PH2

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 at slits (1) Without which waves wouldn't overlap (or superpose) (1)	2
			Question 1 total	**[12]**

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]**

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	*(a)*	(i)		sin $\theta = 1.331$ sin 40.36° **or** by implication (1) 60° (1) Accept 59.5 °	2
		(ii)		*Not* total + attempt at justification even if not worth next mark (1) **For the 2nd mark either:** Light got in at P or gets out at R, so can get out at **Q** [as angles in water the same] **or** 1.331 sin 40.36 reshown to be < 1 **or** $C = 49°$	2
		(iii)		$v_{violet} < v_{red}$ + attempt at justification even if not worth next mark e.g. violet bends more (1) **For the 2nd mark either:** Violet must have larger *n* therefore smaller *v* **or** bending caused by light travelling more slowly in water than in air, so violet must travel most slowly.	2
	(b)	(i)		Speed in glass = $\frac{360}{1.75 \times 10^{-6}}$ [= 2.06×10^8 m s^{-1}] **or** by implication (1) $n = 1.46$ (1) must be to 3 sig figs	2
		(ii)		$C = 75°$ **or** by implication (1) 1.46 sin 75° = n_{clad} [sin 90°] [Accept 1.5 for 1.46] **or** by implic (1) $n_{clad} = 1.41$ [1.45 if n_{core} taken as 1.50] (1) **Award 1 mark only for:** 1.46 sin 15° = n_{clad} [sin 90°]	3
		(iii)		Larger angles give longer propagation times. [Accept longer dists.](1) So each pulse spread out over time on arrival **or** each pulse is less spread out if the angles are restricted (1) So pulses might overlap (Accept pulses muddled) **or** overlap/muddling of pulses less likely if angles restricted. (1) **Award 1 mark only** for less multimode dispersion	3
				Question 4 Total	**[14]**

Question				Marking details	Marks Available
5	*(a)*	(i)		[Maximum] kinetic energy *of* *emitted electron[s]*	1
		(ii)		Photon energy	1
		(iii)		[Minimum] energy needed to release [**or** eject] electron from surface [**or** metal **or** solid]	1
	(b)			$\phi = hf_0$ **or** by implication (1) $f = 3\ f_0$ (1)	2
	(c)	(i)	I	attempt at gradient calculation even if slips, e.g. in 10^n (1) $h = 6.8\ [\pm 0.2] \times 10^{-34}$ [J s] (1)	2
			II	$\phi = 3.1\ [\pm 0.1] \times 10^{-19}$ [J] Don't accept a negative ϕ	1
		(ii)		$\phi_{\text{sodium}} = \phi_{\text{caesium}} + 0.6$ [or 0.7] $\times 10^{-19}$ J **or** parallel line **or** use of equation (1) $\phi_{\text{sodium}} = 3.7\ [\pm 0.3] \times 10^{-19}$ [J] **ecf** (1)	2
				Question 5 Total	**[10]**
6	*(a)*	(i)		$\Delta E = 2.66 - 2.21 \times 10^{-18}$ J [$=0.45 \times 10^{-18}$ J] (1) Use of $[\Delta]E = hf$ **and** $f = \dfrac{c}{\lambda}$ **or** $[\Delta]E = \dfrac{hc}{\lambda}$ (1) 440 n[m] **No ecf** except on **arithmetical slip** in ΔE (1)	3
		(ii)		$\dfrac{15\text{mW}}{\Delta E}$ **ecf** [attempted] (1) 3.3×10^{16} [s^{-1}] **ecf** (1)	2
		(iii)		Pumping energy taken as 3.07×10^{-18} J (1) 15 % **Accept** 14 % (1) **ecf** on photon energy	2
	(b)	(i)		Passing photon causes drop from U to L (1) With emission of another photon (1) Don't accept absorption of incident photon and emission of 2. Process happens repeatedly **and** increases photon number (unless already made clear for single event). (1)	3
		(ii)		Stimulated emission events more probable (or equivalent) (1) Absorption events less probable (1)	2
				Question 6 Total	**[12]**

Question			Marking details	Marks Available
7	*(a)*		$r = 3.07 \times 10^{10}$ m **and** $L = 1.99 \times 10^{29}$ W **or** by implication (1) $L = \sigma 4\pi r^2 T^4$ (1) Correct algebra including fourth-rooting (1) $T = 4\,150$ K **UNIT mark** (1) [Take 5 865 K arising from $A = \pi r^2$ as **ecf**] If only Sun considered $T = 5\,776$ K **award 3 marks only**	4
	(b)		Attempted use of λ_{max} = 700 - 750 [nm] in Wien's Law (1) 3 867 – 4 140 [K] (1)	2
	(c)		Black body absorbs all [electromagnetic] radiation (accept light) falling on it. [Accept: Black body emits more radiation per second [or equivalent] [at every wavelength] than any other body at same temperature. **Don't accept** it is a perfect emitter.	1
	(d)		Spectrum peaks in red or equivalent. Accept infra-red. (1) $r = 44.2\ R_\odot$ is sufficient. Must compare with the Sun. (1)	2
			Question 7 Total	**[9]**
8	*(a)*	(i)	A meson is a quark-antiquark combi; (**don't accept** 2 quark combination) a baryon is a 3 quark combi	1
		(ii)	Charge = $+(\frac{2}{3})[e] + (\frac{1}{3})[e] = +1[e]$ **or** equivalent	1
	(b)	(i)	0 = -1 + 1 or equivalent (which does not include 0 = +1 + −1)	1
		(ii)	Weak; suggested by long decay time **or** Weak; indicated by neutrino involvement **or** Weak; indicated by change of quark flavour **Don't accept:** No quark involvement / (only) lepton involvement	1
	(c)	(i)	1 + 2 + 1 = 2 + 2 **or** equivalent (e.g. 1 + 3 = 2 + 2)	1
		(ii)	**2 × (1) from:** • Mesons decay • Strong force is short-range • π^+ and H repel • Large energy needed to regroup groups **For the 3rd mark:** The relevance of one of the above points must be argued	3
			Question 8 Total	**[8]**