OCR
Oxford Cambridge and RSA

GCE

Physics A

Unit **H156/01:** Breadth in physics

Advanced Subsidiary GCE

Mark Scheme for June 2016

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations available in RM Assessor

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
TE	Transcription error
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
SF	Error in number of significant figures
	Correct response
	Wrong physics or equation

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

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/	alternative and acceptable answers for the same marking point
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
Ignore	Statements which are irrelevant
Allow	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures:

If the data given in a question is to 2 sf, then allow to 2 or more significant figures.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

SECTION A

Question	Answer	Marks	Guidance
1	C	1	
2	B	1	
3	C	1	
4	D	1	
5	B	1	
6	A	1	
7	B	1	
8	B	1	
9	A	1	
10	C	1	
11	D	1	
12	B	1	
13	C	1	
14	C	1	
15	C	1	
16	A	1	
17	D	1	
18	C	1	
19	D	1	
20	B	1	
	Total	20	

SECTION B

Question			Answer	Marks	Guidance
21	(a)		Mass is a scalar (quantity) and velocity is a vector (quantity). (Addition of) velocity depends on direction / sign / vector triangle / resolving (ORA)	B1 B1	 **Allow** 'Velocity can be cancelled out'
	(b)	(i)	An arrow from trolley to ramp along the string (for the tension) and a downwards arrow from the trolley (for the weight).	B1	**Allow** arrows in correct directions anywhere on Fig. 21 **Not** arrow for the tension parallel to the ramp **Not** arrow perpendicular to the ramp for the weight **Not** two arrow heads in opposite directions along the string for the tension
		(ii)	($s = ½ at^2$); $0.80 = ½ \times 3.0 \times t^2$ (Any subject) $t =$ 0.73 (s)	C1 A1	 **Note**: Apply SF penalty if 0.7 s is on the answer line or the final answer **Allow** 1 mark for 0.40 (s); 9.8 m s^{-2} used instead of 3.0 m s^{-2} **Allow** full credit for alternative methods, e.g: $v^2 = 2 \times 0.80 \times 3.0$; $v = 2.19$ (m s^{-1}) $t = \frac{2.19}{3.0}$ **C1** $t = 0.73$ (s) **A1**
			Total	5	

Question			Answer	Marks	Guidance
22	(a)		The gradient remains the same	B1	**Note**: This mark is for the idea that the gradient / slope (of the line) remains the same **Allow**: The line is (just) shifted (to the right) by the same amount (AW)
	(b)		Gradient determined from Fig. 22 and gradient = 16	C1	**Allow** $\pm$ 0.5 for the value of the gradient **Not** u^2/x value using the line or a data point because the gradient is not determined **Allow** this mark even if gradient = a
			gradient = $2a$	C1	
			($F = ma$); $F = 920 \times 8.0$		
			$F = 7.4 \times 10^3$ (N)	A1	Possible ECF for this A1 mark if the gradient is determined but its value is outside the range 15.5 to 16.5 and the second C1 mark has also been scored **Note**: The answer to 3 SF is 7360 (N) **Note**: $F = 920 \times 16 = 14720$ (N) can score the first C1 mark
			Total	4	

Question			Answer	Marks	Guidance
23	(a)				**Note**: In this question any symbols used must be defined or previously mentioned **Note**: Allow full credit for alternative methods, e.g. using the equation pressure = height × density × *g*
			pressure = $\frac{\text{weight (of cylinder)}}{\text{area}}$	**B1**	**Allow** force/area
			Weight (of cylinder) determined using a newtonmeter or Measure mass (of cylinder) using balance / scale(s) <u>and</u> multiplying by *g* / 9.8(1 m s^{-2})	**B1**	**Not** 'gravity' for *g*
			Area determined by measuring the diameter with a ruler / vernier callipers / micrometer <u>and</u> then using (area =) $\pi \times r^2$	**B1**	**Not** measure radius **Allow** other correct methods
			A sensible suggestion that reduces the % uncertainty: Use micrometer / (vernier) calipers / travelling microscope Use balance / newtonmeter with <u>smaller</u> division (AW)	**B1**	**Not** 'repeat readings (of diameter etc.)' because this procedure improves the accuracy and not the precision **Allow** balance / newtonmeter with 'high resolution'
	(b)	**(i)**	The upthrust is equal to the <u>weight</u> of the fluid / liquid / water / air displaced	**B1**	
		(ii)	(upthrust =) 9.0 – 7.8 (N) or (mass =) 9.0/9.8(1)	**C1**	**Note**: This C1 mark for determining the upthrust (1.2 N) or the mass (0.92 kg) of the cylinder
			$V = \frac{(1.2/9.81)}{1000}$ or $V = 1.2(23) \times 10^{-4}$ (m^3) $\rho = \frac{(9.0/9.81)}{1.223\times10^{-4}}$	**C1**	
			$\rho = 7.5 \times 10^3$ (kg m^{-3})	**A1**	**Allow** full credit for alternative methods, e.g: $\rho = \left(\frac{9.0}{1.2}\right)\times1000 = 7.5\times10^3$ (kg m^{-3})
			Total	**8**	

Question			Answer	Marks	Guidance
24	(a)		(Resultant) force is (directly) proportional / equal to the rate of change of momentum	B1	**Not** force = mass × acceleration **Not** 'force ∝ change in momentum <u>over</u> time'
	(b)	(i)	Any <u>two</u> from: momentum, (total) energy and mass	B1	**Not**: <u>kinetic</u> energy
		(ii)	The force will have the same magnitude (at any time *t*) The force is in the opposite direction / has negative value	B1 B1	**Not** 'This is because action = reaction' **Not** Newton's third law **Allow** 1 mark for a correct graph if there is no description or explanation
	(c)		*Method 1: Momentum is conserved* $1.7 \times 10^{-27} \times 500$ or $1.7 \times 10^{-27} \times (-) 420$ or $2.0 \times 10^{-26} \times v$ $1.7 \times 10^{-27} \times 500 = 1.7 \times 10^{-27} \times -420 + 2.0 \times 10^{-26} \times v$ $v = 78$ (m s^{-1}) *Method 2: Kinetic energy is conserved* $½ \times 1.7 \times 10^{-27} \times 500^2$ or $½ \times 1.7 \times 10^{-27} \times 420^2$ or $½ \times 2.0 \times 10^{-26} \times v^2$ $½ \times 1.7 \times 10^{-27} \times 500^2 = ½ \times 1.7 \times 10^{-27} \times 420^2 + ½ \times 2.0 \times 10^{-26} \times v^2$ $v = 79$ (m s^{-1})	 C1 C1 A1 C1 C1 A1	 **Allow** 1 mark for 6.8 (m s^{-1}); + 420 used instead of - 420 **Allow** full credit for correct use of 'velocity of approach = - velocity of recession', e.g: 'speed' of approach = (-) 'speed' of recession **C1** 500 = *v* + 420 **C1** *v* = 80 (m s^{-1}) **A1**
			Total	**7**	

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>25</td><td>(a)</td><td>(i)</td><td>Similarity – same unit (AW)

Difference – For e.m.f, energy is transformed from chemical / other forms to electrical and for p.d., energy is transformed to heat / other forms from electrical</td><td>B1

B1</td><td>Allow ‘both defined as energy (transformed) per unit charge’ or ‘both defined as work done per unit charge’

Allow any pair from:<table><tr><td>e.m.f.</td><td>p.d.</td></tr><tr><td>Energy (transformed) <u>to</u> electrical</td><td>Energy (transformed) <u>from</u> electrical
or
Energy (transformed) <u>to</u> heat /other forms</td></tr><tr><td>Charges gain energy</td><td>Charges lose energy</td></tr><tr><td>Work done <u>on</u> charges</td><td>Work done <u>by</u> charges</td></tr></table></td></tr>
<tr><td></td><td></td><td>(ii)</td><td>$n = \frac{9.6\times10^{16}}{1.2\times10^{-6}\times6.0\times10^{-3}}$ or $n = 1.3(3...) \times 10^{25}$ (m^{-3})

($I = Anev$)

$0.003 = 1.2 \times 10^{-6} \times 1.33... \times 10^{25} \times 1.6 \times 10^{-19} \times v$

$v = 1.2 \times 10^{-3}$ (m s^{-1})</td><td>C1

C1

A1</td><td>

Note Any subject for this equation

Allow 1 mark for $1.6(3) \times 10^{5}$ (m s^{-1}); $n = 9.6 \times 10^{16}$ used</td></tr>
</table>

Question			Answer	Marks	Guidance
	(b)		Circuit with cell in series with an ammeter and variable resistor. A voltmeter is connected across the variable resistor / (terminals of the) cell	B1	**Allow** this B1 mark for a clearly drawn circuit with correct symbols for the cell, variable resistor, voltmeter and ammeter. **Allow** a battery symbol instead of symbol for a cell
			Measure current and p.d. / voltage across variable resistor / cell	B1	**Allow** 'terminal p.d.' for p.d. across the cell **Allow** 'measure I and V' if the circuit is correct **Allow** 'measure voltmeter and ammeter readings' if the circuit is correct Possible ECF for incorrect symbol for variable resistor
			Correct description of how to get multiple readings (of current or p.d) E.g. change the resistance of the variable resistor / use different value resistors, etc.	B1	
			($E = V + Ir$) Plot a graph of V against I and the gradient (of the graph / line) is equal to (-) r (AW)	B1	
			Total	**9**	

Question			Answer	Marks	Guidance
26	(a)	(i)	**A** and **B** move in opposite directions	**B1**	**Allow A** is moving up and **B** is moving down (or vice versa) **Allow** they have a phase difference of $180^{(\circ)}$ or π (rad) **Allow** they are in antiphase
		(ii)	λ = 0.80 (m) $v = f\lambda$; $v = 75 \times 0.80$ v = 60 (m s^{-1}) absolute uncertainty = $\frac{2.0}{40} \times 60$ absolute uncertainty = 3.0 (m s^{-1})	**C1** **A1** **A1**	**Allow** 80 (cm) for this C1 mark **Allow** 1 mark for 30 (m s^{-1}) from the C1A1 marks; λ = 0.40 m used **Note** 60 $\pm$ 3 (m s^{-1}) scores full marks **Allow** 2 marks for 6000 $\pm$ 300 (m s^{-1}); λ in cm (POT error) **Allow** 2 marks for 30 $\pm$ 1.5 (m s^{-1}); λ = 0.40 m used
	(b)	(i)	Reflection (of progressive waves) at (fixed) end(s) / **X** / **Y** Superposition (of these waves gives rise to the stationary wave)	**B1** **B1**	 **Allow**: 'interference' instead of 'superposition'
		(ii)	The wavelength is twice the length of cord / distance between **X** and **Y**	**B1**	**Allow** λ = 2**XY** or equivalent
			Total	**7**	

Question			Answer	Marks	Guidance
27	(a)		-1.0 V to 2.6 V: I = 0 / negligible <u>and</u> $R = \infty$ / (very) large (AW)	B1	
			2.6 V to 3.0 V: R decreases	B1	**Allow** 'rapid decrease in R'
			3.0 V to 3.4 V: R decreases	B1	**Allow** 'slow decrease in R' **Not** R is constant (because it is a straight line)
			Justification of a B1 point in terms of $R = V/I$. For example to show: • R is infinite: $R = 2.0/0 = \infty$ • R decreases: R calculated once and has $R = \infty$, or R calculated twice	B1	**Not** R = gradient^{-1} **Ignore** powers of 10 and units **Note**: V and I values within $\pm$ 1 small square
	(b)		(The circuit does not work because) the LED is reverse biased / incorrect polarity of the cell (AW)	B1	**Allow**: (For the circuit to work) the LED must be forward-biased / 'reverse the LED' / 'reverse the cell'
			V must be <u>greater</u> than 2.6 (V for the LED to be lit)	B1	**Allow** $\pm$ 0.1 V **Not** V must be <u>equal</u> to / 'at least' 2.6 V **Allow** this mark even if the LED is reverse biased
			Use two (or more 1.5 V) <u>cells</u> (in series) / use a <u>supply</u> greater than 2.6 (V) / use a 3.0 (V) <u>supply</u>	B1	**Note**: This B1 mark can be scored on Fig. 27.2 **Allow** this mark even if the LED is reverse biased
	(c)		$E = \frac{6.63\times10^{-34}\times3.0\times10^{8}}{480\times10^{-9}}$ or $E = 4.1(4) \times 10^{-19}$ (J)	C1	
			$N = \frac{1.2\times10^{-3}}{4.1(4)\times10^{-19}}$	C1	
			$N = 2.9 \times 10^{15}$ (s^{-1})	A1	
			Total	**10**	

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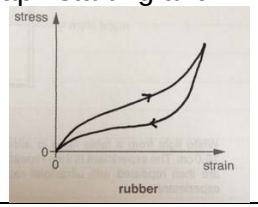
1	(a)		Transverse: vibrations /oscillations are perpendicular / right angles to the direction of travel / energy transfer (AW) Longitudinal: vibrations /oscillations are parallel to / in the same direction as the direction of travel / energy transfer (AW)	B1 B1	**Allow** 1 mark for 'For one of the waves, the oscillations / vibrations are at right angles and for the other they are parallel to the direction of travel' (AW) **Not** move for vibrations / oscillations **Allow** 1 mark for transverse (waves) can be polarised ORA
	(b)	(i)	40 (mV)	B1	
		(ii)	(T =) 3 x 0.5 = 1.5 (ms) f = 670 (Hz)	C1 A1	 **Note**: Answer to 3 SF is 667 (Hz) **Note**: 0.67 or 0.667 scores 1 mark
		(iii)	(330 = 670 × λ) λ = 0.49 (m)	 B1	**Possible** ECF from **(b)(ii)** **Note**: λ = 0.495 (m) if 667 Hz is used, therefore allow 0.50 or 0.5 (m) here
	(c)		Amplitude / height (of trace / signal) is smaller $I \propto A^2$ and amplitude (of sound or signal) is halved / amplitude is 2 div / amplitude is 20 (mV)	B1 B1	 **Note** this will also score the first B1 mark
			Total	**8**	

Question			Answer	Marks	Guidance
2	(a)	(i)	(When two or more waves meet at a point) the resultant <u>displacement</u> is equal to the sum of the <u>displacements</u> of the (individual) waves.	B1	**Allow**: net / total for 'resultant' **Not** amplitude
		(ii)	There is a constant / fixed phase difference (between the waves)	B1	**Allow** constant / fixed phase relationship **Ignore** 'the frequency / wavelength is the same' **Not** the same phase difference **Not** zero phase difference
	(b)		1. λ 2. $\frac{3\lambda}{2}$ or 1.5λ	B1 B1	
	(c)		$\lambda = \frac{ax}{D}$ stated <u>and</u> D and λ are constants. Separation decreases (AW)	M1 A1	**Allow** $x \propto a^{-1}$ **Allow** other correct answers, e.g. in terms of path difference and angles
			Total	6	

Question			Answer	Marks	Guidance
3	(a)	(i)	$(t =)\frac{6.3}{9.8(1)}$ (t =) 0.6(42….s)	M1 A0	**Allow** other correct methods, e.g: $(t) = \sqrt{\frac{2\times 2.0}{9.8(1)}}$ or $(t) = \frac{2\times 2.0}{6.3}$ **Not** a = 10 m s^{-2} **Note** t must be the unknown
		(ii)	(v_H =) $\frac{18}{0.64}$ or $\frac{18}{0.6}$ (v_H =) 28 (m s^{-1}) or 30 (m s^{-1})	M1 A0	**Note** v must be the unknown
		(iii)	$v = \sqrt{6.3^2 + 30^2}$ v = 31 (m s^{-1})	C1 A1	$v = \sqrt{6.3^2 + 28^2}$ **Allow** trigonometry methods v = 29 (m s^{-1}) **Note** 940 scores one mark
	(b)	(i)	$(E_k = \frac{1}{2}mv^2 = \frac{1}{2}\times 0.16 \times 30.7^2)$ E_k = 75 (J)	B1	Possible ECF from **(a)(iii)**
		(ii)	$(E_p = mgh = 0.16 \times 9.81 \times 2.0 =)$ 3.1 (J)	B1	**Allow** $(E_k = \frac{1}{2}mv^2 = \frac{1}{2}\times 0.16 \times 6.3^2) = 3.2(\text{J})$
		(iii)	**(b)(i)** – **(b)(ii)** ; (75 – 3.1) or $(E_k = \frac{1}{2}\times 0.16 \times 30^2)$ kinetic energy = 72 (J)	B1	Possible ECF from **(b)(i)** and **(b)(ii)** **Note:** Answer is 63 (J) when 28 (m s^{-1}) is used from **(a)(ii)**
	(c)		The path is always below the original path The maximum height of path is reached before the front of the hockey goal	M1 A1	
			Total	9	

Question			Answer	Marks	Guidance
4	(a)		(1 C =) (1) A s	C1	**Allow** alternative methods
			(1 J =) (1) $\text{kg m s}^{-2} \times \text{m}$ or (1) N = (1) kg m s^{-2}	C1	
			$V = \frac{\text{kg ms}^{-2} \times \text{m}}{\text{As}} = \frac{\text{kgm}^2\text{s}^{-2}}{\text{As}}$	M1	**Note** this mark is for clear substitution and working
			$\text{kg m}^2\text{A}^{-1}\text{s}^{-3}$	A0	
	(b)	(i)	p.d. across 1.2 kΩ = 0.9 V	C1	
			$\frac{R_{LDR}}{1200} = \frac{5.1}{0.9}$ or determines current and R = 5.1 / I	C1	
			R_{LDR} = 6800 (Ω)	A0	**Allow**: 6.8 k(Ω)
			Or $5.1 = \frac{R}{R+1.2} \times 6.0$	C1	
			0.9R = 6.12 or 0.15R = 1020	C1	**Allow** $\frac{6.8}{6.8+1.2} \times 6.0 = 5.1$ for two marks
			R_{LDR} = 6.8 (kΩ)	A0	**Allow**: 6800(Ω)
		(ii)	$(I = \frac{5.1}{6800} = \frac{6}{8000} = \frac{0.9}{1200})$ current = 7.5×10^{-4} (A)	B1	
	(c)		Resistance of LDR decreases / (total) resistance (of circuit) decreases (AW)	M1	
			Current / ammeter reading increases (AW)	A1	
			With increase in current the p.d. across (fixed) resistor / 1.2 kΩ resistor increases (AW)	B1	**Allow** p.d. across resistor increases / p.d. across LDR decreases / resistor has greater share of p.d. / LDR has smaller share of p.d.
			(For fixed e.m.f.) <u>voltmeter</u> reading decreases (AW)	B1	
			Total	10	

Question			Answer	Marks	Guidance
5	(a)		$(V =)\frac{0.1}{5300}$ 1.89×10^{-5} (m^3)	M1 A0	**Note** the mark is for substitution of values
	(b)	(i)	To ensure whole cross-sectional area or end of the conducting putty is in contact with the metal plate (AW)	B1	**Not** good electrical contact / reduces contact resistance / surface area
		(ii)	Use a (Vernier) caliper / micrometer (screw gauge) Repeat measurements along the conducting putty	B1 B1	**Allow** ruler
	(c)	(i)	6.6	B1	**Allow** 6.56 **Ignore** 10^{-3} factor
		(ii)	$\left(\%\text{ uncertainty} = \frac{2\times0.001}{0.049} \times 100 =\right)$ 4.1 %	B1	**Ignore** significant figures **Allow** 4 %
	(d)	(i)	Plots the missing point to less than a half small square Draws straight line of best fit	B1 B1	**Allow** ECF from **(c)(i)** Penalise blob of half a small square or larger **Allow** ECF Expect to be balance of points about line of best-fit. Judge straightness by eye. **Not** a top point to bottom point line / not a top point to (2.0, 10) line
		(ii)	Gradient $= \frac{y_2-y_1}{x_2-x_1} = \frac{\Delta y}{\Delta x}$ gradient = 5700 (5550 – 5850)	M1 A1	**Not** one R/L^2 value using the line or a data point **Ignore** POT for M1 **Allow** ± 150 for the value of gradient **Ignore** units
	(e)		$\rho = 5700 \times 1.9 \times 10^{-5}$ ρ = 0.108 given to 2 or 3 sf Ω m	C1 A1 B1	**Note**: ECF from **(d)(ii)** **Allow** any subject for equation **Not** use of data points from table
			Total	13	

Question			Answer	Marks	Guidance
6	(a)		**Level 3 (5–6 marks)** Clear procedure, measurements **and** analysis *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Some procedure, some measurements and some analysis. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Limited procedure and limited measurements **or** limited analysis *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1 x6**	**Indicative scientific points may include:** **Procedure** • labelled diagram • incremental increase in load / mass until wire breaks • method of attaching wire at fixed end • method of attaching load at other end • use of safety screen / goggles to protect eyes • method of securing retort stand **Measurements** • measurement of load / mass • measurement of diameter • use micrometer to measure diameter • averages diameter • repeats experiment **Analysis** • equation to determine force, e.g. *mg* • equation to determine cross-sectional area or $A = \pi r^2$ • (breaking) stress = (max) force / cross-sectional area or $\sigma = \frac{F}{A}$
	(b)		Glass: A straight line from the origin. Rubber: A correct sketch for loading and unloading sections, with the graph starting and finishing at the origin.  	**B1** **B1**	**Ignore** arrows **Allow** either arrows or labelled curves
			Total	**8**	

Question			Answer	Marks	Guidance
7	(a)		**Level 3 (5–6 marks)** Clear explanation of observations **and** clear evidence of particulate nature of electromagnetic waves *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Clear explanation of observations **or** clear evidence of particulate nature of electromagnetic waves **or** has limited explanation of observations and limited evidence of particulate nature of EM radiation *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Has limited explanation of observations **or** limited evidence of particulate nature of EM radiation *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1**	**Indicative scientific points may include:** **Explanation of Observations** • Discharge due to the emission of electrons / negative charge • Intensity depends on distance • Rate of incident photons is more at smaller distances • Greater intensity / rate of uv photons linked to quicker fall • uv causes instantaneous discharge • No effect with light • Intensity of light has no effect on the discharge • Natural discharge over a long period of time **Evidence of particulate nature of em** • Wave theory suggests leaf would fall with light • Photon as packet of energy • One to one interaction • uv photon greater energy than work function/greater frequency than threshold frequency • Light photons have less energy than the work function • $E = hf$ / photon energy depends on frequency • Energy of photon independent of intensity • Energy conserved in interaction • Einstein's equation (words or symbol)

Question			Answer	Marks	Guidance
	(b)		$3.2 \times 1.6 \times 10^{-19}$ or $6.63 \times 10^{-34} \times 960 \times 10^{12}$	C1	
			$E_{k\,max} = 6.63 \times 10^{-34} \times 960 \times 10^{12} - 5.12 \times 10^{-19}$	C1	
			$E_{k\,max} = 1.2 \times 10^{-19}$(J)	A1	**Note** answer to 3 SF is 1.24×10^{-19} (J)
			Total	**9**	

Question			Answer	Marks	Guidance
8	(a)		(kinetic energy =) $1.6 \times 10^{-19} \times 300$ $eV = \frac{1}{2}mv^2$ $v = \sqrt{\frac{2\times1.6\times10^{-19}\times300}{9.11\times10^{-31}}}$ speed = 1.03×10^7 (m s^{-1})	C1 C1 C1 A0	**Note** 1.05×10^{14} scores 2 marks; omitted square rooting
	(b)		$\lambda = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times1.0\times10^{7}}$ $\lambda = 7.3 \times 10^{-11}$ (m)	C1 A1	**Allow** ECF from **(a)** **Allow** 2 marks for 7.1×10^{-11}, $v = 1.03 \times 10^7$ used
	(c)		Momentum / (kinetic) energy / speed (of electrons) increases / (de Broglie) wavelength decreases Radius / diameter of rings decreases / pattern becomes 'smaller' (AW) or the rings are now brighter	B1 B1	
			Total	**7**	

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