

PH2

Question		Marking details	Marks Available
1	(a)	(i) Longitudinal waves: Directions of [particle or molecule or air] oscillations and direction of travel of wave [or energy] [NB not particles travelling](1) are parallel [or parallel / antiparallel or the same] (1) [Independent marks]	2
		(ii) Wavelength: [Shortest] distance [along the direction of propagation] between air layers [or particles or molecules or points] oscillating in phase (✓) or distance between [the centre of successive] compressions [or rarefactions]. [NB not ‘peaks’ and ‘troughs’]	1
	(b)	(i) Interference between [or superposition of] [progressive] waves (1) travelling <u>in opposite directions</u> . (1) [Not ‘constructive’ or ‘destructive’ interference only]	2
		(ii) N.B. Working must be shown. $\lambda = 0.44$ m (1) $v = f\lambda$ correctly applied (1) [or $v = \lambda/T$ correctly applied] $v = 330$ m s ⁻¹ ((unit)) (1) [Correct answer only → 1 mark] [No ecf unless wrong answer commented upon!]	3
	(iii) $\frac{\lambda}{2} = 3.3$ m or $\lambda = 6.6$ m (1). So nodes must be further apart than 2 m [or equiv] (1) [ecf from incorrect v]	2	
			[10]
2	(a)	(i) $v_{\text{air}} > v_{\text{glass}}$ (1), $f_{\text{air}} = f_{\text{glass}}$ and $\lambda_{\text{air}} > \lambda_{\text{glass}}$ (1)	2
		(ii) Cycles [or oscillation] can't appear or disappear [at boundary] or equiv. / frequency determined by the source [not just f is constant]	1
	(b)	(i) [1.00]sin 40° = 1.52sin ϕ [where ϕ = angle of refraction] (1) $\phi = 25^\circ$ (1); $\theta = 90^\circ - 25^\circ = [65^\circ]$	3
		(ii) $\sin c = \frac{1}{1.52}$ [or equiv] or : $c = 41^\circ$ (1) $65^\circ > 41^\circ$ or remark (1)[free standing] $\sin^{-1}(1.52 \sin 65^\circ)$ gives “error” (1), so refraction not possible (1)	2
		(iii) I. Diagram: Reasonable path drawn [no gross departure from law of reflection] with emergent ray in correct quadrant (1) II. 2 sensible parallel paths inside block labelled (1) Emergent ray labelled as parallel to incident ray. (1)	1 2
(c)	Any 2× (1) from: <ul style="list-style-type: none"> • minimises <u>multimode</u> dispersion [or equiv](✓) • cuts down range of path lengths (✓) • less pulse broadening or less likelihood of overlapping or more rapid data [allow: smearing and jumbling] sequence possible (✓) [not interfere or distorted] 	2	
			[13]

Question		Marking details	Marks Available
3	(a)	Electrons are emitted [from tin] (1). Electrons are negatively charged [or plate originally neutral] or electrons knocked out by photons (1) Plate left with a positive charge (1)	3
	(b)	(i) Work function: [Minimum] energy [or work] needed for an electron to escape [from metal surface] (1) (ii) $hf_{\min} = \phi$ [or by impl.] or $0 = 6.63 \times 10^{-34} f_{\min} - 7.1 \times 10^{-19}$ (1) $f_{\min} = 1.07 \times 10^{15}$ Hz (1) (iii) $1.5 \times 10^{-19} = hf - 7.1 \times 10^{-19}$ [or equiv. or by impl.] (1) $f = 1.3 \times 10^{15}$ Hz (1)	1 2 2
	(c)	(i) number per second = $\frac{0.64 \times 10^{-6} [\text{C s}^{-1}]}{1.6 \times 10^{-19} [\text{C}]}$ (ii) Number of photons per second = $4.0 \times 10^{12} \times 1200$ Multiplication by 1200 at any stage [or by impl.](1) Photon energy = 8.6×10^{-19} J [or by impl.] (1) UV energy per second = 4.1 m(1)W(1) [4.1×10^{-3} J s ⁻¹ ✓✓]	1 4
			[13]
4	(a)	(i) Ground state to level T labelled I or <i>pumping</i> (1) Level U to level L labelled II or <i>stimulated emission</i> (1) (ii) $E_{\text{phot}} = \frac{hc}{\lambda}$ [or $E_{\text{phot}} = hf$ and $f = \frac{c}{\lambda}$] [or by impl.](1) $E_{\text{phot}} = 1.9[0] \times 10^{-19}$ J (1) Energy of level U = 2.2×10^{-19} J (1) (iii) I. [Stimulated emission is triggered by an incident] photon (1) with energy 1.9×10^{-19} J [ecf but not 2.2×10^{-19}] or equal to the difference between levels U and L (1) [no ecf from incorrect identification of transition in (a)(i)] II. Photon emitted together with the original photon [accept: there are now 2 photons where there was previously 1; also accept correct answer given in I.] III. Stimulated photon and incident photon <u>in phase</u> . (iv) Promotes population inversion [between levels U and L] (1) Either less pumping needed, or population inversion needed so that stimulated emission predominates over absorption (1)	2 3 2 1 1 2
	(b)	Less energy input needed for a given [light] energy output (1) [or more efficient]	1
			[12]

Question		Marking details	Marks Available	
5	(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] <u>Peak</u> 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) $\lambda = 625 \text{ nm}$ [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 <u>arrive</u> [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 \times (1) from: <ul style="list-style-type: none"> • 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]

Question		Marking details	Marks Available
6	(a)	(i) Quark-antiquark combination [or equiv.]	1
		(ii) Only $\bar{u}d$ combination [in the 1 st generation] gives a charge of +e [or $\frac{2}{3} + \frac{1}{3} = 1$]	1
	(b)	(i) I. [$\bar{u}d + uud + udd \rightarrow uud + uud$] u numbers: LHS = 4; RHS = 4, so conserved II. d numbers: LHS = 2; RHS = 2, so conserved	1 1
		(ii) Strong force (1) Any $1 \times (1)$ of: <ul style="list-style-type: none"> • ‘high energies’ suggests strong ✓ • separate conservation of u and d ✓ • no neutrino / lepton involvement ✓ • quark regrouping / only quarks involved ✓ 	2
(c)	(i) Any intelligible method [e.g. baryon and charge conservation or u and d numbers conservation, or quark counting to give $9u+9d$ in X, or comparison with equation in (b) noting that $\pi^+ + n \rightarrow p$] (1) [or by impl.] $A = 6$ and $Z = 3$ (1)	2	
	(ii) Proton number / atomic number [accept: chemical element]	1	
			[11]
7	(a)	(i) $T = \frac{W}{260 \times 10^{-9}} (1 - \text{trans})$ [or by impl.][allow this mark even if 10^{-9} omitted] $= 11 \times 10^3 \text{ K}$ (1) ((unit))	2
		(ii) Black body [accept: non-reflecting surface / radiates <u>equally</u> in all directions]	1
	(b)	Radius is $\times 70$ so area is $\times 70^2$ [or equiv, or by impl.] (1) Temperature is $\times 2$, so T^4 is 2^4 [or equiv. or by impl.] (1) [So] Power is $\times 80\,000$ (1)	3
	(c)	Absorption [by atoms in the stellar atmosphere or in interstellar gas] of specific wavelengths from the star’s continuous spectrum [or from star’s radiation / star’s light] (1) Any $2 \times (1)$ from: <ul style="list-style-type: none"> • because photons of specific <u>energy</u> absorbed ✓ • Photon energies correspond to transitions between [atoms’] energy levels ✓ • Absorbed radiation re-emitted but in all directions ✓ 	3
			[9]