Question			Marking details	Marks Available
SECTION B				
7	*(a)*		Correct substation into speed = $\frac{\text{distance}}{\text{time}}$ (1) $\left[t = \frac{8\times10^8}{3\times10^8}\right]$ = 2.67 s (1) [Accept fraction $^8/_3$]	2
	(b)		After travelling both ways extra distance is $\lambda/2$ (1) Hence destructive **<u>interference</u>** or **<u>antiphase</u> / <u>completely out of phase(1)</u>**	2
	(c)		use of $n\lambda = d\sin\theta$ e.g. $7\times640=815\sin\theta$ (1) $d = 1.23\times10^{-5}$ m (1) [accept $^1/_{81\,500}$] any 2 of $\theta_1 = 2.99$, $\theta_2 = 5.99$, $\theta_3 = 9.00$ (1) Sensible comment, e.g. true, nearly true **<u>or</u>** wrong[if qualified, e.g. separation increases slightly etc.] [e.c.f.](1) [1st mark required for 3rd mark to be awarded]	3
	(d)		$N\times\frac{1}{2}mc^2 = \frac{3}{2}nRT$ **<u>or</u>** $\frac{1}{2}mc^2 = \frac{3}{2}kT$ (1) [or by impl.] Algebra $\overline{c^2} = \frac{3kT}{m}$ (1) [or by impl.] $\sqrt{\overline{c^2}} = \sqrt{\frac{3\times1.38\times10^{-23}\times300}{23\times1.66\times10^{-27}}}$ = [570.35 m s^{-1}] (1) NB. Mixing up *m*/*M* and *n* / *N* with correct algebra → 1.	3
	(e)		Any 3 × (1) from • 0.97 GHz corresponds to Doppler shift [due to 570 m s^{-1}] / red shift / blue shift✓ • Sodium atom moving towards laser we get resonant absorption / wavelength [or frequency or energy] is exactly right ✓ • ∴ slowing down is tuned or more probable etc ✓ • If atom moving away there is a shift <u>away from</u> resonance / absorption less probable ✓ [NB “more strongly absorbed”, “Doppler-shifted up 0.97 GHz”, “Match the resonance frequency” are phrases in the passage.]	3

Question			Marking details	Marks Available
SECTION B				
7	*(f)*		Photon energy = $\dfrac{hc}{\lambda}$ **or** *hf* and $c = \dfrac{f}{\lambda}$ (1) [$=3.825\times10^{-19}$ J] No. of photos/sec = power $\div$ photon energy (1.93×10^{10}) (1) Momentum of 1 photon = $h/\lambda = 1.275\times10^{-27}$ kg ms^{-1} (1) [indep. mark] Force = $1.93\times10^{10}\times1.275\times10^{-27}\times\sin 30 = 1.23\times10^{-17}$ N (1) [Slip with nm / m → allow ecf] **Alternative Method**: Force = $\dfrac{\text{Power}}{c}$ (1) [or by impl.] = 2.467×10^{-17} N (1) Force upwards (on particle) = Force down on light **or** reference to *F* = rate of change of momentum(1) $=2.467\times10^{-17}\times\sin 30^\circ = 123\times10^{-17}$ N (1)	4
	(g)		<u>**Good**</u> • Lasts long time [accept: sustainable / renewable, lasts 000s years] • No nuclear waste [accept: no harmful waste but **not** "no waste"] • High concentration of energy e.g. per kilogram • No carbon emissions / use less non-renewables • Abundance of fuel / deuterium [and lithium] [**not** tritium → sif] • Could be profitable soon <u>**Bad**</u> • Tritium from where / needs generation • Does not work yet / huge energy in for little out [needs slightly more than "hasn't got to breakeven"] • Induced nuclear waste. • Set-up / research costs • Possible military use Any 2 or 3 advantages and/or disadvantage → 1 4 statements with at least 1 of each (1)	2 **[20]**