WJEC EDUQAS A-LEVEL PHYSICS · COMPONENT 3

PHYSICS



EXAM QUESTION PACK

3.2 WAVE PROPERTIES

SCORE	PERCENTAGE
/130	%

STEMUP

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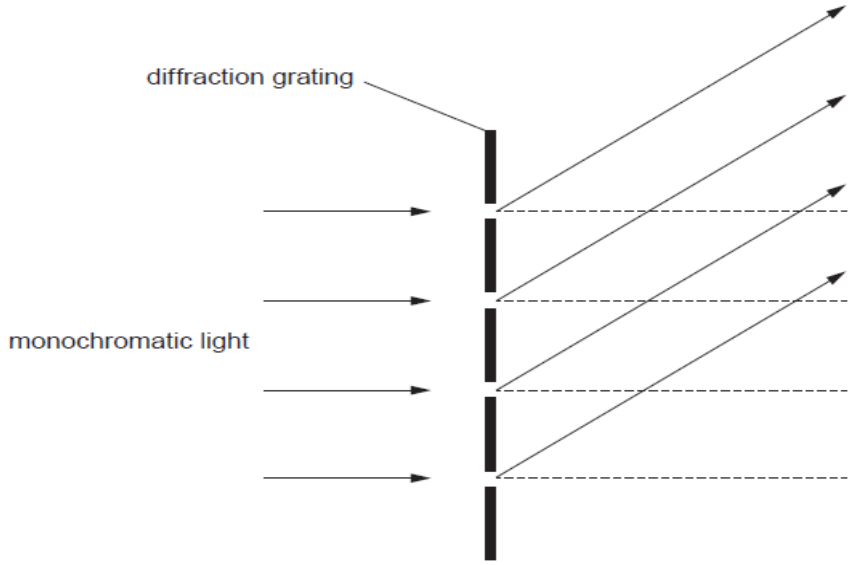
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#1

(a) Adding to the diagram, derive the equation $n\lambda = d\sin\theta$ for a diffraction grating. [3]



(b) A diffraction grating has 250 lines per mm and light of wavelength 532 nm is incident normally upon it. Calculate the angle between the first and second order light beams. [4]

(c) Another diffraction grating has half the angle between the first and second order light beams when light of wavelength 532 nm is incident upon it. Estimate the number of lines per mm of this second diffraction grating. [2]

Question taken from Eduqas examination paper 842103, June 2017

#2

1. *(a)* State what is meant by two coherent sources. [1]

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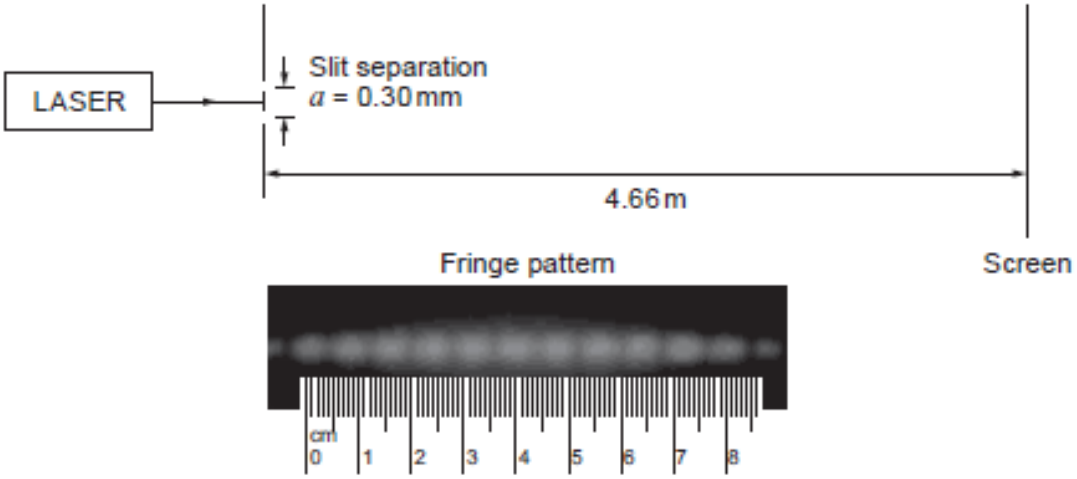
(b) In the 1700s, light was thought to consist of a stream of particles. In the 1800s, it was said to be a wave but since the early 1900s it has been accepted that light behaves both like a wave and like a particle (wave particle duality). Explain briefly the part that Young's double slit experiment played in this history. [2]

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(c) Young's double slit experiment is carried out using laser light.



(i) Calculate the fringe separation from the above diagram. [2]

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(ii) The distance between the slits and the screen is 4.66 m. Calculate the wavelength of the laser light. [2]

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(iii) State one advantage and one disadvantage of using a large slit-to-screen distance. [2]

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Question taken from Eduqas examination paper 842103, June 2018

#3

2. *(a)* Explain what properties of light from a laser can be determined using polarisation and interference. Give practical details. [6 QER]

(b) The polarisation of light is used in Liquid Crystal Display TVs. These have been developed from research into new organic materials. Discuss the importance of research and development into new materials, in general, by giving a benefit and an issue that may arise from using new materials. [3]

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Question taken from Eduqas examination paper 842002, June 2019

#4

2. *(a)* Single slit diffraction of light is demonstrated by using a red laser and the results are shown below. The two different diffraction patterns are obtained by varying the slit width only.

Figure 2a



Figure 2b



(i) Explain whether Figure 2a or Figure 2b has the wider slit. [2]

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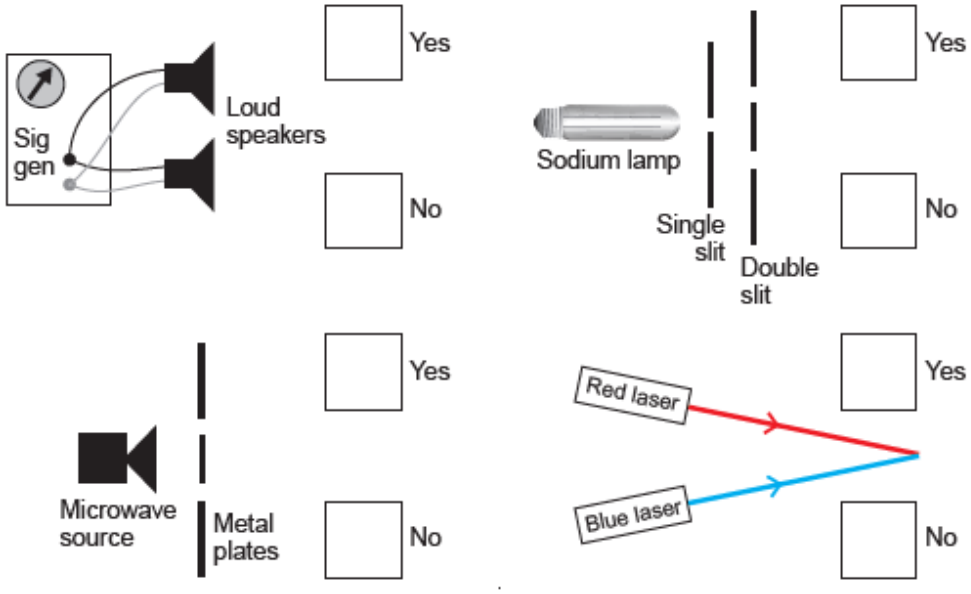
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(ii) State what can be done to the single slit to obtain the greatest amount of diffraction. [1]

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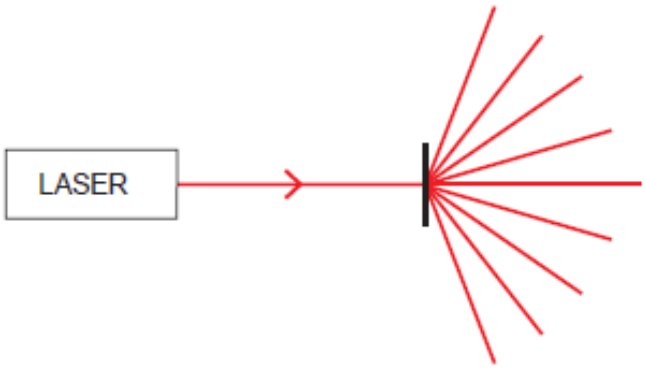
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(b) Tick (✓) the appropriate boxes to show which of the following arrangements allow an interference pattern to be observed/heard. [2]



(c) Laser light is shone at a diffraction grating with slit separation 2.4μm and a total of nine bright beams are produced (see below). Determine the maximum and minimum possible wavelengths for the laser light. [4]

Diagram not to scale



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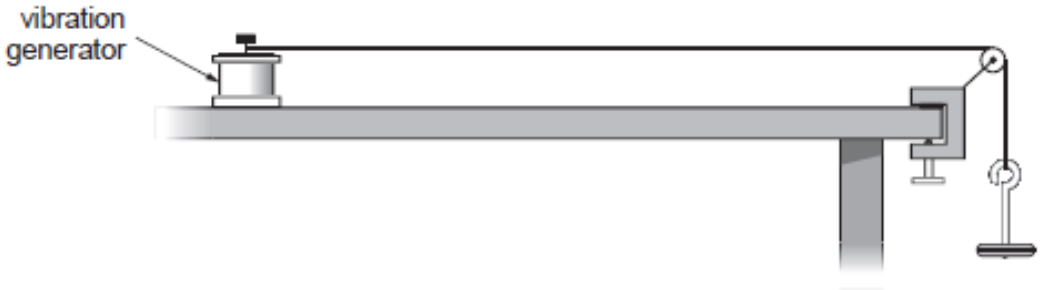
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Question taken from Eduqas examination paper 842103, June 2019

#5

1. The apparatus below is used to demonstrate stationary waves on a string. Both the weight, and the distance between the pin and the pulley are kept constant.



The following stationary wave pattern is observed on the string.



(a) Explain why stationary waves are formed at particular frequencies only. [3]

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(b) Another stationary wave is formed when the frequency is 450 Hz and the length of each loop is 12.0 cm long.

(i) Calculate the speed of the waves on the string. [3]

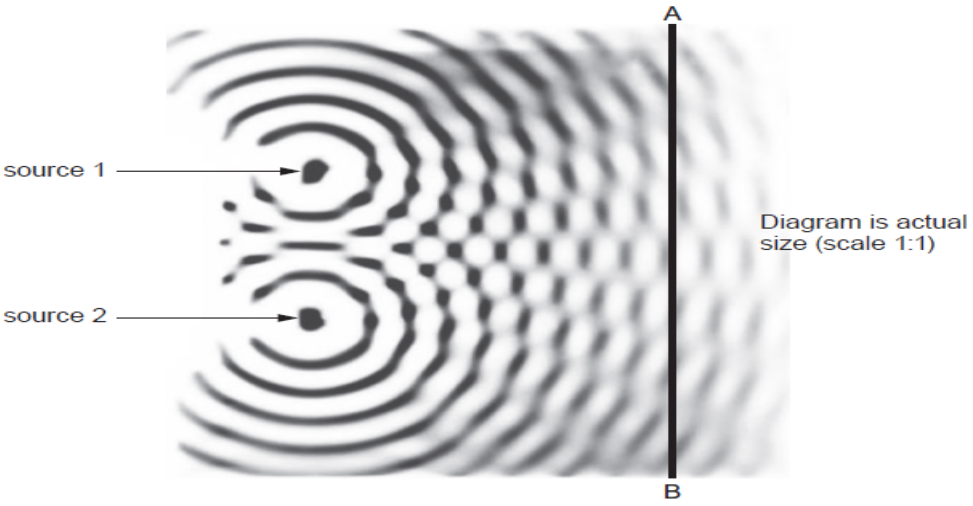
(ii) At a higher frequency there are two more loops formed than at 450 Hz and each is of length 10.0 cm. Determine the number of loops observed at 450 Hz. [4]

Question taken from Eduqas examination paper 842002, June 2019

#6

(a) Explain how two source interference patterns arise. [4]

(b) The diagram shows the two source interference pattern due to two in-phase sources in a ripple/water tank.



(i) **Place an X** on the line AB at any point where there is a path difference of 3 wavelengths between waves from the two sources. [1]

(ii) **Place a Y** on the line AB at any point where there is a path difference of 1.5 wavelengths between waves from the two sources. [1]

(c) (i) The diagram is actual size. Measure the wavelength of the waves accurately by using the distance between wavefronts. [2]

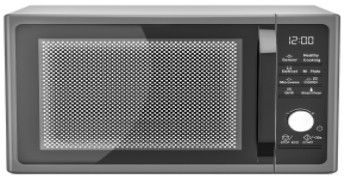
(ii) Hence check whether or not the equation: $\lambda = \frac{a\Delta y}{D}$ is a good approximation for the given diagram. **Show your working.** [3]

Question taken from Eduqas examination paper 842103, June 2017

#7

(a) Bruce throws a lump of coal towards Dani which she catches. Bruce claims that, because chemical energy is being transferred from himself to Dani, the lump of coal is a **wave**. Explain whether or not Bruce is correct. [2]

(b) The door of a microwave oven has a metal grille and this grille has holes in it of diameter 2 mm so that the food can be seen within the oven.

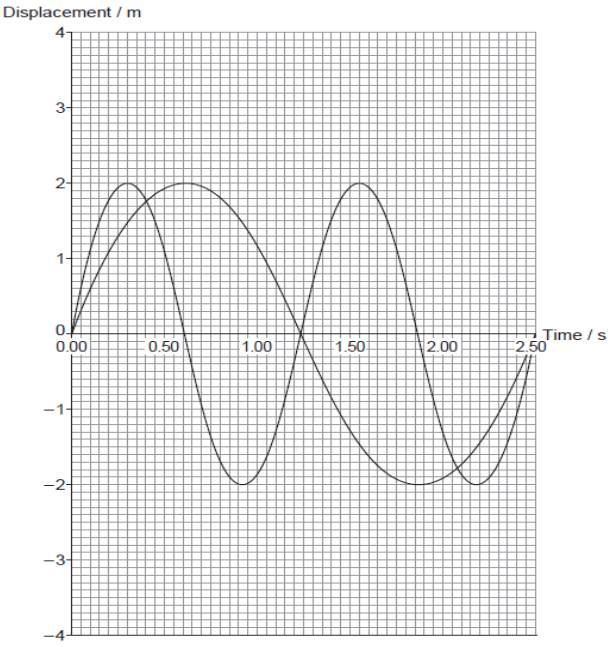


(i) Explain why the food can be seen through the door while the user is safe from dangerous microwaves of wavelength 12 cm. [3]

(ii) State or calculate a typical photon energy of visible light. [1]

(iii) Explain whether or not a microwave photon has a greater or smaller energy than a visible photon. [1]

(c) Two water waves of equal amplitude but different frequencies meet. The variation of the displacements of each wave is shown in the graph at the meeting point of the two waves.

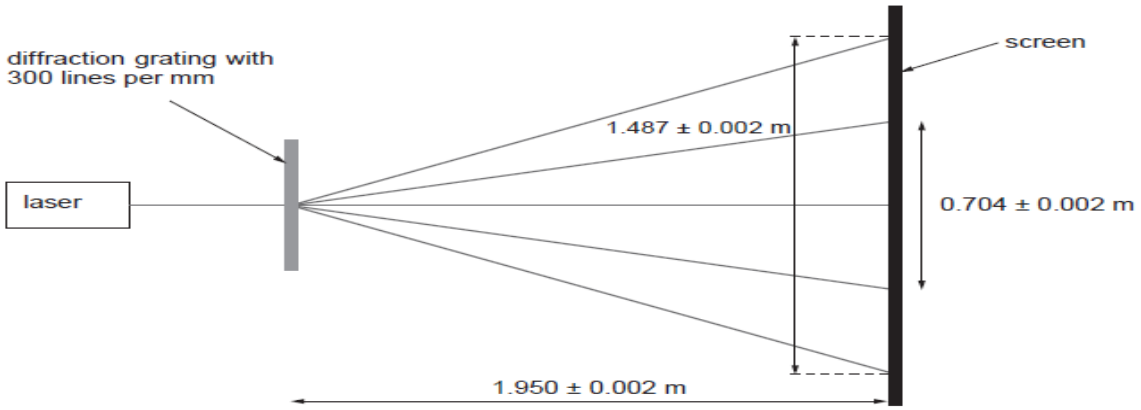


Use the principle of superposition to plot the resultant displacement of the two waves at times 0.00 s, 0.40 s, 1.00 s, 1.25 s, 1.50 s, 2.10 s, 2.50 s **on the same grid** and draw a suitable curve. [4]

Question taken from Eduqas examination paper 842103, November 2020

#8

Rachel carries out an experiment to measure the wavelength of light emitted by a laser. Her measurements and set-up are shown in the diagram below.



(a) (i) **Show clearly** that the measured wavelength of the laser light is 592 nm using the $n = 1$ data in the diagram. [3]

(ii) **Show clearly** that the $n = 1$ data in the diagram leads to an uncertainty in the wavelength of ±2 nm. You may assume that the manufacturer's labelling of 300 lines per mm for the diffraction grating is exact and that $\tan\theta \approx \sin\theta \approx \theta$. [4]

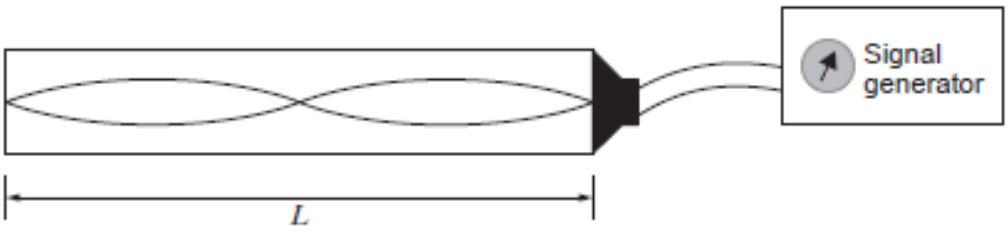
(b) The manufacturer of the laser states that its wavelength is exactly 593.5 nm. The $n = 2$ data in the diagram lead to a measured laser wavelength of 594 ± 1 nm. Explain whether or not these values and the value from part *(a)* are all consistent. [2]

(c) Explain why the $n = 1$ data (592 ± 2 nm) lead to a larger uncertainty than the $n = 2$ data (594 ± 1 nm). [2]

Question taken from Eduqas examination paper 842103, November 2020

#9

5. An experiment is carried out using stationary waves to measure the speed of sound in air. A loudspeaker is placed at one end of a hollow tube so that both ends are closed. The frequency, f, of the signal generator connected to the loudspeaker is varied and those frequencies corresponding to loud noises recorded.



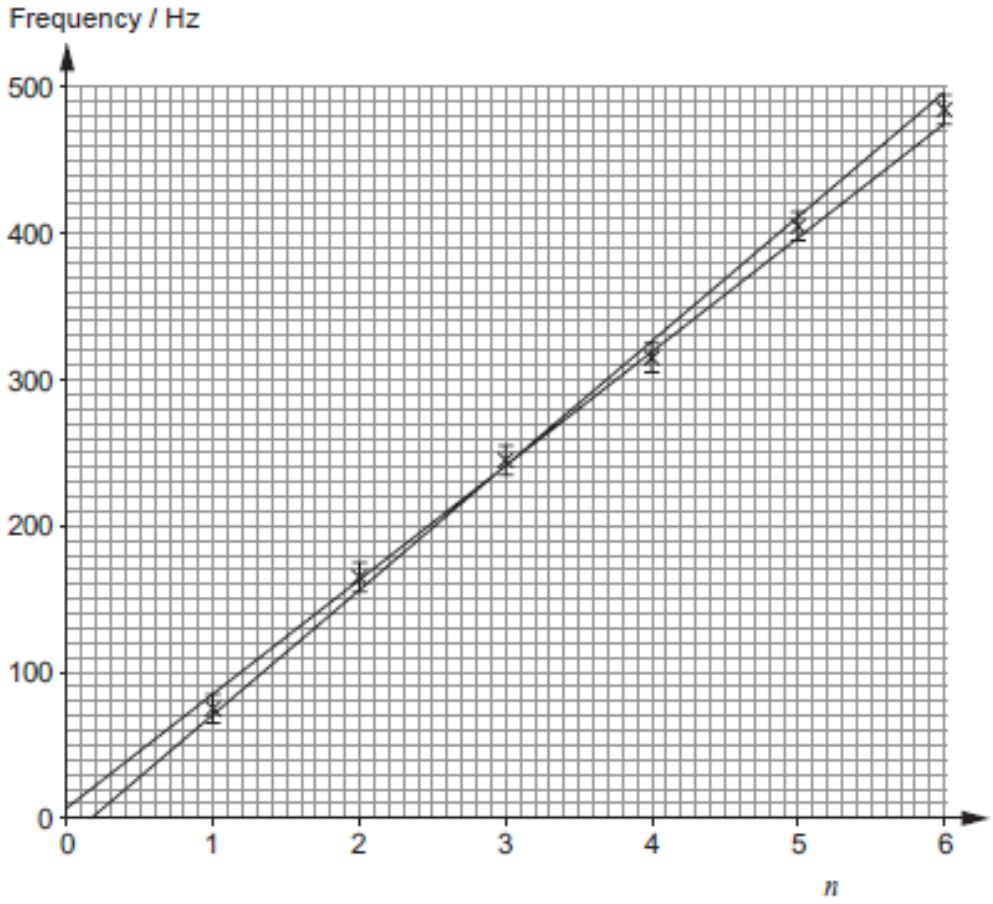
(a) Describe the differences between a stationary wave and a progressive wave in terms of energy, phase and amplitude. [3]

(b) Show that the frequencies corresponding to stationary waves are given by:

$$f = \frac{v}{2L} n$$

where n is any whole number (n = 2 in the above diagram). [3]

(c) The data obtained are plotted on the grid below.



Explain to what extent the graph agrees with the equation: [3]

$$f = \frac{v}{2L} n$$

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(d) The experiment is repeated with the tube filled with nitrogen dioxide (NO_2), a gas that is 1.5 times denser than air. The speed of sound in a gas is inversely proportional to the square root of the density, ρ:

$$v \propto \frac{1}{\sqrt{\rho}}$$

Explain what effect this will have on the gradient of the graph. [3]

(e) A car company is fined £15 billion for excessive NO_2 emissions of its diesel engines. However, there is little or no reliable evidence that NO_2 produces any detrimental health effects at the concentration levels present in the atmosphere. Discuss whether or not the car company or pedestrians have been treated unfairly. [3]

Question taken from Eduqas examination paper 842103, June 2018

#10

The apparatus shown below is used to produce a visible interference pattern on the screen.



Slits B and C act as *coherent* sources.

(a) (i) Explain what is meant by this statement. [1]

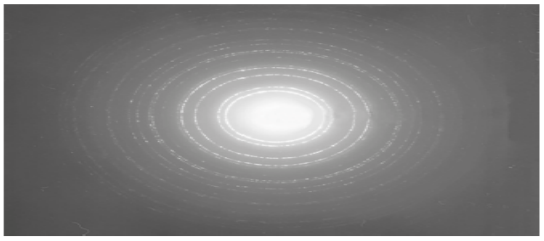
(ii) Explain why destructive interference is observed at certain points on the screen. [3]

(b) (i) The separation of the slits, B and C is 0.090 mm and the perpendicular distance between the slits and the screen is 3.60 m. The slits are illuminated with light of wavelength 4.4×10^{-7} m. A point X on the screen is 52.8 mm away from the central bright fringe at O. Brian states that a bright fringe will be formed at X. Evaluate whether or not he is correct. [4]

(ii) Determine the distance **from** X to the **next dark** fringe formed. [2]

(c) Explain the historical significance of this experiment. [2]

(d) A beam of electrons is fired at a thin sheet of aluminium. A pattern of light and dark circular fringes is observed as shown below.



(i) Explain how this pattern is formed. [2]

(ii) The thin sheet of aluminium is replaced with a foil of copper. The distance between the copper atoms is smaller than in aluminium. Describe how you expect the pattern to change. [2]

Question taken from Eduqas examination paper 842002, June 2017

#11

Question taken from Eduqas examination paper 842101, June 2017

Marking Scheme

#1

Question		Marking details	Marks available					
			AO1	AO2	AO3	Total	Maths	Prac
	(a)	d and θ labelled (1) $d\sin\theta$ is the path difference stated **and** shown (1) Equals $n\lambda$ for in phase / constructive / bright (1)	3			3	1	
	(b)	$d = \frac{1}{\text{number}}$ used or implied (1) Values substituted into $n\lambda = d\sin\theta$ **ecf** on d (1) At least one correct angle 7.6° or 15.4° (no **ecf** here) (1) Correct answer (accept 7.8° or 7.7° even if $\frac{\theta}{2}$) (1) Accept answers in radians i.e. 0.133 and 0.269 Difference = 0.136 [rad]	1 1	 1 1		4	4	
	(c)	Realisation of small angles approximation **ecf** or $d\sin 3.9$ **ecf** = λ(1) 125 lines per mm (1) **accept** 127 or 128		2		2	2	
		Question total	**5**	**4**	**0**	**9**	**7**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)		Constant phase difference [accept: relationship] (between the 2 sources) ['in phase' not enough]	1			1		
	(b)		Interference or diffraction (1) Provided evidence for wave behaviour (1) [NB. independent marks]	2			2		
	(c)	(i)	Using more than one fringe separation (1) Answer = (0.80 ± 0.03) cm (1) [Ignore s.f.]		2		2	1	2
		(ii)	Substitution into $\lambda = \frac{ay}{D}$ [or by implication] (1) Answer = 515 nm ecf from (i) (1) [accept 2 or 3 s.f.]	1	1		2	2	2
		(iii)	Fringes are less bright [so more difficult to see] (1) [not: less clear or wider; not: fewer fringes will be seen] Separation of fringes is greater [can be measured with a smaller % uncertainty] or qualified more accurate based on fringe spacing] (1)			2	2		2
			Question 1 total	**4**	**3**	**2**	**9**	**3**	**6**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*		**Polarisation** Polarised – vibrations in one plane only Use polarising filters Rotate filter If polarised; intensity will change Intensity will change at intervals of 90° Wave is transverse only. **Interference** Laser light is a coherent source Use of double slits to observe pattern Description of interference pattern Constructive interference occurs when path difference = $n\lambda$ Destructive interference when path difference = (n + ½) λ Young's double slit formula quoted $y = \frac{\lambda D}{a}$ Symbols explained Wavelength can be determined AO1 – show understanding of what polarisation and interference are AO3 – evaluate what properties can be determined using polarisation and interference **5-6 marks** Comprehensive description including both polarisation and interference. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive description of either polarisation or interference OR limited description including both polarisation and interference. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Limited description of either polarisation or interference. *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** No attempt made or no response worthy of credit.	2		4	6		6
	(b)		Advantage – Efficiency; improvements to society (1) Issue – Disposal of materials (1) Benefit of research and development given - impact on environment should always be considered before developing new materials (1)			3	3		
			Question 2 total	**2**	**0**	**7**	**9**	**0**	**6**

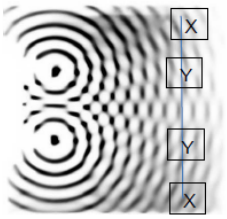
#4

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
2	*(a)*	(i)	Answer = 2a [1] Diffraction pattern is narrower / smaller central maximum / brighter [1]	2			2		
		(ii)	Make slit width approximately one wavelength or similar to one wavelength Don't accept smaller or smaller than one wavelength	1			1		
	(b)		Sound, sodium & microwaves only give interference [2] (or only 2 lasers don't) Only 1 incorrect - allow 1 mark		2		2		
	(c)		Use of equation: $n\lambda = d\sin\theta$ [1] Max possible n = 5 or min = 4 [1] λ = 600 n[m] [1] λ = 480 n[m] [1]	1	1 1 1		4	2	
			Question 2 total	**4**	**5**	**0**	**9**	**2**	**0**

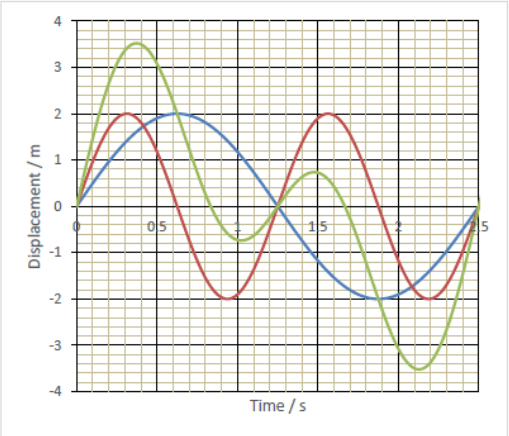
#5

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	*(a)*		Each end has zero displacement (1) Only integers of half wavelengths can fit on string (1) As $c = f\lambda$ and speed is constant - this only occurs at particular frequencies (1) OR Waves are reflected from the fixed end (1) At particular frequencies only - arrive in phase with the next wave leaving / complete half wavelengths / nodes created (1) By principle of superposition *or* interference occurs to create nodes / antinodes (1)	3			3		
	(b)	(i)	Node to node distance = $\frac{\lambda}{2}$ (1) Wavelength = 0.24 [m] (1) Speed ($v = f\lambda$) = 108 [m s^{-1}](1)	1	1 1		3	2	
		(ii)	At 450 Hz: Length of string = $n \times 0.12$ (n = no. of loops) (1) At higher f: $(n + 2) \times 0.1$ = length of sting (1) Therefore $0.12n = 0.1\,(n + 2)$ (1) n = 10 (1)		4		4	4	
			Question 1 total	**4**	**6**	**0**	**10**	**6**	**0**

#6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Coherent sources or inphase and superposition (1) There is a path difference or waves from sources travel different distances (1) Constructive interference **and** destructive interference happens (1) Condition for constructive or destructive stated: $n \times 360$ or $n\lambda$ or $(n+½) \times 360$ or $(n + ½)\lambda$ (1)	4			4		
	(b)	(i) & (ii)	 (i) 1 mark (ii) 1 mark		2		2		2
	(c)	(i)	Distance of 2 or more wavelengths used (1) 0.50 – 0.70 [cm] (1)		2		2		2
		(ii)	Measuring $a = 2.9 \pm 0.2$, $\Delta y = 1.0 - 1.3$, $D = 5.2 \pm 0.1$ (note that $\frac{\Delta y}{D} \approx \frac{1}{6}$ or 0.23) (1) Making a calculation using 3 of the 4 e.g. $\lambda = \frac{2.9 \times 1.2}{5.2}$ = 0.67 [cm] (1) Evaluative comment in line with figures e.g. correct order of magnitude but not a very good approximation (1)			3	3	1	3
			Question total	**4**	**4**	**3**	**11**	**1**	**7**

#7

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Matter also transferred / no vibrations involved (1) So wrong (1) Accept de Broglie wavelength argument for 1 mark			2	2		
	(b)	(i)	Holes far smaller than wavelength of micro (1) So nothing passes (1) Light wavelength far smaller than 2 mm (so little or no diffraction) (1)	1 1	1		3		
		(ii)	1.6-3.3 eV or 2.56-5.28 $\times$ 10^{-19}J (or calculation leading to said numbers)	1			1		
		(iii)	Smaller because f smaller or lambda longer		1		1		
	(c)		Evidence of application of superposition e.g. 0 s (1) 0.4 and 2.1 s correct i.e. 3.4/3.6 and -3.4/-3.6 (1) 1 s and 1.5 s i.e. -0.7 and +0.7 (1) Smoothish curve through points (1) 		4		4	2	
			Question total	**3**	**6**	**2**	**11**	**2**	**0**

#8

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Use tan to find sin e.g. 10.23° or 0.1776 seen (1) can be implied Correct conversion of d i.e. $d = \frac{1}{300\,000}$ (1) Substitution in diffraction grating equation for n = 1 e.g. $\lambda = \frac{0.178}{300}$ Leading clearly to correct answer (1)		3		3	2	3
		(ii)	A correct percentage uncertainty i.e. 0.10 or 0.13 **OR** 0.28 or 0.3(1) Correct percentage uncertainty for tanθ (0.28 or 0.3) (1) Adding percentage uncertainties (0.38) or 0.4 or 0.41 (1) $\frac{592 \times 0.38}{100}$ or similar seen (1) NOTE: accept fractional uncertainty throughout instead of %		4		4	4	4
	(b)		Value is inside uncertainty (of both values) OR overlap region is 593-594 nm (1) Hence agreement (1)			2	2		2
	(c)		Smaller distance (same uncertainty) (1) Larger percentage/fractional uncertainty (1) Accept converse argument **if referring to n = 2 data**			2	2		2
			Question total	**0**	**7**	**4**	**11**	**6**	**11**

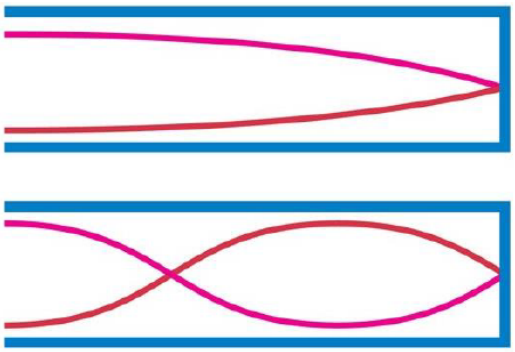
#9

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*		Energy - progressive carries [stationary not] or converse (1) Phase – stationary: constant in loop or successive loops in antiphase; progressive: varies with distance [or can have any value] along (1) Amplitude - antinodes & nodes or varies in stationary, constant amplitude in progressive(1)	3			3		
	(b)		$n \times \frac{\lambda}{2} = L$ (1) Multiply by the frequency or substitution: $\lambda = \frac{v}{f}$ (1) Neatly laid out algebra (1) NB.Stating $\lambda = \frac{2L}{n} \rightarrow$ no credit for 2nd mark.		3		3	2	3
	(c)		'Good agreement' on its own → 0 Straight line [with positive gradient] & good agreement (1) Lines / line of best fit [allow: mean line] pass(es) through all error bars (1) Lines straddle the origin [accept: line of best fit passes through the origin] (1)			3	3		3
	(d)		Velocity decreases (1) Gradient decreases [implied if factor < 1] (1) By factor $\sqrt{1.5}$ (1) [changes by factor $\frac{1}{\sqrt{1.5}}$ or ×0.82 - not: 25%]		3		3	1	3
	(e)		**Any sensible 2 ×(1) from:** e.g. higher concentrations (might) cause bad effects (precautionary principle) Some pedestrians suffer health effects die - respiratory problems Respiratory problems caused by other chemicals Acid rain produced by NO_2 Some pedestrians claim NO_2 bad - psychosomatic Reliable data difficult to obtain - Worse for asthma sufferers Data may be more conclusive in future Accept cheating NO_2 figures is fraud Sensible conclusion (1)			3	3		
			Question 5 total	**3**	**6**	**6**	**15**	**3**	**9**

#10

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Constant phase difference/relationship	1			1		
		(ii)	Waves arrive out $\pi/180^\circ$ out of phase / in antiphase (1) Path difference will be different [for various points on the screen] (1) Path difference = $(n + \frac{1}{2})\lambda$ or $\frac{1}{2}\lambda$ and $\frac{3}{2}\lambda$ or $\frac{5}{2}\lambda$ (1)		3		3		
	(b)	(i)	Using $y = \frac{\lambda D}{a}$ (1) Fringe spacing = 17.6 [mm] (1) Attempt at $\frac{52.8}{17.6} = 3$ (1) Since whole number – a bright fringe is formed at X (1)			4	4	4	
		(ii)	Dark fringe at $\frac{y}{2}$ (1) Therefore distance = 8.8 mm **ecf unit mark** (1)		2		2		
	(c)		This experiment showed that light is a wave (1) up until this point it was thought light was made up of particles (1)	2			2		
	(d)	(i)	Electrons behave as waves **or** [beam of] electron diffracts (1) Atoms cause diffraction/interference **or** behaves like diffraction grating **or** reference to wavelength [of the beam] similar to atom spacing (1)	1	1		2		
		(ii)	Radius is greater for copper or implied by description of pattern change (1) Intensity decreases (1) Accepts stays similar	1		1	2		
			Question total	**5**	**6**	**5**	**16**	**4**	**0**

#11

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)		 or equivalent diagrams with A & N, dots (for nodes) and double-headed arrows (for antinodes) etc.	1 1			2		2
	(b)		f = 141 [Hz] (1) λ = 2.4 [m] (1)		2		2	2	2
	(c)		Correct reference to polarised light as having vibrations (or equivalent) in one direction (1) At θ = 0 and / or 180° polaroids aligned (1) At θ = 90° polaroids crossed (1) Intermediate angles partial blocking or partial transmission or equivalent (1)	4			4		4
	(d)	(i)	When θ = 0, cos θ = 1 or $(\cos\theta)^2 = 1$ so $I = I_0$ Accept substitution of I and θ for any other value of θ		1		1	1	1
		(ii)	$(\cos 140°)^2$ = 0.587 (1) predicted I = 340 × 0.587 = 200 agreeing with graph point (1) [or $\frac{I}{I_0} = \frac{200}{340}$ =0.588 agreeing with $(\cos 140°)^2$]	1	1		2	2	2
	(e)		More grip for smooth rubber seems to contradict (1) 4° difference but a resolution of 0.1° (accept 1°) **or** an uncertainty of <1% (1) Not random error **or** a less firm conclusion argued because more info needed about repeats (1)			3	3		3
	(f)		Valid demonstration of inverse cube, for e.g. $9.8 \times 8.0^3 = 5\,018$; $2.9 \times 12.0^3 = 5\,011$ (1) Comment: accept either "good agreement" or with reservations, such as more results needed (1)			2	2	1	2
	(g)	(i)	12.5 [m s^{-1}]		1		1		1
		(ii)	First 25 s: straight line from (0,0) to (25,12.5) **and** vertical scale (accept single label at 12.5) (1) 25 s – 30 s v continues to rise but at decreasing rate (curve) (1) 30 s – 50 s constant velocity with continuity of line at 30 s (1)		3		3	3	3
			Question total	**7**	**8**	**5**	**20**	**9**	**20**