Question			Marking details	Marks Available
1	*(a)*	(i)	$I \propto V$ (1)	
			Providing the temperature / physical conditions remain constant (1)	2
		(ii)	V A^{-1} circled	1
	(b)	(i)		

Switch combination	P	Q	S	
X open, Y open	On	On	Off	
X closed, Y open	Off	On	Off	(1)
X open, Y closed	On	On	On	(1)
X closed, Y closed	Off	On	On	(1)

3

(ii) Either $R = \frac{9}{0.18}$ (1) (= 50 Ω) → $R_P + R_Q = 50$ (1)

R_{each} buzzer = 25[Ω] (1) ecf between 2nd and 3rd marks

Or $R = \frac{4.5\ (1)}{0.18}$ (1) = 25[Ω] (1) — 3

(iii) $R_{Total} = 16\frac{2}{3}$ [Ω] (1) $I = \frac{9}{16\frac{2}{3}} = 0.54$ [A] (1) — 2

ecf from (b)(ii) / no ecf for R_{Total}

(iv) Either ecf from (b)(ii) or (b)(iii) or both

$P_S = \left(\frac{2}{3} \text{ x } 0.54\right)^2$ x 25 (1) $P_S = 3.24$ [W]

$P_Q = \left(\frac{1}{3} \text{ x } 0.54\right)^2$ x 25 (1) $P_Q = 0.81$ [W]

Or

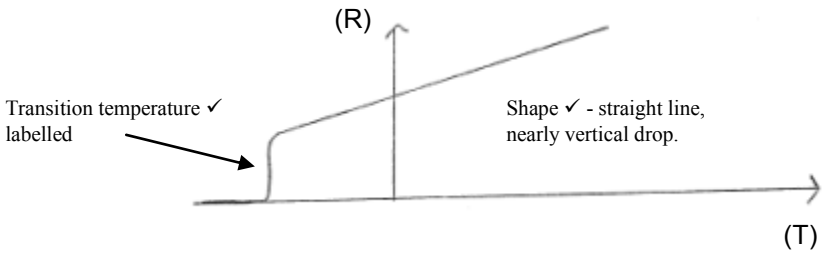
$P_S = \frac{9^2}{25}$ (1) = 3.24 [W] $P_Q = \frac{4.5^2}{25}$ (1) = 0.81 [W]

Or

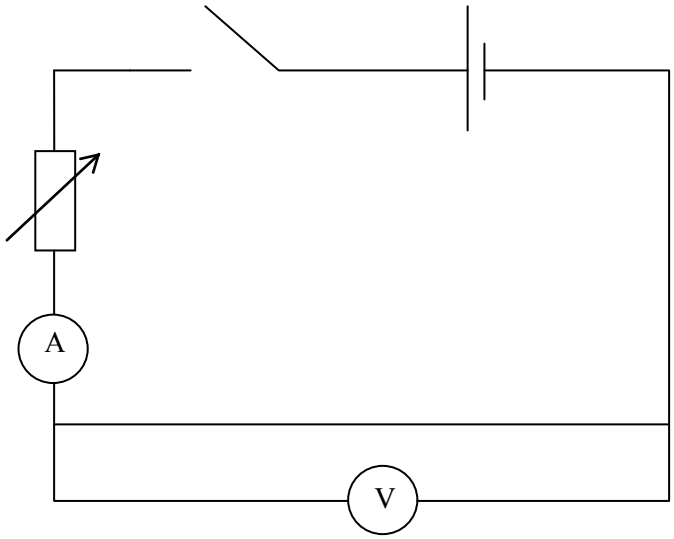
$P_S = \frac{2}{3}$ x 0.54 x 9 (1)= 3.24 [W] $P_Q = \frac{1}{3}$ x 0.54 x 4.5 (1) = 0.81 [W]

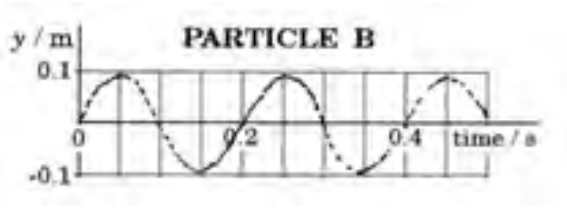
→ $\frac{3.24}{0.81} = 4$ (1) or any correct algebraic solution = 3 marks — 3

Question 1 total — [14]

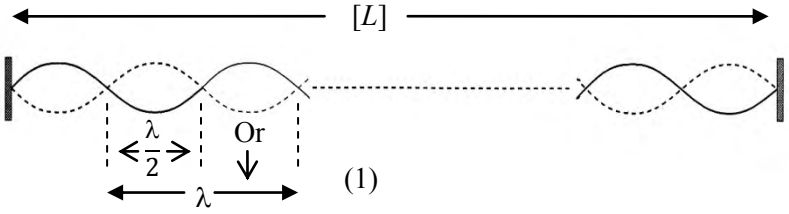
Question			Marking details	Marks Available
2	*(a)*		A <u>material</u> with <u>zero/negligible</u> resistance	1
	(b)	(i)	Transition temperature (accept critical temperature)	1
		(ii)	 If axes labelled, must be correct.	2
		(iii)	0 / negligible / almost zero	1
	(c)		Collisions between <u>free/delocalised/flowing/conducting</u> electrons and ions/atoms in lattice/atoms/particles (1) increase vibrations of ions /atoms / particles or electrons transfer <u>KE</u> to ions (1)	2
			Question 2 Total	[7]

Question			Marking details	Marks Available
3	*(a)*	(i)	<u>12</u> Joules per coulomb (1)	
			Supplied from cell / source / battery / chemical to electrical (1)	2
		(ii)	Energy lost in the resistance of cell	1
	(b)		$\left\{\frac{3.6(1)}{120}\right\}$ = 0.03 [Ω] (1)	2
	(c)		$I = \frac{12}{0.03}$ = 400 [A] ecf from (b)	1
	(d)	(i)	Q = 3 x [(16 x 60^2) or 57 600 (1)]	
			= 172800 [C] (1)	2
		(ii)	$t = \frac{172,800}{120}$ = 1440 seconds / 24 mins UNIT mark	1
			Allow ecf from (d) (i)	
			Question 3 Total	[9]

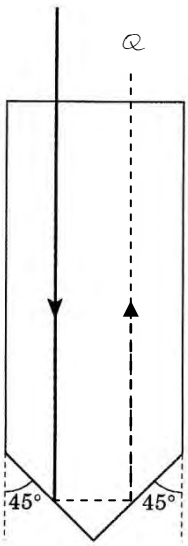
Question			Marking details	Marks Available
6	*(a)*	(i)	 Circuit (without voltmeter and ammeter) (1) Voltmeter and Ammeter correctly positioned (1)	2
		(ii)	$R = \frac{10}{0.9}$ = 11.11 [Ω] (1) $A = 3.14\text{x}10^{-8}$ [m^2] (1) $\rho = \frac{11.11 \text{ x } 3.14\text{x}10^{-8}}{3.2}$ (1) substitution $\rho = 1.09\text{x}10^{-7}$ [Ω m] (1) ecf for R and A	4
		(iii)	Platinum and Tin	1
	(b)		$\rho = \frac{0.74\text{x}10^{-3}}{(3.14\text{x}10^{-8} \text{ x } 3.2)(1)} = 7365$ [kg m^{-3}] (1) ecf for A Tin (1) ecf from density value	3
			Question 6 Total	[10]

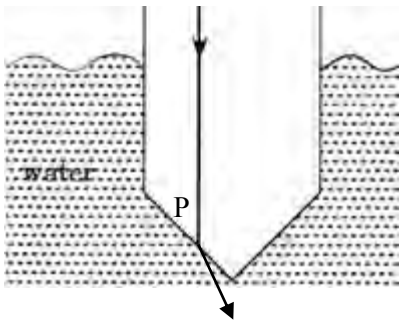
Question			Marking details	Marks Available
1	*(a)*	(i)	I. 2.0 [m] / 2.5 or <u>clear</u> equivalent	1
			II. The same	1
		(ii)	I. 5.0 Hz / s^{-1} UNIT	1
			II. 	
			Same *f* and *A* (1) Delayed by $\frac{1}{4}$ cycle (1)	2
		(iii)	4.0 [m s^{-1}] ecf	1
	(b)		Statement that *f* doesn't change (1), or working based on this principle (e.g. *v* = 5.0 [Hz] x 0.60 [m]) *v* = 3.0 [m s^{-1}] (1) ecf	2
			Question 1 total	[8]

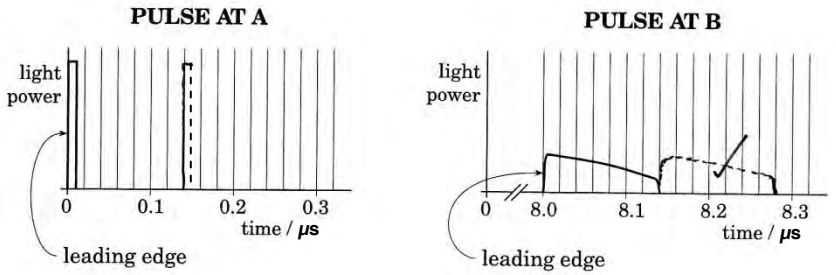
Question			Marking details	Marks Available
2	*(a)*		Waves arrive in phase at P. (1) Accept twin graphs: displacement along paths or displacement versus time at P.	
			This occurs if path difference = [0], λ, 2λ …… (1) Accept $n\lambda$	2
	(b)	(i)	Insertion of *a*, *D* and *y* into $\lambda = \frac{ay}{D}$, <u>even if powers of 10 incorrect</u>. (1)	
			λ = 600 n[m] (1)	2
		(ii)	Beams (fringes, orders) :	
			brighter / sharper or more defined or narrower / further apart / slit separation more accurately known (Any 2 x (1))	2
			Question 2 total	[6]

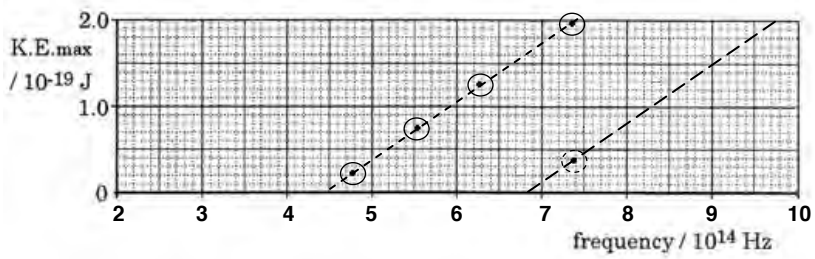
Question			Marking details	Marks Available
3	*(a)*		 (1) Convincing algebra, e.g. $n\frac{\lambda}{2} = L$ (1)	2
	(b)	(i)	When λ = 820.0 nm, $\frac{2L}{\lambda} = 500$ (1) When λ = 821.0 nm, $\frac{2L}{\lambda} = 499.4$ (1) (Give 1 mark if same arithmetical error in both)	2
		(ii)	n = 499.00 (1) ecf [or by implication] λ = 821.60 [nm] (1) No mark if previous mark not given.	2
	(c)		Less amplitude [or fewer photons…] reflected back from [partially reflecting] mirror than arrive at it. (1) + (1) of the following: • Mirror not a proper node • Amplitudes of progressive waves travelling in opposite directions not equal. (Except near fully reflecting mirror).	2
			Question 3 total	[8]

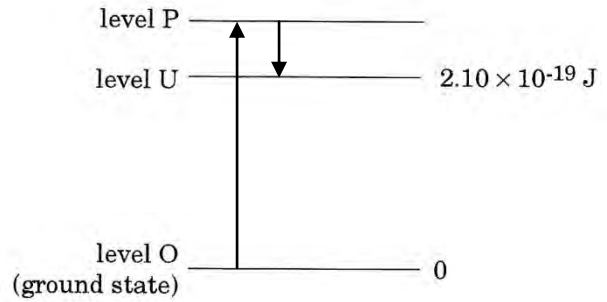
Question			Marking details	Marks Available
4	*(a)*	(i)	$1.55 \sin c = 1.00 \sin 90°$ (1) [or equivalent, or by implication]	
			$c = 40°$ (1)	2
		(ii)	First reflection (1) No ecf	2
			Rest of path (1)	
	(b)	(i)	$1.55 \sin 45° = 1.33 \sin w$ (1) [or equivalent, or by implication]	
			$w = 56°$ (1)	2
		(ii)	Bends as shown	1
		(iii)	[Sensor at] Q receives more light when water level drops and exposes lower end of rod to the air. No ecf if paths badly wrong.	1
			Question 4 Total	[8]





Question			Marking details	Marks Available
5	*(a)*	(i)	$d = v \times t$ (1) [Attempt to use, or by implication] $v = \frac{3.00 \times 10^8}{1.50}$ [m s^{-1}] (1) d = 1600 [m] (1) [Omission of n (giving 2400 [m]) loses 1] Arithmetical error loses 1 mark.	3
		(ii)	Zig-zag routes [take] longer than straight. (1) (1) For one of the following: • Good diagram (angles equal by eye) • A continuous range of zig-zag routes, all of different lengths	2
	(b)	(i)	0.14 [μs] [± 0.02μs]	1
		(ii)	 1 mark for the correct pulse on each graph. ecf from (b)(i)	2
			Question 5 Total	[8]

Question			Marking details	Marks Available
6	*(a)*	(i)	Maximum k.e. of <u>emitted / photo electrons</u>	1
		(ii)	Energy of a photon[s]	1
		(iii)	[Minimum] energy needed to remove electron [from surface]. Don't accept from an atom	1
	(b)	(i)	I. Gradient calculation attempted (1) – no penalty for wrong powers of 10. $6.6 [\pm 0.3] \times 10^{-34}$ [J s] (1) <u>agreeing with working</u>	2
			II. $f_{thresh} = 4.4 \times 10^{14}$ Hz (1) $[\pm 0.1 \times 10^{14}$ Hz] <u>or</u> valid algebraic method $\phi = 2.9 \times 10^{-19}$ J UNIT (1) ecf	2
		(ii)	I.  Correct point (1), parallel line (1)	2
			II. Ultraviolet [or UV]	1
			III. Lithium has higher work function / needs more energy to remove an electron	1
			Question 6 Total	[11]

Question			Marking details	Marks Available
7	*(a)*	(i)	P and U : zero or very low and / or O : 100%	1
		(ii)	Absorption (accept excitation) (1) : electron promoted from O to U (1)	2
	(b)	(i)	More electrons in U than O or more electrons in higher level	1
		(ii)		1
		(iii)	Incident (or by implication) photons (1) causes an electron to drop (1). Emitting photon: so two photons where one previously (or by implication) (1). (1) For one of the following: • Atom / electron drops [from U] to O. • Incident photon energy must be 2.10 x 10^{-19} J or equivalent • Process happens repeatedly as photons traverse cavity to and fro • Stimulated photon in phase with incident photon	4
		(iv)	$\lambda = \frac{hc}{\Delta E}$ or $\lambda = \frac{c}{f}$ and $f = \frac{\Delta E}{h}$ or equivalent or by implication (1) λ = 950 n[m] (1)	2
	(c)		Electrons in lower level drop [spontaneously] to ground state (1) (accept de-excite) Making population inversion easier to maintain or lowering number of electrons in lower level or making photon absorption less likely. (1) [or equivalent]	2
			Question 7 Total	[13]