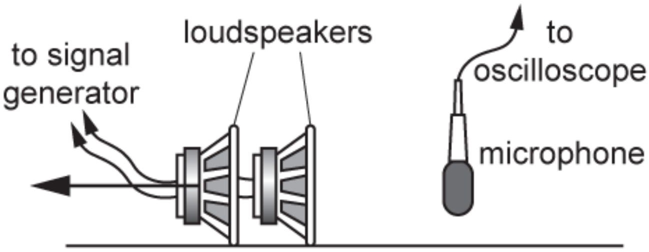


Fig. 4.2(a)

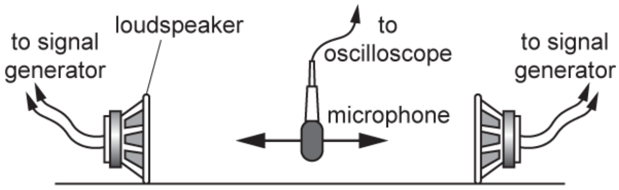


Fig. 4.2(b)

In method **(a)** the microphone is fixed and one loudspeaker is moved to the left as shown in Fig. 4.2(a).
In method **(b)** the microphone is moved to the left or to the right with the loudspeakers fixed a certain distance apart as shown in Fig. 4.2(b).

Describe and explain how both methods can be used to accurately determine the speed of sound. In your description, discuss how the uncertainty in the value for the speed of sound can be minimised in one of the methods, without using any other apparatus.

[6]

5. A student is investigating stationary waves in a hollow tube. The tube is open at one end and closed at the other end. The student connects a signal generator to a loudspeaker which is placed just above the tube as shown in Fig. 5.

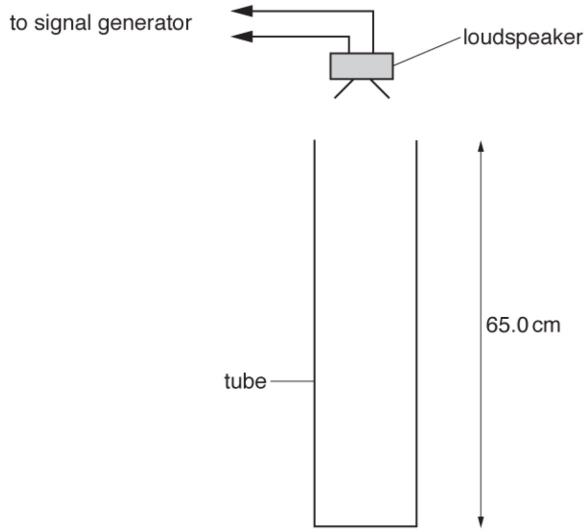


Fig. 5

The length of the tube is 65.0 cm.

As the frequency of the signal generator is slowly increased from 0 Hz the student observes sound that varies in loudness. The loudest sound occurs at frequencies 130 Hz, 390 Hz and 650 Hz.

The experiment is then repeated with a hollow tube of the **same** length but open at both ends. The loudest sound now occurs at frequencies 260 Hz, 520 Hz and 780 Hz.

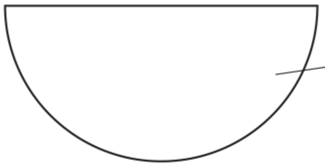
Using your knowledge and understanding of stationary waves explain these observations. Include in your answer how you could determine an experimental value for the speed of sound in air.

[6]

6.

A student is given a semi-circular glass block.

Describe with the aid of a ray diagram how an experiment can be conducted to accurately determine the critical angle for light within the glass block and hence the refractive index of the glass.



[3]

7. *A student wishes to investigate how the fringe spacing *x* of an interference pattern produced by sound waves varies with the frequency *f* of the sound waves.

It is suggested that $\frac{v}{f} = \frac{ax}{D}$ where

a is the separation of the sources of sound
D is the distance from the sources of sound to the interference maxima and minima
v is the speed of sound in air.

Describe with the aid of a suitable diagram how an experiment can be safely conducted in the laboratory, and how the data can be analysed to determine *v*.

[6]

8. *The speed v of surface water waves in shallow water of depth d is given by the equation $v = \sqrt{gd}$, where g is the acceleration of free fall.

The speed v is about 1 m s^{-1} for a depth of about 10 cm.

You are provided with a rectangular plastic tray, supply of water and other equipment available in the laboratory.

Describe how an experiment can be conducted in the laboratory to test the validity of the equation above and how the data can be analysed to determine a value for g.

[6]

9(a). In an experiment to measure the wavelength of yellow light from a sodium lamp, a beam of light from a lamp passes through a pair of narrow slits **S_1** and **S_2**.This produces a pattern of regularly spaced bright and dark lines, called fringes, on a screen as shown in **Fig. 9.1**.

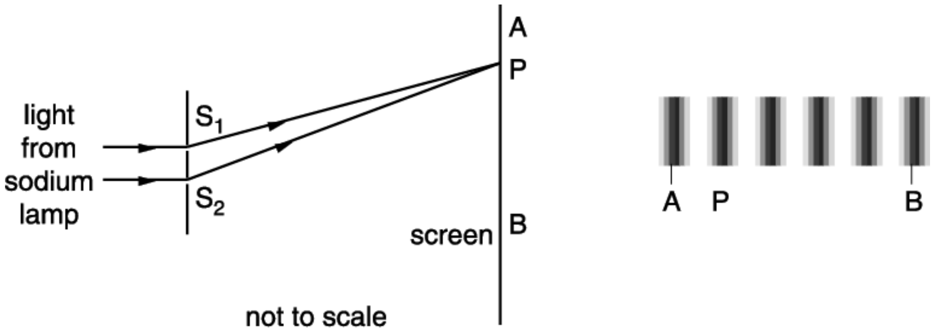


Fig. 9.1

*Fig. 9.2 shows a microscope slide, blackened with graphite paint, with the two slits **S_1** and **S_2** scratched through the paint, very close together, to form the double slit.

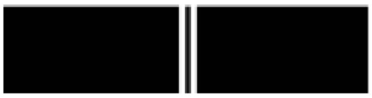


Fig. 9.2

Describe how you could reduce the uncertainty in calculating the value of the wavelength of the light used when carrying out the experiment in Fig. 9.1**.**

In your answer, include how to achieve the conditions necessary to produce a visible interference pattern on the screen and how you would make the measurements to calculate the wavelength, identifying the measurement which will give the greatest uncertainty.

---

[6]

(b). To reduce the uncertainty in the calculated value of the wavelength, one student suggests making a different slide with a greater slit separation.

Discuss whether you think this change will reduce the uncertainty.

--- **[3]**

10(a). A group of students are conducting an experiment to determine the wavelength of monochromatic light from a laser.
Fig. 10.1 shows the laser beam incident normally at a diffraction grating.

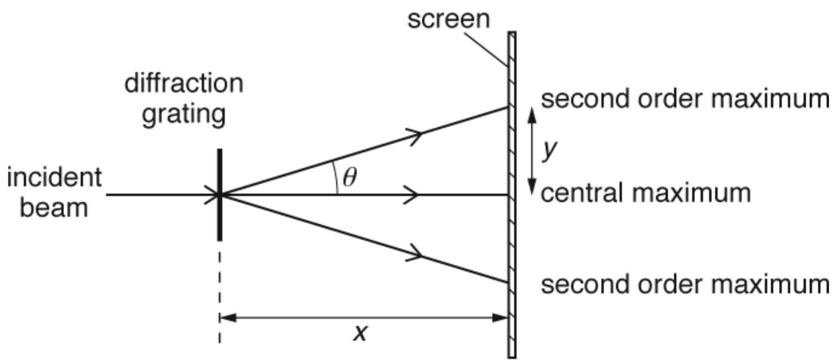


Fig. 10.1

The students use a diffraction grating with 600 lines mm^{-1}. They vary the distance *x* between the grating and the screen from 1.000 m to 2.000 m. They measure the distance y from the *central* maximum to the *second order* maximum.

The students decide to plot a graph of *y* against $\sqrt{x^2 + y^2}$.

Show that the gradient of the graph is equal to sin θ, where θ is the angle between the central maximum and the *second* order maximum.

[1]

(b). Fig. 10.2 shows the graph plotted by the students.

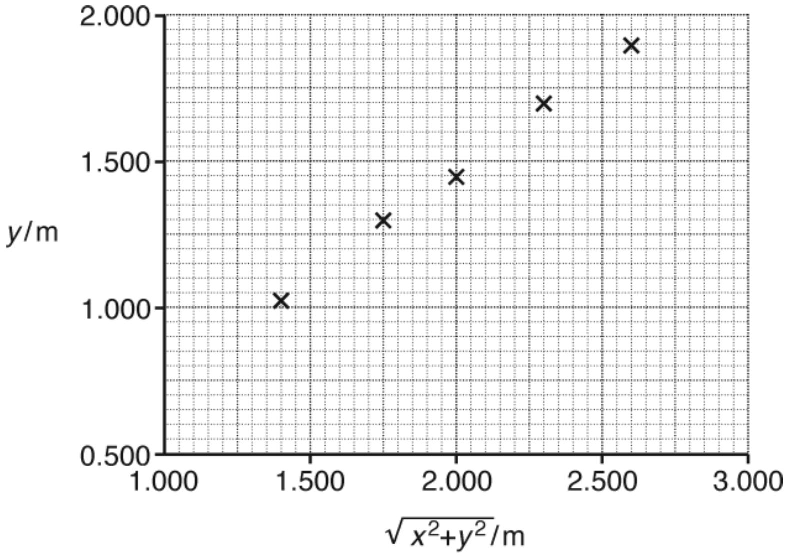


Fig. 10.2

i. Use Fig. 10.2 to determine an accurate value of the wavelength λ of the light from the laser.

λ = -- m **[3]**

ii. Suggest why there are no error bars shown in Fig. 10.2.

-- **[1]**

11(a). Fig. 11.1 shows the pattern of light observed on the screen placed 3 m away from a pair of slits spaced 1 mm apart. The total width of the pattern shown was measured to be 1.3 cm.

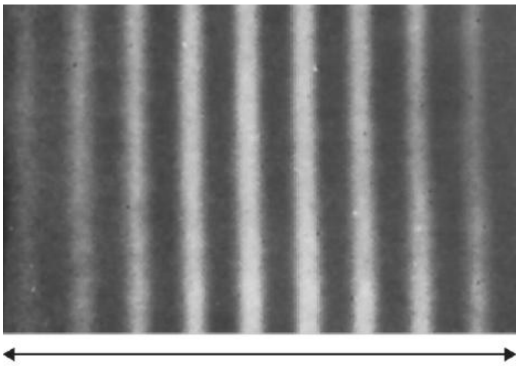


Fig. 11.1

Use data from Fig. 11.1 to estimate the wavelength, λ, of the light used in this experiment.

λ = ……………………………………m **[3]**

(b). * Some changes were suggested to improve the experiment:

Increase the distance between the slits and the screen to increase the fringe spacing.
Increase the slit width to increase the intensity of light reaching the screen.
Reduce the distance between the light source and the slits to increase the intensity of the fringes.
Use coloured filters to enable the wavelengths of specific colours to be measured.

Comment on each of the proposals, pointing out any difficulties that may result from the changes mentioned.

[6]

12. Hydrogen atoms excited in a discharge tube only emit four different discrete wavelengths of visible photons.

*In a semi-darkened room, a single slit is placed in front of the discharge tube. A student holds a diffraction grating which has 300 lines per millimetre.
The student looks through the grating at a 15 cm plastic ruler placed 0.50 m away, as shown in Fig. 12.1.
The paths of the different colours of light from the slit to the student's eye are shown in Fig. 12.2.

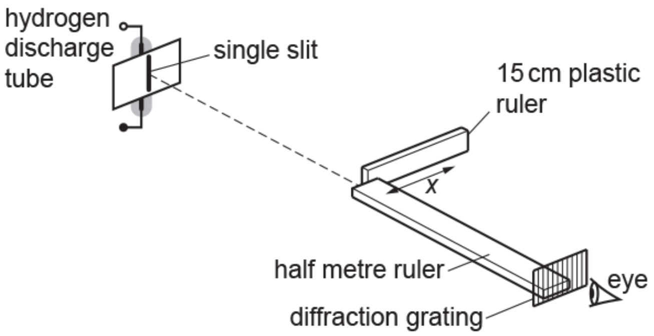


Fig. 12.1 (not to scale)

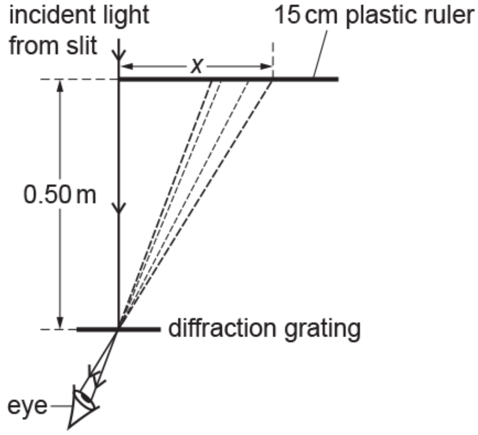


Fig. 12.2 (not to scale)

Four **first** order images of the slit, one at each photon wavelength, are observed as vertical lines against the background of the plastic ruler, as shown in Fig. 12.3.

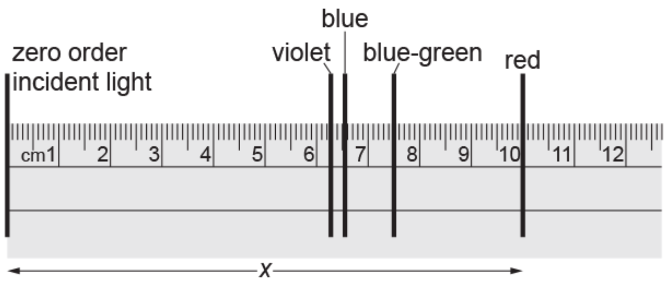


Fig. 12.3

The student decides to determine the wavelength of the photons which form the red line observed at *x* = 10 cm on the ruler.

- Describe how the information that has been given can be used to determine the wavelength of the red photons.
- Estimate the percentage uncertainty in the measured value of the wavelength.

[6]

Total: 63

END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			**B**	1	
			Total	**1**	
2		i	Hard to judge the point when it is quietest (consistently) / intensity will have a broad minimum	1	**Expect** answers which relate to a judgement of where the minimum is **Allow** answers referring to hearing **Allow** any reference to stray signals / reflections / difficulty in reading small changes in oscilloscope trace
		ii	(Difficult to produce consistent results because of) placement of ruler / measuring tape may sag / uncertain where centre of microphone or speaker is	1	**Allow** suggestions relating to unknown location of detection of sound on microphone or speaker **Allow** suggestions which would improve the precision e.g position marker at centre of each speaker
			Total	**2**	
3			measurement = 3 cm **or** $\lambda/2$ = 6 cm so λ = 0.12 m $c = f\lambda = 2.5 \times 10^9 \times 0.12$ $= 3.0 \times 10^8$ (m s^{-1})	B1 C1 M1 A1	measurement to within ± 1 mm **ecf** measurement, i.e. λ = 4 x measurement there must be a valid calculation shown

					scores 1 out of final 3 for answer of 1.5×10^8 **allow** 1 SF, i.e. 3×10^8
			Total	**4**	
4			**Level 3 (5 – 6 marks)** Clear description and explanation for **both** experiments **and** some discussion of uncertainty *There is a well-developed line of reasoning which is clear and logically structured. The information presented is clear relevant and substantiated.* **Level 2 (3 – 4 marks)** Some description and explanation for **both** experiments **or** clear description and explanation for **one** experiment **and** some discussion of uncertainty *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1 – 2 marks)** Limited description and explanation for **one** experiment *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**B1 × 6**	**Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc.** **Indicative scientific points may include:** **Description and explanation** **Experiment (a)** • Coherent signals / (sound) waves • Interference / superposition • Maximum signal / minimum signal • Idea of how wavelength is determined (e.g. distance between adjacent max positions = λ) • $v = f \times \lambda$ **Experiment (b)** • Stationary / standing wave produced • Superposition of waves travelling in opposite directions • Nodes / antinodes • Idea of how wavelength is determined (e.g. distance between adjacent nodes = $\lambda/2$) • $v = f \times \lambda$ **Uncertainty** • Measure multiples of λ • to reduce % uncertainty (by factor n) • move from minimum signal to minimum signal • so can increase sensitivity of scope to get better fix on each minimum position / increase loudness from speaker • Lower frequency from signal generator • so increases A with (%) uncertainty reduced • Do experiment outside • to reduce background reflections from room (so that sharper minima should be observed)

			Total	**6**	
5			**Level 3 (5–6 marks)** Clear explanation of observations **and** correct method to determine the speed of sound *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear explanation of observations **or** correct method to determine the speed of sound **or** has limited explanation of observations and limited method for the determination of the speed of sound *There is a line of reasoning presented with some structure. The information presented is in the mostpart relevant and supported by some evidence.* **Level 1 (1–2 marks)** Has limited explanation of observations **or** limited evidence of method to determine the speed of sound *The information is basic and communicated in an unstructured way.* *The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1 x6**	**Indicative scientific points may include:** **Explanation of Observations** • Understanding of how the standing wave is formed from the interference between the incident and reflected wave • Idea of nodes and antinodes • Node at closed end and antinode at open end • Understanding of the direction of oscillation of particles • Fundamental frequency/1st harmonic indicated for closed tube. • Fundamental frequency/1st harmonic indicated for open tube • Harmonics indicated for closed tube • Harmonics indicated for open tube **Determination of speed of sound** • λ correctly linked to length • $v = f\lambda$ • v calculated for different harmonics / tube or appropriate graphical method • 338 ms^{-1}
			Total	**6**	
6			Laser / ray box **or** protractor mentioned Ray diagram showing (incident) ray **within** the block, (refracted) ray along the straight edge of block **and** critical angle marked between the incident	**B1** **B1**	**Not** 'ray of light' for laser / ray box **Allow** C, critical angle, θ or i for the angle marked between the incident ray and normal **Note**: No labelling of rays or normal is required **Ignore** direction of rays

			ray and the normal (Refractive index determined using) $n = 1/\sin C$	 **B1**	**Ignore** any internally reflected ray **Note** this mark is for the **ray diagram. Ignore** description, unless there are multiple refracted rays shown **Allow** any subject and terms do not need to be defined **Not** bald '$n_1\sin\theta_1 = n_2\sin\theta_2$'
			Total	**3**	
7			**Level 3 (5–6 marks)** Clear procedure, measurements and analysis *There is a well-developed line of reasoning which is clear* ***and*** *logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some procedure, some measurements **and** some analysis. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited procedure, limited measurements **and** limited analysis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	B1 x 6	**Indicative scientific points may include:** **Procedure** • labelled diagram • two loudspeakers OR loudspeaker and double slit • signal generator connected to loudspeaker(s) • microphone and oscilloscope/sound sensor • microphone and oscilloscope/sound sensor moved between loudspeakers • safety precaution (ear defenders) • method to avoid reflections of sound • change frequency and repeat measurements for x • $D >> a$ **Measurements** • frequency determined from oscilloscope/ reading from signal generator • additional detail from use of oscilloscope e.g. time-base to determine period and $f = 1/T$ • use of rule(r) to measure distances a, D and x • measures over several maxima/minima **Analysis** • rearrangement of equation for v or into $y=mx$ • plot a graph of x against $1/f$ or equivalent • straight line through origin confirms relationship • gradient = vD / a • $v = \frac{a \times \text{gradient}}{D}$.
			Total	**6**	

8			**Level 3 (5–6 marks)** Clear description **and** clear analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear description **or** Clear analysis **or** Some description **and** some analysis *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited description **or** Limited analysis *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.	B1× 6	Use level of response annotations in RM Assessor **Indicative scientific points may include:** **Description** • Method for creating wave / pulse, e.g. lifting and releasing tray, dropping a ball into the water, ripple-tank arrangement, etc. (Details not expected) • speed = distance ÷ time **or** $v = x \div t$ **or** $v = f\lambda$ • Measure distance travelled using a ruler • Use a stopwatch / timer/ video technique / strobe to measure time / frequency • Measure the depth of water using a ruler etc • Record / measure / determine v for different d • Repeat to find average v **Analysis** • Plotting a graph, e.g. v against $\sqrt{d}$ **or** v^2 against d **or** lg$v$ against lg$d$ etc. • Correct determination of g from straight-line graph **or** • Table with v and $\sqrt{d}$ **or** v^2 and d • Correct calculation of average value of g from the table
			Total	**6**	
9	a		*Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Expect all points to be addressed, coherence or	B1x6	**Indicative scientific points may include** **Coherence (C)** 1. Light from slits must be coherent / have constant phase relationship 2. use narrow slit close to lamp or lens to focus beam

			means of achieving this, all experimental measurements, and an identification of the greatest uncertainty consistent with the methodology described. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Sufficient detail is given to demonstrate an understanding of the execution of the experiment and taking measurements of different orders of magnitude. Reference is made, with limited reasoning to uncertainty. Some detail may be omitted. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Basic information on equipment and measurements or measurements and uncertainty are given. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.		3. diffract 'same' light through both slits **Experiment (E)** 1. $S1S_2$: vernier caliper or micrometer, travelling microscope, projected image with known lens 2. AB : vernier caliper, calipers, mm rule (magnifying glass) 3. D from slits to screen : ruler or tape measure with mm markings **Uncertainty (U)** 1. $S1S_2$: 0.1 mm in 0.8 mm with travelling microscope,vernier or micrometer, 2. AB on screen : 0.1 mm in 6 mm with travelling microscope or vernier, 1mm in 6mm with rule 3. D from slits to screen: 1 mm in 1.6.m so very small uncertainty **Conclusion** Expected answer S_1S_2, 12.5% uncertainty Alternatives based on equipment selected should be credited: AB on screen with ruler giving 16.7% uncertainty
	b		percentage uncertainty in *a* decreases fringes move closer together / percentage uncertainty in *x* increases / actually measuring 5*x* so smaller effect / **AW** with both measurements to 0.1 mm, measurement of *a* gives larger improvement so decrease in uncertainty in λ	B1 B1 B1	**Allow** any argument qualitative or quantitative, which considers: effect on *a*, effect on *x* and correct conclusion Allow alternative arguments, e.g. D is easily increased increasing *x* so increase in a will decrease uncertainty in λ as $\Delta a / a$ smaller

			Total	**9**	
10	a		y = sin (θ) $\sqrt{x^2+y^2}$ compared with "y=mx+c"	**B1**	**Allow:** gradient = $\frac{\Delta y}{\Delta(\sqrt{x^2+y^2})}$ with sin (θ) = O/H **Not:** gradient = $\frac{y}{(\sqrt{x^2+y^2})}$ **unless** "c=0" seen.
	b	i	(Straight line of best fit showing) <u>gradient</u> = 0.73 ($d$sin θ = $n\lambda$) $\frac{1.0 \times 10^{-3}}{600} \times 0.73 = 2 \times \lambda$ λ = 6.1 × 10^{-7} (m)	**C1** **C1** **A1**	**Allow:** gradient in range 0.70–0.76. **Allow:** evaluation of θ = 44−50 (degrees) in place of gradient **Allow:** any subject **Note:** Gradient in range 0.70−0.76 gives λ in range (5.8 – 6.4) × 10^{-7} m
		ii	(Scales/distances are large compared with the absolute uncertainty so) **<u>absolute uncertainty</u> is too small** to be shown (reasonably on this graph's scale) (AW)	**B1**	**Ignore: error** too small
			Total	**5**	
11	a		Fringe spacing = 1.3/8 = 0.16 cm ✓ λ = d sinθ = 1 × 10^{-3} × 0.16 × 10^{-2} / 3 ✓ = 5.4 × 10^{-7}	3	OR λ = dx / L
	b		**Level 3 (5-6 marks)** ✓✓ Addresses all four points with reasoned comments regarding practicality and disadvantages. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** ✓✓ Addresses each point but may not appreciate the	6	e.g. Increasing the distance between slits and screen will have the desired effect of increasing the fringe spacing but the intensity of the fringes may become so low that fewer if any are clearly visible, making measurement difficult. Increasing the slit width to increase the intensity of light reaching the screen will allow more light to reach the screen but the larger slits will allow less diffraction to occur at each slit so the waves from each slit are less likely to superimpose and fringes will not be formed. Reduce the distance between the light source and the slits increase the intensity of the fringes. More diffraction at first slit will be required in order for both the secondary slits to be illuminated. Therefore

			associated difficulty in some cases *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1-2 marks) ✓✓** Comments on at least two points with a least one difficulty described. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence mav not be clear.* **0 marks** No response or no response worthy of credit.		narrower slit required and lower light intensity will result. Use coloured filters to enable the wavelengths of specific colours to be measured. A useful improvement but filters will reduce the intensity of light reaching the screen so the fringes may not be visible.
			Total	**9**	
12			**Level 3 (5 - 6 marks)** Clear procedure or correct determination of wavelength, plus reasonable estimation of uncertainty in λ or (sin) θ *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3 – 4 marks)** Description of procedure or correct determination of λ, but no estimation of uncertainty **or** Clear estimation of uncertainty in wavelength but limited description of procedure and/or determination of λ or (sin) θ **or** Some description of procedure, an attempt to	1 (AO3)	Use level of response annotations in RM Assessor, e.g. L2 for 4 marks, L2^ for 3 marks, etc. <u>L1 maximum for any answers which use formula $\lambda = ax/D$</u> **Indicative scientific points may include:** **Procedure** • use formula $n\lambda = d\sin\theta$ • n = 1 since first order spectrum • find d using number of lines/mm = 300 mm^{-1} • find θ using distance of grating from plastic ruler = 0.50 m and x = 0.10 m (**not** protractor) **Determination of wavelength** • calculate d (= $10^{-3}/300$) = 3.3×10^{-6} m • use x = 0.10 m and distance to grating = 0.50 m to calculate tan θ (= 0.2) • θ = 11.3°

			determine the wavelength, and an attempt to estimate uncertainty in some of the measurements (e.g. in *x*) *There is a line of reasoning presented with some structure. The information presented is in the most part relevant and supported by some evidence.* **Level 1 (1 – 2 marks)** A limited selection from the scientific points worthy of credit. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.* <u>Frontal</u>		• sin θ = 0.196 • alternatively, calculate hypotenuse of triangle (using Pythagoras's theorem) = 0.51 m, giving sinθ (= $0.10/0.26^{½}$) = 0.196 • allow use of small angle rule (sinθ ≈ tanθ ≈ θ = 0.2) • calculate λ (= 0.196 x 10^{-3}/300) = 650 nm **Estimation of uncertainty** • negligible uncertainty in *d* (and *n*) • uncertainty in sin θ is found using uncertainty in distance measurements • uncertainty in each distance measurement is ± 1.0 mm or ± 0.5 mm **or** ± 2.0 mm • maximum % uncertainty in tan θ / θ / sin θ = 3% • so % uncertainty in λ = % uncertainty in sin θ = 3%
			Total	**6**	