Marking Scheme

1.

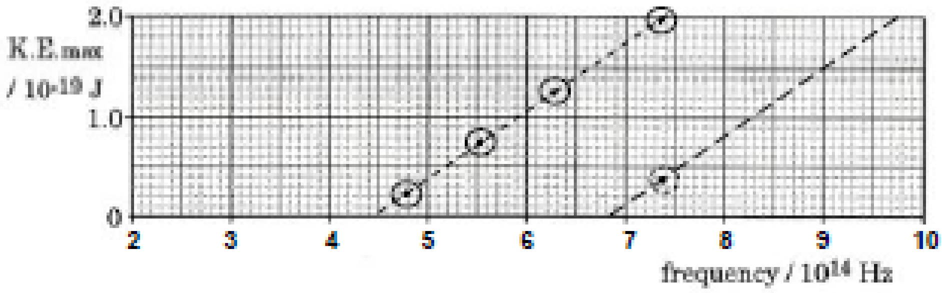
Question				**Marking details**	**Marks Available**
5	*(a)*	(i)		[Maximum] kinetic energy *of <u>emitted electron[s</u>]*	1
		(ii)		Photon energy	1
		(iii)		[Minimum] energy needed to release [**or** eject] <u>electron</u> from surface [**or** metal **or** solid]	1
	(b)			$\phi = hf_0$ **or** by implication (1) $f = 3f_0$ (1)	2
	(c)	(i)	I	attempt at gradient calculation even if slips, e.g. in 10^n (1) $h = 6.8$ [± 0.2] × 10^{-34} [J s] (1)	2
			II	ϕ =3.1 [± 0.1] × 10^{-19} [J] Don't accept a negative ϕ	1
		(ii)		$\phi_{sodium} = \phi_{caesium} + 0.6$ [or 0.7] × 10^{-19} J **or** parallel line **or** use of equation (1) $\phi_{sodium} = 3.7$ [± 0.3] × 10^{-19} [J] **ecf** (1)	2
				Question 5 Total	**[10]**

2.

3	*(a)*		Electrons are emitted [from tin] (1). Electrons are negatively charged [**or** plate originally neutral] **or** electrons knocked out by photons (1) Plate left with a positive charge (1)	3
	(b)	(i)	Work function: [Minimum] energy [or work] needed for an electron to escape [from metal surface]	1
		(ii)	$hf_{min} = \phi$ [or by impl.] or $0 = 6.63 \times 10^{-34} f_{min} - 7.1 \times 10^{-19}$ (1) $f_{min} = 1.07 \times 10^{15}$ Hz (1)	2
		(iii)	$1.5 \times 10^{-19} = hf - 7.1 \times 10^{-19}$ [or equiv. or by impl.] (1) $f = 1.3 \times 10^{15}$ Hz (1)	2
	(c)	(i)	number per second = $\frac{0.64 \times 10^{-6} [\text{C s}^{-1}]}{1.6 \times 10^{-19} [\text{C}]}$	1
		(ii)	Number of photons per second = $4.0 \times 10^{12} \times 1200$ Multiplication by 1200 at any stage [or by impl.](1) Photon energy = 8.6×10^{-19} J [or by impl.] (1) UV energy per second = 4.1 m(1)W(1) [4.1×10^{-3} J s^{-1} ✓✓]	4
				[13]

3.	(i)	$[\pi \times 22^2]$(1) [accept πr^2] × 14 (1) [=21 287 $m^3\ s^{-1}$] [21 287 → 1 mark]	2
	(ii)	mass every second = 1.2 × 21000 [or as calculated in (i)] [= 25 200] kg s^{-1}	1
	(iii)	Initial $E_{k1} = ½ \times 25\,200 \times 14^2$ (1) e.c.f. from (ii) Final $E_{k2} = ½ \times 25\,200 \times 14^2$ (1) e.c.f. from (ii) $\Delta E_k = 945 \times 10^3\ J\ s^{-1}$ (1) e.c.f. from E_{k1} and E_{k2} NB. "Solutions" based upon $½\,m \times (14 - 11)^2 \rightarrow 0$	3
	(iv)	Useful power available = 614 250 J s^{-1} (1) e.c.f. from (iii) $N_{turbines} = \frac{1000 \times 10^6}{614250}$ [=1628] (1)	2
			[8]

4.	*(a)*		[Minimum] energy needed to release [or eject] electron from magnesium [or metal or surface or solid not atom]	1
	(b)		$E_{k\,max} = 6.63 \times 10^{-34} \times 1.16 \times 10^{15}$ [J] – 5.9×10^{-19} [J] (1) $E_{k\,max} = 1.79 \times 10^{-19}$[J] (1)	2
	(c)		<u>Photon</u> energy < work function (1) don't accept photon energy in symbols. Accept not enough energy to liberate an electron. Don't accept $E_{k\,max}$ can't be negative. $E_{phot} = 5.4 \times 10^{-19}$[J] **accept** $f_{thresh} = 8.9 \times 10^{14}$ [Hz] (1) If negative energy award 1 mark only	2
	(d)	(i)	Planck constant. **Accept** Planck's constant or *h*.	1
		(ii)	[–] work function. **Accept** [–] ϕ.	1
		(iii)	f_0 or minimum frequency to eject electron or threshold frequency	1

5.	*(a)*	(i)	Maximum k.e. of emitted / photo electrons	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 [± 0.3] $\times 10^{-34}$ [J s] (1) agreeing with working	2
			II. $f_{thresh} = 4.4\times10^{14}$ Hz (1) [$\pm 0.1\times10^{14}$ Hz] or valid algebraic method $\phi = 2.9\times10^{-19}$ 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

6.

(a)	(i)	ϕ is [minimum] energy needed to release an electron from surface [or from metal or from material]. (1) No marks for giving meaning of f_0 . So [minimum] *photon* energy needed is ϕ. (1) So $hf_0 = \phi$ or $E_{photon} = hf$ (1)	[3]
	(ii)	Award 2 x (1) of: • More photons per second • Individual photon energies unchanged • E_{kmax} depends on energy of individual photon or $E_{kmax} = hf - \phi$ does not include intensity. Accept: Photons don't co-operate [in releasing electrons].	[2]
(b)		Increase / adjust pd until nano-ammeter shows zero current [or equiv.] (1) Read voltmeter (1) or by implication $E_{kmax} = eV$ (1)	[3]
(c)	(i)	Gradient = 6.7 [± 0.2] x 10^{-34} [J s] (1) Mention of Planck's constant and sensible comparison (1)	[2]
	(ii)	ϕ = 4.1 [± 0.2] x 10^{-19} [J] (1) barium but only award mark if some reasoning given e.g. correct reference to intercept (1)	[2]

7.

Question			Marking details	Marks Available
	(a)		Any 4 x (1) from: • light [energy] in discrete packets • one electron ejected by one photon OR photons don't co-operate • energy not accumulated [by electron] over time or emission from instant light shines • intensity has no effect on E_{kmax} or accept intensity affects number emitted per second • wave theory doesn't predict Einstein's equation or doesn't predict threshold frequency	[4]
	(b)	(i)	E_{kmax} = (6.63 x 10^{-34} x 8.7 x 10^{14} – 3.8 x 10^{-19}) (1) E_{kmax} = 1.97 x 10^{-19} [J] (1)	[2]
		(ii)	These photons eject electrons with smaller E_{kmax} (1) E_{kmax} same as previously with some explanation given (1)	[2]
		(iii)	Correct use of $c = f\lambda$ (1) e.g. to give λ_{thresh} = 523 [nm] OR $f_{400\ nm}$ = 7.5 x 10^{14} [Hz] OR $f_{700\ nm}$ = 4.3 x 10^{14} [Hz] Comparison of 400 [nm] with λ_{thresh} (1) or 7.5 x 10^{14} [Hz] with f_{thresh} (5.73 x 10^{14} [Hz]) or substitution of 7.5 x 10^{14} [Hz] into Einstein's equation. Conclusion : It can (1) [if reasoned]	[3]
			Question 4 Total	**[11]**

8.	(a)		$f_{\text{Thresh}} = \frac{\phi}{h}$ (1) [or by impl.] = 5.1[3] × 10^{14} [Hz] (1)	2
	(b)	(i)	Photon $E = 6.63 \times 10^{-34} \times 7.4 \times 10^{14}$ [= 4.91 × 10^{-19}J][or by impl.](1) $E_{k\ max}$ [= 4.91 × 10^{-19} – 3.4 × 10^{-19}] = 1.5 × 10^{-19} [J] (1)	2
		(ii)	[A single] photon gives its energy to an electron (1) Some of the energy used to escape from the metal (1).	2
	(c)	(i)	Points plotted at (5.1 × 10^{14}Hz, 0) and (7.4 × 10^{14} Hz, 1.5 × 10^{-19} J) (1) Allow e.c.f. from (a) and (b)(i) Straight line drawn through points (1) (One correct point only and a positive slope line = 1 mark)	2
		(ii)	*h* / the Planck constant	1
		(iii)	Straight line drawn with same gradient as (i) and to the right	1