Question			Marking details	Marks Available
1	*(a)*	(i)	$v = \frac{0.15\text{ m}}{0.0030\text{ s}}$ (1) [or equiv. or by impl.] = 50 m s^{-1} ((**unit**)) (1)	1
		(ii)	**Either**: T = 0.012 s (1) $f = \frac{1}{T}$ [or by impl.] (1) = 83 Hz (1) **Or**: λ = 0.60 m (1) $f = \frac{v}{\lambda}$ [in this form – or by impl] (1) = 83 Hz (1) [e.c.f. on v from (i)]	2
	(b)	(i)	Two of: 0.90 m, 1.20 m, 1.50 m, 1.80 m	1
		(ii)	I. Varies [smoothly] between maxima and minima / zeroes (1); Maxima midway between minima [**or** maxima 0.30 m / λ/2 apart; minima 0.30 m / λ/2 apart] (1) II. No – for a progressive wave the amplitude is constant along string [or falls gradually]	2 1
	(c)		Waves reflected by wall (1) Reflected wave interferes with wave straight from generator [or equivalent, e.g. the two waves travelling in opposite directions interfere] (1) Nodes occur where interference is destructive [accept: where the two waves cancel] (1)	3
				[12]
2.	*(a)*	(i)	$\lambda = \frac{2.0 \times 1.8}{12.0}$ m (1) [or by impl.] = 0.30 m (1)	2
		(ii)	Reflected sound [would affect the pattern].	1
	(b)		Previously, sound from the two speakers superposed / interfered [or by implication](1) destructively [accept: cancel] at that point (1) as it arrived in antiphase [accept: exactly out of phase] (1)	3
	(c)		Quiet spots are where loud sounds used to be [or equiv.]	1
	(d)	(i)	$y = \frac{D\lambda}{a}$ (1) thus [or other qualification, e.g. recalculation] y halves (1) [or equiv] [because a doubles] [Qual. answer "y decreases" + correct qual reasoning → 1 mark]	2
		(ii)	Wavelength halves [or equiv] (1) Separation halves (1)	2
				[11]

Question			Marking details	Marks Available
3	*(a)*	(i)	$[1.00]\sin x = 1.52\sin 25^\circ$ [or by impl, or equiv with data inserted] (1) $\sin x = 0.642$ [or by impl.] (1) $x = 40°$ (1)	3 1
		(ii)	65°	
		(iii)	**Either:** $[1.52\sin c = 1.00\sin 90^\circ$ so] $c = 41°$ (1). 65°>*c* so no escape (1) [No penalty for omission of last point if first mark awarded] **Or:** $\sin^{-1}\left(1.52\sin 65^\circ\right)$ / 1.38 (1) doesn't exist (1) [so refraction doesn't occur].	2
		(iv)	I. total internal reflection [not: TIR, total or internal] reflection] II. equal	1 1
	(b)	(i)	beam confined to small angle to axis [or damage avoided to reflecting surface] [accept: fewer int. refl^s]	1
		(ii)	small (1); equal to a few wavelengths (1)	2
		(iii)	light propagates parallel to axis [or without being reflected **or** along only one path]. [Not – 'only one beam']	1
				[12]
4.	*(a)*	(i)	When e-m radn^n [accept: light, u-v, photons] [of high enough frequency] falls on a surface [or metal] (1) electrons are emitted (1)	2
		(ii)	Photon knocks out electron [or not] **or** gives energy to e(1). Photon carries energy *hf* (1). Electron needs [a minimum] energy ϕ to escape (1) Remainder of photon's energy given to electron as KE (1) [KE_{max} corresponds to minimum energy ϕ to escape]	4
	(b)	(i)	$E_{k\,max} = 6.63\times10^{-34}\times7.99\times10^{14} - 4.97\times10^{-19}$ J (1) [or photon energy shown to be greater than ϕ] $E_{k\,max} = 3.27\times10^{-20}$ J (1)	2
		(ii)	Photon energy = 4.47×10^{-19} J < ϕ [or equiv], so no emission	1
		(iii)	3.27×10^{-20} J(1) Photons don't co-operate releasing electron [or equiv] (1)	2
				[11]

Question			Marking details	Marks Available
5.	*(a)*	(i)	Fraction $= \frac{\left[3.297\times10^{-18} - 2.983\times10^{-18}\right](1)}{3.297\times10^{-18}} = 0.095$ (1) [accept $\frac{2}{21}$]	2
		(ii)	$\lambda = \frac{hc}{E_{\text{photon}}}$ (1) [or $\lambda = \frac{c}{f}$ **and** $f = \frac{E_{\text{photon}}}{h}$] (1) [or by impl.] $\lambda = 633$ nm (1)	2
	(b)	(i)	A[n incident] photon (1) of energy equal to ($E_U - E_L$) (1) [or equiv.]	2
		(ii)	Now 2 photons [original and emitted] [or by impl.] (1) Photons in phase / travel in same dir^n / have same f, λ or E (1)	2
		(iii)	Fewer electrons in L than U (1) [accept pop^n inversion] [So] stimulated emission commoner than absorption (1) [**or** less pumping needed]	2
		(iv)	Mirrors cause light to traverse cavity [or HeNe etc] to and fro (1) increasing chances of stimulated emission / increases amplification / increases intensity (1) [or any other correct point, e.g. resonant selection of particular λ]. [No credit for light escaping from r.h. mirror]	2
				[12]
6	*(a)*		A surface / body that absorbs all radiation incident / falling on it.	1
	(b)		$\lambda_{\text{l max}} = 250$ [± 10] nm (1) $T = \frac{W}{\lambda_{\text{l max}}}$ (1)[thus or by impl.] = 11500 K (1) [e.c.f. on $\lambda_{\text{l max}}$]	3
	(c)	(i)	$A = \frac{\text{power}}{\sigma T^4}$ [transposition at any stage] (1) $= \frac{2.53\times10^{31}}{5.67\times10^{-8}\times11500^4}$ (e.c.f.) (1) = 2.55 × 10^{22} m^2 ((**unit**)) [e.c.f. on T, e.g. 10^4 K → 4.46 × 10^{22} m^2]	3
	(d)	(ii)	**Either** $A_{\text{Sun}} = 4\pi r_{\text{Sun}}^2$ [or by impl.] (1) = 6.1 × 10^{18} m^2 « A_{Rigel} (1) e.c.f over slips in 4 or π **Or** $r_{\text{Rigel}} = A_{\text{Rigel}} / 4\pi$ (1) = 4.5 × 10^{10} m » r_{Sun} (1) e.c.f over slips in 4 or π	2
		(iii)	Spectral intensity higher at 400 nm than at 700 nm (1) 400 nm is at violet end of visible spectrum (1) [or converse] So Rigel not a red giant [Not a freestanding mark] [NB – "Peak closer to violet than red," unsupported by figures, loses first mark]	3
				[12]

Question			Marking details	Marks Available
7.	*(a)*	(i)	e	1
		(ii)	zero	1
	(b)		baryon	1
	(c)		p = uud (1) u quark number for x = 4 – 3 [= 1][or equiv] (1) d quark number for x = 2 – 1 – (–1) [=2] [or equiv] (1) So x is a neutron (1) [or Δ^0]	4
	(d)		Lepton number zero before and after	1
	(e)		Any 1 × (1) of • High KE means short contact time ✓ • u and d numbers separately conserved [so not weak] ✓ • no γ involvement [suggests not e-m] ✓ So strong (1)	2
				[10]