Photoelectric Effect & Wave Particle Duality

Mark Scheme 3

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Quantum Physics
Sub Topic	Photoelectric Effect & Wave Particle Duality
Paper Type	Theory
Booklet	Mark Scheme 3

Time Allowed: **62 minutes**

Score: **/51**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a** minimum frequency for electron to be emitted (from surface) M1
of electromagnetic radiation / light / photons A1 [2]

(b) $E = hc / \lambda$ *or* $E = hf$ and $c = f\lambda$ C1
either threshold wavelength $= (6.63 \times 10^{-34} \times 3.0 \times 10^{8}) / (5.8 \times 10^{-19})$
$= 340$ nm
or energy of 340 nm photon $= 4.4 \times 10^{-19}$ J
or threshold frequency $= 8.7 \times 10^{14}$ Hz
or 450 nm $\rightarrow 6.7 \times 10^{14}$ Hz A1
appropriate comment comparing wavelengths / energies / frequencies B1
so no effect on photo-electric current B1 [4]

2 **(a)** wave theory predicts any frequency would give rise to emission of electron M1
if exposure time is sufficiently long A1
photon has (specific value of) energy dependent on frequency M1
emission if energy greater than threshold / work function / energy to remove electron from surface A1 [4]

(b) photon is packet/quantum of energy M1
of electromagnetic radiation A1
(photon) energy = h × frequency B1 [3]

every particle has an (associated) wavelength B1
wavelength = h / p M1
where p is the momentum (of the particle) A1 [3]

3	(a)	(i)	packeVdiscrete quantity/quantum (of energy) of e.m. radiation	B1	[1]
		(ii)	either $E = (6.63 \times 10^{-34} \times 3 \times 10^{8}) / (350 \times 10^{-9})$		
			or $E = (6.63 \times 10^{-34} \times 8.57 \times 10^{14})$	M1	
			$E = 5.68 \times 10^{-19}$ J	AO	[1]
		(iii)	0.5	B1	[1]
	(b)	(i)	energy of photon	M1	
			to cause emission of electron from surface		
			either with zero k.e *or* photon energy is minimum	A1	[2]
		(ii)	correct conversion eV ⇒ J or J ⇒ eV seen once	B1	
			photon energy must be greater than work function	C1	
			350 nm wavelength and potassium metal	A1	[3]

4	(a)	(i)	quantum/packet/discrete amount of energy	M1	
			electromagnetic mentioned	A1	[2]
		(ii)	max. k.e. corresponds to electron emitted from surface	B1	
			energy is required to bring electron to surface	B1	[2]
	(b)		at higher frequency, fewer photons (per second) for same intensity	M1	
			so rate of emission decreases	A1	[2]
			(allow argument based on photoelectric efficiency)		

5 **(a** 'uniform' distribution B1 **[1]**

(b) concentric rings B1 **[1]**

(c) higher speed, more momentum M1
$\lambda = h / p$ M1
so λ decreases and ring diameter decreases A1 **[3]**

6 **(a** $\lambda = h/p$ or $\lambda = h/mv$ M1
with λ, h and (or mv) p identified A1 **[2]**

(b)
$E = \frac{1}{2} mv^2$ C1
$= p^2/2m$ or $v = \sqrt{(2E/m)}$, <u>hence</u> M1
$\lambda = h/\sqrt{(2mE)}$ A0 **[2]**

(c)
$E = qV$ C1
$(0.4 \times 10^{-9})^2 \times 2 \times 9.11 \times 10^{-31} \times 1.6 \times 10^{-19} \times V = (6.63 \times 10^{-34})^2$ C1
$V = 9.4$ V *(2 s.f. scores 2/3)* A1 **[3]**

7 **(a)** packet/quantum of energy.....M1
energy = hf..... A1 [2]

(b) e.g. threshold frequency outlined
max. k.e. independent of intensity
max. k.e. dependent on frequency (n.b. NOT proportional)
photoelectric current depends on intensity
instantaneous emission …. (*1 each, max 3*)..... B3 [3]

(c) **(i)** photons have same energy so E_{max} unchanged
intensity *OR* number of photons per unit time is halved,
so ½*n OR n* reduced..... B1
(allow 1 mark for statement that E_{max} unchanged and *n* reduced)

(ii) photons have higher energy so E_{max} increases..... B1
but fewer photons per unit time so *n* decreases..... B1 [4]
(allow 1 mark for statement that E_{max} increases and n reduced)
(allow any argument based on increased efficiency)