Marking Scheme

1.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)		Transverse – oscillations / vibrations 90° or perpendicular to energy transfer/wave direction [1] Longitudinal – oscillations / vibrations parallel/same direction to energy transfer / wave direction [1] Penalise missing oscillations / wave direction only once	2			2		
	(b)	(i)	4 [cm]	1			1	1	
		(ii)	0.8 [m]	1			1	1	
		(iii)	Period = 0.3 [s] [1] $f = \frac{1}{T}$ and $v = f\lambda$ used or $v = \frac{\lambda}{T}$ [1] ecf on T Answer = 2.67 [m/s] [1] don't accept 2.6 [m/s]	1	1 1		3	1	
	(c)	(i)	Arrow radially outward (accept inward) based on point S	1			1		
		(ii)	S and T only	1			1		
			Question 1 total	**7**	**2**	**0**	**9**	**3**	**0**

2.

Question			Marking details		Marks available				
				AO1	AO2	AO3	Total	Maths	Prac
1	(a)		A pattern of disturbances travelling through a medium and carrying energy with it (1) involving the particles of the medium oscillating about their equilibrium positions (1) [Accept answers appropriate to e-m waves: A travelling pattern of oscillating electric and magnetic fields (1) carrying energy with it (1)]	2			2		
	(b)	(i)	Phase difference between A and B = 90° or $\frac{\pi}{2}$ accept fractions of cycle i.e. ¼ (1) Phase difference between B and C = 0 or n 2π or n 360°(1)		2		2	1	
		(ii)	Determining $f = \frac{1}{T} = \frac{1}{0.4} = 2.5$ Hz (1) Wavelength = 1.5 km (1) Using $v = f\lambda$ (1) 3.75×10^3 m s^{-1} accept 3.75 km s^{-1} (1)	1	1 1 1		4	4	
	(c)		Substituting values in Young modulus = $= \frac{\text{stress}}{\text{strain}}$ (1) Rearranging strain $= \frac{900\text{ MPa}}{70\text{ GPa}}$ (1) Strain = 0.013 (1) (ecf power of 10)	1	1 1		3	3	
	(d)		Data can be used to determine locations/frequency of Earthquakes (hotspots) (1) Informs planning and sites for new builds or increases knowledge of structure of the Earth (1)			2	2		
			Question 1 total	**4**	**7**	**2**	**13**	**8**	**0**

3.

Question				Marking details	Marks Available
3	*(a)*	(i)		1.6 [m]	1
		(ii)		0.4 [m], 1.2 [m], 2.0 [m]	1
		(iii)	I	$t_1 = \frac{T}{4}$ **or** $T = 0.02$ [s] (1) $t_1 = 0.005$ s (1) **UNIT mark**	2
			II	down, up, down	1
	(b)			half sinusoid: up, down or both (1) $c = 80$ [m s^{-1}] **and** $\lambda = 4.8$ [m] **or** frequency of fundamental = third frequency of 3rd harmonic **or** by implication (1) $f = 17$ [Hz] (1)	3
				Question 3 Total	**[8]**

4.

Question			Marking details	Marks Available
1	*(a)*	(i)	In phase [Accept: in step.]	1
		(ii)	Same amplitude everywhere [Accept: amplitude gets less and less.]	1
	(b)	(i)	$v = 500$ mm s^{-1} or 0.5 m s^{-1} or $T = 0.03$ s. Accept without units. (1) Attempted use of $f = \frac{v}{\lambda}$ not $c = 3 \times 10^8$ m s^{-1}) **or** $f = \frac{1}{T}$ **or by implication** (1) 33 [Hz] (1)	3
		(ii)	Working shows crests have moved $\frac{\lambda}{3}$ or 5 mm **or by implic** (1) Positions convincing by eye (1) Accept at 5 mm or third distance between crests. Fewer than 3 lines shown **award 1 mark only**.	2
	(c)	(i)	80 mm, 320 mm and 15 mm correctly put in double slit equation (1) states or implies that first const int is at 60 mm from axis. (1) concludes that there is dest int at P (1) • Give 1 mark if candidate claims first const int at 120 mm, having put in 40 mm instead of 80 mm for slit separation, and another mark if goes on to conclude that neither dest not const at P. • If equation used 'backwards', putting in 30 mm and finding 7.5 mm for λ award 1 mark and 2nd mark if also states that dest int at P. For the 3rd mark it must be carefully explained why destructive interference at P for λ = 15 mm **Alternative solution:** Path difference = 7.7 ± 0.1 mm (1) This is equal to / approximately equal to $\frac{\lambda}{2}$ (1) Hence destructive interference will occur (1)	3
		(ii)	Diffraction is spreading of waves <u>at slits</u> (1) Without which waves wouldn't overlap (or superpose) (1)	2
			Question 1 total	**[12]**

5.

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**

6.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	*(a)*		T = 0.60 [s] or f = 1.67 [Hz] in working or by implication (1) Sinusoid of correct frequency and amplitude drawn from t = 0 to t = 1 s (1) Reasonable graph: Correct phase (–sin ωt) (1)		3		3	2	
	(b)	(i)	1 500 [nm] sin 24.9° = λ or by implication (1) λ = 632 nm (1)	1	1		2	2	
		(ii)	Diagram of right-angled triangle (by eye) with 57.4° (accept θ) marked in a correct position [i.e. wavefront from bottom slit perpendicular to top direction] (1) Either 2λ (or path difference) marked on diagram or statement that path difference [for light from adjacent slits] = 2λ (1) 57.4° (or θ) = $\sin^{-1}\frac{2\lambda}{d}$ or equivalent [e.g. $\sin^{-1}(2\sin 24.9°)$] (1) [Last mark free-standing]	1 1	1		3		
			Question 4 total	**3**	**5**	**0**	**8**	**4**	**0**

7.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4.	*(a)*		**Requirements** • Direction of polarisation in common • Comparable amplitude • Same frequency / wavelength • Coherent • Diffraction **Possible explanation material** • Coherent sources means constant [or constant or zero] phase difference between sources • Sketch-graphs showing meaning of constant phase difference • Rapidly shifting interference pattern if phase difference varies • No cancellation if polarisation directions or amplitudes different • Diffraction needed for overlap **Possible examples of compliance and non-compliance** • Two *slits* illuminated by single laser would fulfil requirements • Slits illuminated by ordinary lamp or separate lamps wouldn't • Contrived cases e.g. sources polarised at 90° to each other; polaroids crossed or one source (e.g. slit) covered by dark glass acceptable **5-6 marks** Comprehensive account of all areas i.e. requirements, explanations and examples given. *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** Comprehensive account of 2 out of the 3 areas i.e. requirements, explanations and examples given **or** limited attempt of all 3 areas. *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** Comprehensive account of 1 out of the 3 areas i.e. requirements, conditions and examples given **or** limited attempt of 2 areas. *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.	6			6		
	(b)	(i)	Mean of measurements i.e. x (= $5\Delta y$) = 6.6[2] [mm] **or** by impl (1) Mean of Δy = 1.3[2] [mm] (1) Absolute uncertainty in x = 0.3 [mm] **or** in Δy = 0.06 [mm] or by implication (1) % uncertainty = 5 % Accept 4.5 % **ecf** on Δy and unc in Δy and on x and unc in x (1)		4		4	3	4
		(ii)	Correct substitutions into $\lambda = \frac{a\,\Delta y}{D}$, with **ecf** on Δy and allowing slips in powers of 10 (1) λ = 520 n[m] or 528 n[m] with **ecf** on Δy (1) % uncertainty = 10 % Accept 9.5 % **ecf** on uncertainty in Δy (1)		3		3	3	3
	(c)	(i)	$\lambda = \frac{1500\text{ nm}\sin 45°}{2}$ substitution in re-arranged eq. allow slips of powers of 10 (1) λ = 530 n[m] Accept 530.3 n[m] (1)		2		2	2	
		(ii)	Bright areas further apart in case of grating (1) Because slits closer together in grating [than double slits] (1) not freestanding Bright areas sharper **or** smaller **or** brighter for grating or equivalent (1) Because more slits in grating or more destructive interference **or** (for brighter fringes) more constructive interference (1) not freestanding	4			4		
			Question 4 total	**10**	**9**	**0**	**19**	**8**	**7**

8.

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**

9.

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**

10.

(a) (i) Formula correctly transposed at any stage (1).
$n = 2$ (1); $d = 2.2$ μm (1) — 3

(ii) Uncertainty [accept error] in measuring angle makes lower uncertainty [accept error] in d. — 1

(b) (i) $2\lambda = 2.2 \times 10^{-6} \sin 35.1°$ [e.c.f.] (1) [or by impl.]
$\lambda = 633$ nm (1) — 2

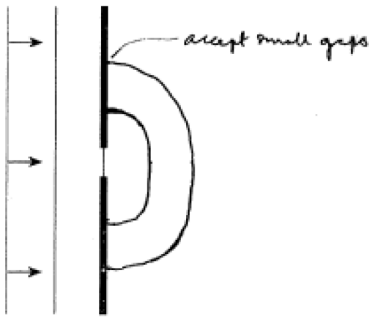
(ii) **Either** $\frac{d}{\lambda} = 3.5$ [or < 4] **or** $\frac{3\lambda}{d}$ and $\frac{4\lambda}{d}$ evaluated [in an attempt to find $\sin\theta$]. (1) [e.c.f. on d or λ]
3rd order deduced by valid reasoning (1). — 2

[8]

11.

(a)	(i)	Diffraction	1
	(ii)	[Slit width much] greater than the wavelength (1) [Angular] spread [of central maximum] is small. (1)	2
	(iii)	[Width of] spread decreases (1) [accept: less diffraction] Peak intensity increases (1)[**or** intensity increases because more light is let through].	2
(b)	(i)	1.25 mm	1
	(ii)	Use of $\lambda = \frac{ay}{D}$ with symbols correctly interpreted (1) λ = 625 nm [ecf on y] (1)	2
	(iii)	When path difference is a whole number of wavelengths [not just: path difference = 0] (1), waves from the slits arrive [or equiv.] in phase (1) and interfere constructively (1)	3
	(iv)	Less light diffracted at greater angles / intensity envelope the same as the diffraction graph.	1
(c)		Any 2 × (1) from: • Light from laser may be brighter ✓ [not just collimated] • Light from laser coherent / no need for single slit / light source need not be distant ✓ • light [more nearly] monochromatic ✓	2
			[14]

12.

Question			Marking details	Marks Available
	(a)	(i)	3.0 [cm] [accept 3 cm]	[1]
		(ii)	v = 3.0 x 5.0 (1) [cm s^{-1}] or by implication. **Full ecf on λ** $t = \frac{d}{v}$ applied (1) t = 0.70 s (**ecf** on λ) (1) OR $d = \frac{10.5}{3.0}$ (1) T = 0.20 [s] (1) [$t = 0.20x\frac{10.5}{3.0}$] t = 0.70 [s] (1)	[3]
		(iii)	B in phase, C not in phase (in antiphase not acceptable), D in phase - irrespective of explanations. (1) Correct answer and understandable explanation or 'in phase' explained, for one of B, C or D. (1) Correct answer and understandable explanation for another of B, C, or D. (1)	[3]
	(b)	(i)	Diffraction	[1]
		(ii)	Rounded and (almost) semicircular (Accept gaps of <=3 mm) (1) λ constant (1) (within about 30%) 	[2]
		(iii)	Any 2 x (1) from: • λ decreased [No penalty for (say) 'halved'] • less spreading • side beams	[2]
			Question 1 total	**[12]**

13.

(a)		[Flat, opaque] screen / sheet/ plate / material with slits / gaps (1) Slits are parallel / vertical **or** equally spaced **or** closely spaced **or** many / multiple (1)	2
(b)	(i)	$\frac{1}{400000} = [2.5 \times 10^{-6}\ \text{m}]$	1
	(ii)	$2\lambda = 2.5 \times 10^{-6} \sin 25.2°$ even with the 2 missing or mishandled (1) Correct placing of the 2 (1) $\lambda = 532 \times 10^{-9}$ [m] **ecf** on d only (1)	3
	(iii)	$3 \times 532 = 2\,500 \sin\theta$ or equivalent **ecf** on λ (1) $\theta = 39.7°$ or $40°$ **ecf** on λ (1)	2
	(iv)	Young's slits much further apart than slits in grating Don't accept slits much narrower or gaps are much smaller	1

14.

Question			Marking details	Marks Available
2	*(a)*	(i)	λ and d correctly inserted (nm is fine) in equation **or by implic** (1) 26° (1) 62° (1)	3
		(ii)	Beams drawn at 0° and at two different angles one side of normal (1) 2 beams either side of normal with some regard for symmetry (1) **ecf** on 1 angle found in (i)	2
	(b)		Only 3 beams emerge (this must be stated in words) [Accept: no second order beams.] (1) First order beams at greater angle to zeroth (a calculation is acceptable) **or** equivalent (1) Reference to colours is irrelevant	2
			Question 2 total	[7]

15.

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
5	*(a)*	(i)	$\lambda \geq 25$ mm / gap / w. [Accept >, not =]	1			1		1
		(ii)	Intensity increased straight in front of gap (or equivalent) [or more total power – accept total intensity – passes through gap] (1) Intensity reduced at large angles to normal / 'at the sides' [accept: waves don't diffract as much] (1)			2	2		2
	(b)		$S_1P = 250$ mm (1) $S_2P = 264$ mm (1) Path difference = 14 mm or by implication ecf on S_1P and S_2P (1) λ = 28 mm (1) NB Use of Young slits formula → 0 marks	1	1 1 1		4	2	
			Question 5 total	2	3	2	7	2	3