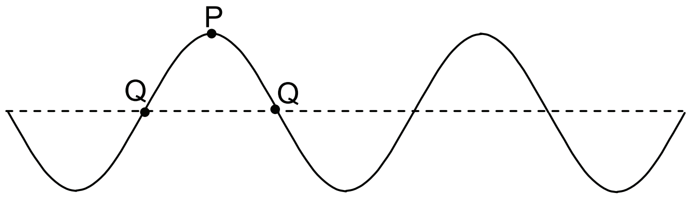
Question			Marking details	Marks Available
3	*(a)*	(i)	**Graph**: Straight line through the origin [any reasonable gradient]	1
		(ii)	Snell's	1
	(b)	(i)	$n_g \sin\theta_g = n_{air} \sin\theta_{air}$ (1) [or by impl.] $n_g \left[= \frac{\sin 64^\circ}{\sin 32^\circ} \right] = 1.70$ (1) $n_g = \frac{1}{\sin c}$ (1) $\therefore$ $c = 36\ °$ (1) Accept: $_{glass}n_{air} = 0.59$ (2) then 0.59 = sin c (1) $c = 36\ °$ (1)	4
		(ii)	critical angle	1
		(iii)	speed of light in this glass = $\frac{3.0\times10^8}{1.7\text{e.c.f.}} = 1.76\times10^8\ \text{m s}^{-1}$ (1) radius = speed × time [**or** 1.76×10^8e.c.f × 0.34×10^{-9}] (1) [N.B. e.c.f. also applies to $3.0 \times 10^8\ \text{m s}^{-1}$] radius = 6 cm (1)	3 **[10]**
4.	*(a)*		Reasonable looking graph with: high central peak (1) width of peaks corresponding to diagram (approx) (1) minima on baseline (1) and subsidiary maxima (1)	4
	(b)	(i)	both waves diffracted by double slit began together at single slit – broader initial source would produce overlapping pattern **[accept** to act as a coherent source for the double slits]	1
		(ii)	$\lambda = \frac{ay}{D}$ (1); [or by impl.] $D = \frac{0.5\times10^{-3}\times2.0\times10^{-3}}{5.9\times10^{-7}}$ (rearranging + unit conversion) (1) D = 1.7 m (1) [e.c.f. for incorrect powers of 10]	3
		(iii)	Correct explanation in terms of path difference from slits(1) arrive completely (180°) out of phase (1) **Or** [Vector] sum of displacements of waves = 0 [for 2nd mark] [Just: "destructive interference" → 0 marks]	2 **[10]**

Question			Marking details	Marks Available
6.	*(a)*	(i)	[Progressive wave]: amplitude remains constant (1) [Stationary wave]: amplitude increases and decreases (rises and falls) (1) [or: max at antinodes and min at nodes] [Mention of nodes and antinodes not enough]	2
		(ii)	Energy flows in one direction (or away from source) for a progressive wave (1). No energy flow (or energy is 'trapped') for a stationary wave (1)	2
	(b)			
		(i)	Q labelled in one of the places shown	1
		(ii)	Wavelength: <u>Minimum</u> (1) distance between 2 points [oscillating] in phase [allow peak to peak distance] (1) $\lambda = 1.20$ m (1)	3
		(iii)	$c = f\lambda$ (1) $f = \frac{1}{0.05} = 20$ Hz (1) $c = 20 \times 1.2$ (e.c.f.) $= 24$ m s^{-1} (1) [accept answer based on $c = \frac{\lambda}{T}$]	3
		(iv)	Distance travelled by P over 1 cycle = 0.08 m (1) Speed = $\frac{0.08\text{e.c.f.}}{0.05} = 1.6$ m s^{-1} (1) [NB e.c.f. only on incorrect attempt at calculating distance travelled over 1 cycle. No e.c.f. for e.g. 1.20 m [i.e. λ] or 0.2 m]	2
	(c)	(i)	Node labelled	1
		(ii)	3 points in phase labelled [can be within one half wavelength]	2
		(iii)	$\lambda = 1.2$ m (1) speed = $1.2 \times 10.4 = 12.5$ m s^{-1}. (1)	2
		(iv)	λ halved justified in terms of number of loops being doubled(1) c does not change (1) because $c = \lambda f$ (1)	3
				[20]

Question			Marking details	Marks Available
6	*(a)*	(i)	$\frac{\Omega m^2}{m}[=\Omega m]$	1
		(ii)	$R=\frac{\rho l}{A}$ (1) [transposition at any stage) = $4.9\times10^{-5}\,\Omega$ (1)	2
		(iii)	• R << resistance of connecting wires • Can't make contact over a whole opposite faces • Meters can't read such a low resistance [or small pd and/or too high current] any 2 × (1)	2
		(iv)	$l=\frac{AR}{\rho}$ (1) [transposition at any stage] $A = 1.26\times10^{-7}\,m^2$ (1) l = 0.77 m (1) [1 mark penalty for slips of factors of 4 or 10^n]	3
	(b)	(i)	Parallel combination: $R=\frac{6\times3}{6+3}$ or $\frac{1}{R}=\frac{1}{6}+\frac{1}{3}$ **or** by impl. (1) $R = 2.0\,\Omega$ Overall resistance = 2.0 + 3.0 Ω [e.c.f. on $R_{//}$]	3
		(ii)	I. 1.2 A e.c.f II. 3.6 Ve.c.f. III. V across // combination = 2.4 V (1) e.c.f. I_2 = 0.40 A (1)	1 1 2
	(c)	(i)	I. 2.0 V II. 4.0 V	1 1
		(ii)	I. increase (1) higher I, so higher V across bottom 3.0 Ω (1) **or** bottom 3.0 Ω larger fraction of total resistance **or** quantitative [2.4 V] II. decreases because higher I so higher V across top resistor leaving less for the bottom two. **or** quantitative [3.6 V] **or** equivalent	2 1 **[20]**

Question			Marking details	Marks Available
7	*(a)*	(i)	Maximum kinetic energy of an electron (1) emitted from a surface [**or** metal **or** material] (1)	2
		(ii)	energy of [incident] photon	1
		(iii)	[Minimum] energy needed to release an electron from the surface [**or** metal **or** material]	1
	(b)	(i)	No electrons emitted.	1
		(ii)	$\frac{\Delta(\text{KE}_{\text{max}})}{\Delta f}$ attempted (1) Correct apart from slips, e.g. in powers of 10 (1) 6.7 [± 0.2] × 10^{-34} J s (1)	3
		(iii)	I. The Planck constant / Planck's constant II. Comparison with $y = mx + c$	1 1
		(iv)	Line extrapolated **or** $W = hf$ cited **or** correct substitution of data into Einstein's equation. (1) 3.1 [± 0.2] × 10^{-19} J (1) N.B. '–' sign penalised.	2
		(v)	Division of any energy by e (1) 0.59 [± 0.03] V (1)	2
		(vi)	Line drawn on graph to the right of the caesium line (1) of the same slope (1)	2
	(c)		Target labelled as "thin sample of [poly]crystalline material / metal / graphite"	1
			Concentric (1) [bright] circles (1) [accept: bright circles with dark in between for both marks].	2
			Diffraction [**or** interference]	1
				[20]