CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 22: Quantum Physics

Past Papers 2021 – 2025

MARK SCHEME 28 Questions

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Question 1 — Mark Scheme

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Question	Answer	Marks
10(a)(i)	photoelectric effect	B1
10(a)(ii)	electron diffraction	B1
10(b)(i)	$\lambda = h / p$	M1
	h is the Planck constant	A1
10(b)(ii)	de Broglie (wavelength)	B1
10(c)(i)	$\frac{1}{2}mv^2 = eV$	C1
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ so $v = 4.1 \times 10^7$ m s^{-1}	A1
10(c)(ii)	$\lambda = h / mv$ $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^7)$	C1
	$= 1.8 \times 10^{-11}$ m	A1

Question 2 — Mark Scheme

9702/41 Cambridge International AS & A Level – Mark Scheme **PUBLISHED** May/June 2021

Question	Answer	Marks
12(a)	• frequency determines energy of photon • intensity determines number of photons (per unit time) • intensity does not determine energy of a photon *Any two points, 1 mark each*	**B2**
	kinetic energy (of the electron) depends on the energy of one photon	**B1**
12(b)(i)	$E = hc / \lambda$ **or** $E = hf$ **and** $c = f\lambda$	**C1**
	$E = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (250 \times 10^{-9})$	**C1**
	$(= 7.96 \times 10^{-19}$ J) $= 5.0$ eV	**A1**
12(b)(ii)	E_{MAX} = photon energy – work function	**C1**
	work function = 5.0 – 1.4 = 3.6 eV	**A1**

Question 3 — Mark Scheme

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Question	Answer	Marks
12(b)(ii)	$p = h / \lambda$	C1
	$= (6.63 \times 10^{-34}) / (2.2 \times 10^{-12})$ $= 3.0 \times 10^{-22}$ N s	A1
	or	
	$p = E / c$	(C1)
	$= (0.57 \times 10^{6} \times 1.60 \times 10^{-19}) / (3.00 \times 10^{8})$ $= 3.0 \times 10^{-22}$ N s	(A1)
12(c)(i)	mass (of Sm-157 nucleus) $= 157 \times 1.66 \times 10^{-27}$ **or** mass (of Sm-157 nucleus) $= 0.157 / (6.02 \times 10^{23})$	C1
	recoil speed $= (3.00 \times 10^{-22}) / (157 \times 1.66 \times 10^{-27})$ $= 1.2 \times 10^{3}$ m s^{-1}	A1
12(c)(ii)	$(1.2 \times) 10^{3}$ m s^{-1} is <u>much</u> less than $(3.0 \times) 10^{8}$ m s^{-1}	B1

Question 4 — Mark Scheme

Question	Answer	Marks
10(a)(i)	photoelectric effect	**B1**
10(a)(ii)	electron diffraction	**B1**
10(b)(i)	$\lambda = h / p$	**M1**
	h is the Planck constant	**A1**
10(b)(ii)	de Broglie (wavelength)	**B1**
10(c)(i)	$\frac{1}{2}mv^2 = eV$	**C1**
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ so $v = 4.1 \times 10^7$ m s^{-1}	**A1**
10(c)(ii)	$\lambda = h / mv$ $= 6.63 \times 10^{-34} / (9.11 \times 10^{-31} \times 4.1 \times 10^7)$	**C1**
	$= 1.8 \times 10^{-11}$ m	**A1**

Question 5 — Mark Scheme

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Question	Answer	Marks
9(a)(i)	emission of electrons (from a metal surface)	**B1**
	when electromagnetic radiation is incident (on electrons)	**B1**
9a(ii)	minimum energy required for an electron to leave surface	**B1**
9(b)(i)	threshold (frequency)	**B1**
9(b)(ii)	• photons are (discrete) packets of energy • energy of photons depends on frequency (of EM radiation) • electrons can only absorb a single photon (of energy) *Any two points, 1 mark each*	**B2**
	emission only possible if photon energy is at least the work function	**B1**
9(b)(iii)	work function = hf_0 $= 6.63 \times 10^{-34} \times 6.93 \times 10^{14}$	**C1**
	$= 4.59 \times 10^{-19}$ (J) $= 4.59 \times 10^{-19} / 1.60 \times 10^{-19}$ (eV) $= 2.87$ eV	**A1**

Question 6 — Mark Scheme

Question	Answer	Marks
8(a)	$\lambda = \frac{h}{p}$ or $\lambda = \frac{h}{mv}$	**M1**
	where *h* is the Planck constant **and** *p* is the momentum (of particle) / *mv* is the momentum (of particle) / *m* is the mass (of particle) and *v* is the velocity (of particle)	**A1**
8(b)(i)	(electron) diffraction	**B1**
8(b)(ii)	moving electrons behave like waves	**B1**
8(b)(iii)	spacing between atoms ≈ wavelength of electron *or* diameter of atom ≈ wavelength of electron	**B1**
8(b)(iv)	Any one of: • wavelength has decreased • electron had greater momentum	**M1**
	so (accelerating) p.d. was increased	**A1**

Question 7 — Mark Scheme

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Question	Answer	Marks
8(a)(i)	energy required to separate the nucleons (in the nucleus)	**M1**
	to infinity	**A1**
8(a)(ii)	curve starting close to the origin and forming a single peak	**B1**
	peak shown to left of centre, with steep line on LHS of peak and shallow line on RHS of peak	**B1**
8(b)(i)	fusion	**B1**
8(b)(ii)	both particles have low A values **or** both particles are at left-hand end of graph	**B1**
	He-3 has higher binding energy (per nucleon) than H-2	**B1**
8(c)	$\Delta m = [(2 \times 2.014102) - (3.016029 + 1.008665)]$ u $(= 0.00351$ u$)$	**C1**
	$E = \Delta mc^2$	**C1**
	$= 0.00351 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$ $(= 5.24 \times 10^{-13}$ J$)$	**C1**
	1.00 mol of deuterium forms 0.500 mol of helium-3	**C1**
	total energy $= 0.500 \times 6.02 \times 10^{23} \times 5.24 \times 10^{-13}$ $= 1.58 \times 10^{11}$ J	**A1**

Question 8 — Mark Scheme

Question	Answer	Marks
8(a)(i)	photoelectric effect	**B1**
8(a)(ii)	electron diffraction	**B1**
8(b)(i)	$\lambda = h / p$	**C1**
	$p = 4 \times 1.66 \times 10^{-27} \times 6.2 \times 10^{7}$ $(= 4.1 \times 10^{-19}\ \text{N s})$	**C1**
	$\lambda = 6.63 \times 10^{-34} / 4.1 \times 10^{-19}$ $= 1.6 \times 10^{-15}\ \text{m}$	**A1**
8(b)(ii)	line with negative gradient throughout	**B1**
	curve asymptotic to both axes with non-zero λ at $v = 6.2 \times 10^{7}\ \text{m s}^{-1}$	**B1**
8(c)	(de Broglie) wavelength negligible compared with width of doorway	**B1**

Question 9 — Mark Scheme

Question	Answer	Marks
8(a)	photon energy (to remove electron)	**B1**
	minimum energy to remove electron **or** energy to remove electron from surface **or** energy to remove electron with zero kinetic energy	**B1**
8(b)(i)	photon energy = hf	**C1**
	number per unit time = $8.36 \times 10^{-3} / (1.36 \times 10^{15} \times 6.63 \times 10^{-34})$ $= 9.27 \times 10^{15}\ s^{-1}$	**A1**
8(b)(ii)	$hf = \Phi + E_{MAX}$	**C1**
	$\Phi = (1.36 \times 10^{15} \times 6.63 \times 10^{-34}) - (3.09 \times 10^{-19})$ $= 5.93 \times 10^{-19}$ J	**A1**
8(c)(i)	greater photon energy (and same work function)	**M1**
	so maximum kinetic energy is increased	**A1**
8(c)(ii)	(greater photon energy and same power so) lower number of photons (per unit time)	**M1**
	(each electron absorbs one photon) so lower rate of emission	**A1**

Question 10 — Mark Scheme

Question	Answer	Marks
9(a)(i)	• energy of photon has a corresponding frequency • change in electron energy level emits a single photon • photon energy = difference in energy levels • discrete frequencies must have come from discrete energy gaps • discrete energy changes imply discrete energy levels *Any three points, 1 mark each*	**B3**
9(a)(ii)	transition (to – 3.400 eV) from X corresponds to 658 nm line	**C1**
	$E_1 - E_2 = hc / \lambda$	**C1**
	$E_1 - (-3.400) = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (658 \times 10^{-9} \times 1.60 \times 10^{-19})$ and so $E_1 = -1.51$ eV (*full substitution and answer needed*)	**A1**
9(b)(i)	redshift	**B1**
9(b)(ii)	moving away (from observer)	**B1**
9(b)(iii)	$\Delta\lambda / \lambda = v / c$ e.g. for 658 nm line: $\Delta\lambda$ = 686 – 658 (= 28 nm) (*other lines may be used*)	**C1**
	$28 / 658 = v / (3.00 \times 10^{8})$ (*other lines may be used*)	**C1**
	$v = 1.3 \times 10^{7}$ m s^{-1}	**A1**
9(c)	$v = H_0 d$	**C1**
	$H_0 = (1.3 \times 10^{7}) / (5.7 \times 10^{24})$ $= 2.3 \times 10^{-18}$ s^{-1}	**A1**

Question 11 — Mark Scheme

Question	Answer	Marks
7(a)	photon absorbed (by electron) and electron excited	**B1**
	photon energy equal to difference in (energy of two) energy levels	**B1**
	photon energy relates to a single wavelength / single frequency	**B1**
	electron de-excites and emits photon in any direction	**B1**
7(b)	$\frac{hc}{\lambda} = \Delta E$	**C1**
	uses 658 nm	**C1**
	$\frac{6.63\times10^{-34}\times3.00\times10^{8}}{658\times10^{-9}} = -E_1 - (-3.40 \times 1.60 \times 10^{-19})$ $E_1 = -2.42 \times 10^{-19}$ J	**A1**

Question 12 — Mark Scheme

Question	Answer	Marks
7(a)	wavelength associated with a moving particle	**B1**
7(b)(i)	(electron) diffraction	**B1**
7(b)(ii)	beam spreads out indicating diffraction **or** light and dark regions indicate an interference pattern	**B1**
	electron beam is behaving as a wave	**B1**
7(c)(i)	central blob and concentric rings	**B1**
	rings closer together (than previously)	**B1**
7(c)(ii)	(greater p.d. so) electrons to have greater momentum	**B1**
	greater momentum so decrease in (de Broglie) wavelength	**B1**
	lower (de Broglie) wavelength (for same grating spacing in crystal) causes: smaller diffraction angle **or** smaller angle of intensity maxima (for each order) **or** decrease in fringe spacing in diffraction pattern	**B1**

Question 13 — Mark Scheme

Question	Answer	Marks
8(a)	transition (emits) (one) photon with energy equal to the difference in energy between the two levels	**B1**
	frequency of radiation corresponds to energy of photon	**B1**
8(b)(i)	line to the left of the pair in Fig. 8.2, labelled A	**B1**
	larger gap between line A and the nearest of the pair in Fig. 8.2 than between the lines in the pair	**B1**
8(b)(ii)	line to the left of both the pair in Fig. 8.2 and line A, labelled B	**B1**
	larger gap between line B and line A than between line A and the nearest one of the pair in Fig. 8.2	**B1**
8(c)	$E = hf$	**C1**
	$E_3 = E_1 + h(f_A + f_B)$	**A1**

Question 14 — Mark Scheme

Question	Answer	Marks
9(a)	difference between mass of nucleus and (total) mass of nucleons	M1
	when infinitely separated	A1
9(b)(i)	neutron	B1
9(b)(ii)	$E = \Delta m\, c^2$	C1
	Δm = (0.030377 – 0.002388 – 0.009105)u (= 0.018884u)	C1
	energy release = $(0.030377 - 0.002388 - 0.009105) \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 = 2.8 \times 10^{-12}$ J	A1
9(c)(i)	number of atoms per unit time = $(1.4 \times 10^{28}) / (2.8 \times 10^{-12})$ (= $5.0 \times 10^{39}\ s^{-1}$)	C1
	mass of one atom = $4 \times 1.66 \times 10^{-27}$ or $(4 \times 10^{-3}) / (6.02 \times 10^{23})$ (= 6.64×10^{-27} kg)	C1
	mass per unit time = $6.64 \times 10^{-27} \times 5.0 \times 10^{39}$ = 3.3×10^{13} kg s^{-1}	A1
9(c)(ii)	$L = 4\pi\sigma r^2 T^4$ $1.4 \times 10^{28} = 4\pi \times 5.67 \times 10^{-8} \times (2.3 \times 10^9)^2 \times T^4$	C1
	T = 7800 K	A1

Question 15 — Mark Scheme

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Question	Answer	Marks
8(a)(i)	$p = E / c$	M1
	$E = hc / \lambda$ and completion of algebra leading to $p = h / \lambda$	A1
8(a)(ii)	wavelength = $(6.63 \times 10^{-34}) / (9.5 \times 10^{-28}) = 700 \times 10^{-9}$ m so red	B1
8(b)(i)	power = intensity × area	C1
	number per unit time = $(160 \times 2.5 \times 10^{-6}) / (9.5 \times 10^{-28} \times 3.00 \times 10^{8}) = 1.4 \times 10^{15}$ s^{-1}	A1
8(b)(ii)	pressure = force / area	C1
	force = rate of change of momentum $= 2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}$	C1
	pressure = $(2 \times 9.5 \times 10^{-28} \times 1.4 \times 10^{15}) / (2.5 \times 10^{-6})$ $= 1.1 \times 10^{-6}$ Pa	A1
8(c)	photons have greater momentum **or** fewer photons per unit time	B1
	greater photon momentum but smaller number of photons (per unit time) so pressure is the same	B1

Question 16 — Mark Scheme

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Question	Answer	Marks
9(a)	(two small) nuclei join together	M1
	to form one larger nucleus	A1
9(b)	line with a peak at $A \approx 56$	B1
	line with steep initial positive gradient on the left of peak and shallower negative gradient at all points to the right of peak and line does not return to 0 binding energy	B1
9(c)(i)	X shown at value of A to the right of the peak	B1
9(c)(ii)	Y shown at value of A close to 1	B1
9(d)	energy from 1 nucleus = $(1.77 \times 10^{13}) / (6.02 \times 10^{23})$ ($= 2.94 \times 10^{-11}$ J)	C1
	binding energy of Z = $[(1.25 + 1.81) \times 10^{-10}] - 2.94 \times 10^{-11}$ ($= 2.77 \times 10^{-10}$ J)	C1
	nucleon number of Z = 93 + 139 + 2 – 1 (= 233)	C1
	binding energy per nucleon = $(2.77 \times 10^{-10}) / (233 \times 1.60 \times 10^{-13})$ = 7.43 MeV	A1

Question 17 — Mark Scheme

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Question	Answer	Marks
8(a)	packet / quantum of energy	M1
	of electromagnetic radiation	A1
8(b)(i)	photoelectric effect	B1
8(b)(ii)	• electron needs a minimum energy to escape **or** electron emitted if energy in packet is enough • energy must be absorbed in packets that are related to frequency • intensity relates to number of packets (not to energy in packet) • electron absorbs only a single whole packet *Any three points, 1 mark each*	B3
8(c)(i)	Planck constant	B1
8(c)(ii)	– work function (energy)	B1

Question 18 — Mark Scheme

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Question	Answer	Marks
7(a)	$p = E / c$	C1
	$= (3.11 \times 10^{-19}) / (3.00 \times 10^{8})$ $= 1.04 \times 10^{-27}$ N s	A1
7(b)(i)	$E = hf$ and $c = f\lambda$ so energy of one photon = hc / λ $350 \times 10^{-3} = N \times (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (640 \times 10^{-9})$	C1
	$N = 1.1 \times 10^{18}$	A1
7(b)(ii)	F = (change in) momentum / time	M1
	Clear use of $p = E / c$ and $t = E / P$ to complete the algebra and arrive at the final equation: e.g. $F = [E / c] / [E / P] = P / c$	A1
7(c)(i)	maximum wavelength (of electromagnetic radiation) that causes electrons to be emitted (from surface of metal)	B1
7(c)(ii)	work function = $2.26 \times 1.60 \times 10^{-19}$ (J) $E = hc / \lambda$ so $(2.26 \times 1.60 \times 10^{-19}) = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / \lambda_0$	C1
	$\lambda_0 = 5.50 \times 10^{-7}$ m	A1

Question 19 — Mark Scheme

Question	Answer	Marks
8(a)	(minimum) energy required to separate the nucleons (of a nucleus)	M1
	to infinity	A1
8(b)(i)	4	A1

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Question	Answer	Marks
8(b)(ii)	energy = (142 × 8.37) + (90 × 8.72) – (235 × 7.59)	C1
	= 190 MeV	A1
8(b)(iii)	**either** it has too many neutrons (for the number of protons) **or** its neutron to proton ratio is too high	B1

Question 20 — Mark Scheme

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Question	Answer	Marks
9(a)	energy required to separate (all) the nucleons (in the nucleus)	M1
	to infinity	A1
9(b)(i)	Δm = {[(84 × 1.007276) + (128 × 1.008665)] – 211.942749} (u) (= 1.778 u)	C1
	= 1.778 × 1.66 × 10^{-27} (kg)	C1
	= 2.95 × 10^{-27} kg	A1
9(b)(ii)	$E = (\Delta)mc^2$	C1
	binding energy = 2.95 × 10^{-27} × (3.00 × 10^{8})^2 = 2.66 × 10^{-10} J	A1
9(b)(iii)	binding energy per nucleon = (2.66 × 10^{-10}) / 212 = 1.25 × 10^{-12} J	A1
9(c)(i)	line rising to a single peak that is to the left of the '9' in the Fig. 9.1 label and then continually decreasing	B1
	steep positive gradient on the left of the peak and shallow negative gradient on the right	B1
9(c)(ii)	X shown on the line at a value of *A* that is to the right of the left-hand edge of the '*A*' in the axis label, and to the left of '2' in the 250 label	B1
9(c)(iii)	nucleus formed (as a result of the decay) has a lower nucleon number	B1
	(nucleus formed has a) greater binding energy per nucleon	B1

Question 21 — Mark Scheme

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Question	Answer	Marks
8(a)	photoelectric effect	**B1**
8(b)(i)	$E = hf$	**C1**
	work function $= 6.63 \times 10^{-34} \times 8.8 \times 10^{14}$ $= 5.8 \times 10^{-19}$ J	**A1**
8(b)(ii)	$hf = \Phi + \frac{1}{2} m v_{MAX}^2$	**C1**
	$6.63 \times 10^{-34} \times 11 \times 10^{14} = (5.8 \times 10^{-19}) + (\frac{1}{2} \times 9.11 \times 10^{-31} \times v_{MAX}^2)$	**C1**
	$v_{MAX} = 5.7 \times 10^5$ m s^{-1}	**A1**
8(c)	E_{MAX} shown as zero from $f = 8.0$ to 8.8 and non-zero from $f = 8.8$ to 11	**B1**
	all non-zero E_{MAX} shown as a single straight line with a positive gradient	**B1**
	line passing through (11, 1.45)	**B1**

Question 22 — Mark Scheme

Question	Answer	Marks
9(a)	diffraction is characteristic of wave behaviour so shows that electrons can behave like waves	**B1**
9(b)	$qV = ½mv^2$	**C1**
	$p = mv$	**C1**
	$p = m \times \sqrt{(2qV / m)}$ $= \sqrt{(2qVm)}$	**A1**
9(c)	(electrons have) greater momentum so smaller (de Broglie) wavelength	**B1**
	fringes become closer together	**B1**
9(d)(i)	straight line with positive gradient	**B1**
	line with positive gradient passing through the origin	**B1**
9(d)(ii)	Planck constant	**B1**

Question 23 — Mark Scheme

Question	Answer	Marks
8(a)	• quantum of energy	M1
	• of electromagnetic radiation	A1
8(b)(i)	$(\Delta)E = hc / \lambda$	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.96 \times 1.60 \times 10^{-19})$	C1
	$= 6.3 \times 10^{-7}$ m	A1
8(b)(ii)	number per unit time = power / energy per photon $= (1.0 \times 10^{-2}) / (1.96 \times 1.60 \times 10^{-19})$ $= 3.2 \times 10^{16}$ s^{-1}	A1

Question	Answer	Marks
8(b)(iii)	*either*: force = rate of change of momentum *or*: $F = \Delta p / t$	C1
	$p = E / c$	C1
	half the photons have change in momentum p, the other half have change in momentum $2p$	C1
	$F = [(1.96 \times 1.60 \times 10^{-19}) / (3.00 \times 10^{8})] \times 3.2 \times 10^{16} \times [(2 + 1) / 2]$ $= 5.0 \times 10^{-11}$ N	A1

Question 24 — Mark Scheme

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Question	Answer	Marks
8(a)	wavelength associated with a moving particle	**B1**
8(b)	$\lambda = h / p$	**C1**
	$= (6.63 \times 10^{-34}) / (9.11 \times 10^{-31} \times 4.9 \times 10^{7})$ $= 1.5 \times 10^{-11}$ m	**A1**
8(c)	similarity: *any one point from*: • same mass • same magnitude of charge • both leptons	**B1**
	difference: *any one point from*: • electron has negative charge, positron has positive charge • positron is anti-particle of electron • electron is a particle, positron is an anti-particle	**B1**
8(d)(i)	(pair) annihilation	**B1**
8(d)(ii)	their mass gets converted into energy	**B1**
	(their mass–energy) becomes the energy of the gamma photons	**B1**
8(d)(iii)	they travel in opposite directions to conserve momentum	**B1**
8(d)(iv)	kinetic energy $= ½ \times 9.11 \times 10^{-31} \times (4.9 \times 10^{7})^2 = 1.1 \times 10^{-15}$ J	**A1**

Question 25 — Mark Scheme

Question	Answer	Marks
9(a)	emission of electrons (from a metal surface)	**B1**
	when electromagnetic radiation is incident (on surface / electrons)	**B1**
9(b)(i)	current falls to zero when applied voltage equals energy per unit charge of emitted electrons	**B1**
	energy of photon depends on frequency	**B1**
	maximum energy of electron depends on energy of photon	**B1**
9(b)(ii)	*Any three points from:* • threshold frequency = 1.5×10^{15} Hz • threshold wavelength = 2.0×10^{-7} m • work function = 6.2 eV (or 9.9×10^{-19} J) • Planck constant = 6.6×10^{-34} J s (**not** 6.63×10^{-34} J s) • number per unit time (of photons / electrons) = 1.7×10^{16} s^{-1} (in stage 1) • power of incident radiation = 0.028 W (in stage 1)	**B3**

Question 26 — Mark Scheme

Question	Answer	Marks
9(a)(i)	electromagnetic wave can behave like a particle	**B1**
	moving particle can behave like a wave	**B1**
9(a)(ii)	$\lambda = h / p$	**M1**
	h is the Planck constant	**A1**
9(b)(i)	*Any two points from:* • pattern similar to diffraction of light • diffraction (pattern) is characteristic of wave behaviour • rings show constructive and destructive interference	**B2**
9(b)(ii)	(de Broglie) wavelength decreases	**B1**
	rings become closer together	**B1**

Question 27 — Mark Scheme

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Question	Answer	Marks
8(a)	*Any three points from*: • electrons moving between levels emit a single photon • energy of photon = difference between energy levels • energy of photon depends on frequency • discrete frequencies (in spectrum) so differences between electron energies must be discrete • discrete differences between electron energies means energy levels must be discrete	**B3**
8(b)(i)	energy $= -(13.6 \times 1.60 \times 10^{-19})$ $= -2.18 \times 10^{-18}$ J	**A1**
8(b)(ii)	$\Delta E = hf$	**C1**
	$= (6.63 \times 10^{-34} \times 2.47 \times 10^{15}) / (1.60 \times 10^{-19}) = 10.2$ eV	**A1**
8(b)(iii)	$n = 2$ energy level = – 3.4 eV	**A1**
	$n = 3$ energy difference = 12.1 eV	**A1**
	$n = 4$ energy difference = 12.8 eV	**A1**
	$n = 3$ energy level = – 1.5 eV **and** $n = 4$ energy level = – 0.8 eV	**A1**

Question 28 — Mark Scheme

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Question	Answer	Marks
9(a)	emission of electrons (from a metal surface)	**M1**
	when electromagnetic radiation is incident (on surface)	**A1**
9(b)(i)	threshold frequency = $2F$	**A1**
9(b)(ii)	Planck constant = Φ / F	**A1**
9(c)	two diagonal straight lines with positive gradient in the positive E_K region only, starting at non-zero values of f	**B1**
	line labelled X passing through (F, 0) **and** line labelled Y passing through ($2F$,0) and extending to $3F$ or $+2\Phi$	**B1**
	two diagonal straight lines with equal gradients	**B1**
	X line extrapolates back to (0, $-\Phi$) **and** Y line extrapolates back to (0, -2Φ)	**B1**

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