PH2

Question			Marking details	Marks Available
1	*(a)*	(i)	Attempt at sinusoid, right way up, passing within 1 mm of all dots	1
		(ii)	P and Q are in phase (1) Amplitude of P > amplitude of Q (1)	2
		(iii)	Q and R are in antiphase / exactly out of phase (1) Amplitude of Q = amplitude of R (1)	2
		(iv)	$\frac{\lambda}{2}$ = 0.20 [m] **or** λ = 0.40 [m] **or** by implication (1) v = 96 m s^{-1} **UNIT ecf** (1)	2
	(b)		$\frac{\lambda}{2}$ = 0.15 [m] (**or** λ = 0.30 [m]) **or** v = 96 [m s^{-1}] **ecf** from *(a)*(iv) **or** $f = \left(\frac{4}{3}\right)$ 240 [Hz] **or** by implication (1) f = 320 [Hz] but not by cancellation of errors, **ecf** on v from *(a)*(iv) (1)	2
			Question 1 total	**[9]**
2	*(a)*	(i)	$S_2Q = \sqrt{(350^2 + 120^2)}$ [mm] **or** equivalent (1) Therefore $S_2Q - S_1Q$ = (370 – 350) [mm] (1)	2
		(ii)	For any dot, path difference = $n\lambda$, **or** for P, path difference = 0 **or** any other remark relevant to the conclusion that ... (1) λ = 10 [mm] (1)	2
		(iii)	$\lambda = \left(\frac{120\text{x}30}{350}\right)$ (1) λ = 10 mm **or** 10.3 mm **UNIT** (1)	2
	(b)		With sensor in front of source **either** rotate sensor [at least through 90°] **or** interpose array of metal rods /metal grille and rotate [at least through 90°] (1) Don't accept metal grid Signal strength changes (1) Accept in words or in diagram	2
			Question 2 total	**[8]**

Question			Marking details	Marks Available
3	*(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)	$\frac{1}{400000}$ = [2.5×10^{-6} 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
			Question 3 Total	**[9]**
4	*(a)*	(i)	medium 1: 2.0×10^8 [m s^{-1}] **and** medium 2: 2.5×10^8 [m s^{-1}]	1
		(ii)	Correct use of sin 30° seen clearly (1) Rest of argument, including use of $t = \frac{d}{v}$ [**ecf** on v and on value of sin 30°, if failure to reach the stated time is noted]. (1)	2
		(iii)	BD = 2.5×10^8 **ecf** $\times$ 2.5×10^{-11} [m] [= 6.25 mm] **or** by implication (1) $\theta_2 = 38.7°$ (or 39°) **ecf** on $v = 2.5 \times 10^8$ [m s^{-1}] (1)	2
		(iv)	$1.50 \sin 30° = 1.20 \sin \theta_2$ (1) Therefore $\theta_2 = 38.7°$ (or 39°) **no ecf** (1)	2
	(b)	(i)	Use of $v = 2.0 \times 10^8$ [m s^{-1}] (1) $t = \frac{1600}{2.0\text{x}10^8}$ [s] **ecf** on v (1)	2
		(ii)	Critical angle = 76° **or** by implication (1) n_{clad} [× sin 90°] = 1.500 sin 76° **ecf** on 76° **or** by implication (1) n_{clad} = 1.455 **or** 1.46 **do not accept** 1.45 **no ecf** (1)	3
		(iii)	$\frac{AC}{AB}$ = cos 14° **or** equivalent **or** by implication (1) Δt = 0.24 μs **ecf** on v (1)	2
			Question 4 Total	**[14]**

Question			Marking details	Marks Available
5	*(a)*		[Minimum] energy needed to release [**or** eject] electron from magnesium [**or** metal **or** surface **or** solid **not** atom]	1
	(b)		$E_{k\ max} = 6.63 \times 10^{-34} \times 1.16 \times 10^{15}$ [J] – 5.9×10^{-19} [J] (1) $E_{k\ max} = 1.79 \times 10^{-19}$[J] (1)	2
	(c)		<u>Photon</u> energy < work function (1) don't accept photon energy in symbols. Accept not enough energy to liberate an electron. Don't accept $E_{k\ max}$ can't be negative. $E_{phot} = 5.4 \times 10^{-19}$[J] **accept** $f_{thresh} = 8.9 \times 10^{14}$ [Hz] (1) If negative energy award 1 mark only	2
	(d)	(i)	Planck constant. **Accept** Planck's constant **or** *h*.	1
		(ii)	[–] work function. **Accept** [–] ϕ.	1
		(iii)	f_0 **or** minimum frequency to eject electron **or** threshold frequency	1
			Question 5 Total	**[8]**
6	*(a)*	(i)	**Any 2 × (1) from:** • Monochromatic **or** same frequency **or** same wavelength • Wavefronts continuous **or** light in phase across width of beam • <u>Photons</u> in phase	2
		(ii)	Use of $E = hf$ **and** $f = \frac{c}{\lambda}$ **or** $E = \frac{hc}{\lambda}$ (1) 1.87×10^{-19} [J] (1)	2
		(iii)	1.3×10^{20} [s^{-1}] **ecf**	1
		(iv)	Downward arrow from U to L (1) 2.29×10^{-19} J (or 2.3×10^{-19} J) (1) **ecf**	2
	(b)		[Passing] photon stimulates electron to drop <u>from U to L</u> (1) Emitting another photon (1) **Any 2 × (1) from:** • Process may happen repeatedly (or equivalent) as photons traverse cavity • Population inversion [between U and L] needed for stimulated emission to predominate over absorption • Pumping to P and drop to U brings about inversion • Level L self-emptying so less pumping needed **or** population inversion easier to accomplish • In phase with **or** travelling in the same direction as **or** polarised in the same direction as **or** identical to passing photon • Stimulated photon must have an energy of 1.87×10^{-19} J or equivalent	4
			Question 6 Total	**[11]**

Question			Marking details	Marks Available
7	*(a)*	(i)	$\lambda_{\text{peak}} = \dfrac{2.90\text{x}10^{-3}}{9900}$ [m] **or equivalent** (1) $\lambda_{\text{peak}} = 293 \times 10^{-9}$ [m] (1)	2
		(ii)	Peak between 280 and 300 nm (1) Curve goes through origin [with zero gradient at origin] and is consistent with approaching zero at very long wavelengths (1)	2
		(iii)	Blue accept white **or** violet **or** purple	1
	(b)		$A = \dfrac{L}{\sigma T^4}$ with A as subject, with symbols **or** data **or** 1.84×10^{19} m^2 (1) Attempt to use $A = 4\pi r^2$ and $d = 2r$ **or** $A = \pi l^2$ (1) $d = 2.4 \times 10^9$ m **ecf** on slips of 2^n or 10^n if already penalised (1)	3
	(c)	(i)	Absorption **accept** excitation **Don't accept** pumping	1
		(ii)	Dark / black lines crossing **or** missing wavelengths [continuous] spectrum **or** coloured background	1
		(iii)	B almost absent **and** any reference to populations of levels (1) First excited state not populated [so no transitions start here] **or** all electrons in ground state (1)	2
			Question 7 Total	**[12]**
8	*(a)*	(i)	$\text{uud} + \text{uud} \rightarrow \text{uud} + \text{udd}$ (1) $+\text{u}\bar{\text{d}}$ (1)	2
		(ii)	1 + 1 > 1 + 1 + 0 (all numbers must be shown) **or** equivalent	1
		(iii)	Strong because no [photons (gammas) or] neutrinos **or** no flavour changes	1
		(iv)	Charge **or** momentum **or** energy **or** strangeness Accept up quark number **or** down quark number	1
	(b)	(i)	0 + 0 > 0 + (–1) + 1 (all numbers must be shown)	1
		(ii)	Weak interaction **accept** fusion (1) Takes place in the Sun [accept stars] (1) Part of the process whereby we get sunlight **or** energy **or** equivalent (1)	3
			Question 8 Total	**[9]**