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)	$v_{air} > v_{glass}$ (1), $f_{air} = f_{glass}$ **and** $\lambda_{air} > \lambda_{glass}$ (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)	$[1.00]\sin 40^\circ = 1.52\sin\phi$ [where ϕ = angle of refraction] (1) $\phi = 25°$ (1); $\theta = 90° - 25°$ (1) = [65°]	3
		(ii)	$\sin c = \frac{1}{1.52}$ [or equiv] $c = 41°$ (1) 65° > 41° or remark (1)[free standing] **or**: $\sin^{-1}(1.52\sin 65^\circ)$ 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: • 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]**

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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)	2
		(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)	2
	(c)	(i)	number per second = $\frac{0.64 \times 10^{-6}[\text{C s}^{-1}]}{1.6 \times 10^{-19}[\text{C}]}$	1
		(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} ✓✓]	4
				[13]
4	*(a)*	(i)	Ground state to level T labelled I or *pumping* (1) Level U to level L labelled II or *stimulated emission* (1)	2
		(ii)	$E_{phot} = \frac{hc}{\lambda}$ [or $E_{phot} = hf$ **and** $f = \frac{c}{\lambda}$] [or by impl.](1) $E_{phot} = 1.9[0] \times 10^{-19}$ J (1) Energy of level U $= 2.2 \times 10^{-19}$ J (1)	3
		(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)]	2
			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.]	1
			III. Stimulated photon and incident photon <u>in phase</u>.	1
		(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
	(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] 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]

Question			Marking details	Marks Available
6	*(a)*	(i)	Quark-antiquark combination [or equiv.]	1
		(ii)	Only $\bar{u}d$ combination [in the 1st generation] gives a charge of +e [or $\frac{2}{3}+\frac{1}{3}=1$]	1
	(b)	(i)	I. [$u\bar{d} + uud + udd \rightarrow uud + uud$] u numbers: LHS = 4; RHS = 4, so conserved	1
			II. d numbers: LHS = 2; RHS = 2, so conserved	1
		(ii)	Strong force (1) Any 1 × (1) of: • '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)	$T = \frac{W}{260\times10^{-9}}$ (1 – trans) [or by impl.][allow this mark even if 10^{-9} omitted]	
			= 11 × 10^3 K (1) ((**unit**))	2
		(ii)	Black body [accept: non-reflecting surface / radiates <u>equally</u> in all directions]	1
	(b)		Radius is × 70 so area is × 70^2 [or equiv, or by impl.] (1) Temperature is × 2, so T^4 is 2^4 [or equiv. or by impl.] (1) [So] Power is × 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 × (1) from: • ….. because photons of specific <u>energy</u> abso rbed ✓ • Photon energies correspond to transitions between [atoms'] energy levels ✓ • Absorbed radiation re-emitted but in all directions ✓	3
				[9]