Oxford Cambridge and RSA

GCE

Physics A

Unit **G482**: Electrons, Waves and Photons

Advanced Subsidiary GCE

Mark Scheme for June 2014

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

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.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

Annotation	Meaning
BP	Blank Page – this annotation **must** be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
BOD	Benefit of doubt given
CON	Contradiction
✗	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error or repeated error
SF	Error in number of significant figures
✓	Correct response
AE	Arithmetic error
?	Wrong physics or equation

Abbreviations, annotations and conventions used in the detailed Mark Scheme

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
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

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Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC 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 answer.

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 answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

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 that the candidate knew the equation, then the **C**-mark is given.

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

IMPORTANT UPDATE:

ADDITIONAL OBJECTS: You **must** annotate the additional objects for each script you mark. If no credit is to be awarded for the additional object, please use annotation as agreed at the SSU, likely to be 'seen', a cross or the highlighting tool.

CROSSED OUT, RUBRIC ERROR (OPTIONAL QUESTIONS) AND MULTIPLE RESPONSES

Crossed-out Responses: Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

Rubric Error Responses – Optional Questions: Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses: When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses: When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**): Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**): If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response): Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked.

Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a ‘new start’ or simply a poorly expressed continuation of the first response.

Note about significant figures:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf.
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.

Please put a tick for every mark awarded in the body of the text at the point where the mark is given.

Question			Answer	Marks	Guidance
1	a	i	V is not proportional to I	B1	**accept** not a straight line; R is not constant
		ii	R (approximately) constant up to V = 0.5 V and I = 50 mA so R = 0.5/0.05 = 10 (Ω)	B1 B1	**allow** graph is (almost) linear/straight (to V = 0.5 V) or constant gradient **allow** any correct calculation, e.g. 0.2/0.02
		iii	the resistivity/resistance of the (metal) filament increases with temperature the larger the current in the filament the hotter it becomes/AW	B1 B1	larger current heats filament so resistance increases **or** electron-ion collisions increase/AW; **allow** atom for ion
	b		Any potential divider argument or calculation *In the light* parallel combination less than or about 1 Ω/AW so V across lamp less than 0.5 V (so lamp out)/ small compared to V across 25 Ω	B1 B1 B1	**QWC** the arguments must be clear for full marks **allow** R_{lamp} = 10 to 25 Ω for any calculation **or** comparison of voltage across 25 Ω to 1 Ω **N.B.** answers given in terms of current are likely to score zero
			In the dark parallel combination about 25 Ω/AW so V across lamp approximately 6.0 V so lamp on	B1 B1	
			Total	**10**	

Question			Answer	Marks	Guidance
2	a		emf – J C^{-1}, resistance – V A^{-1}, energy – V C, charge – A s	**B1** **B1**	4 correct 2 marks; 2 correct 1 mark
	b	i	energy per unit charge transferred from electrical to other forms	**B1** **B1**	**NOT** coulomb **allow** any other form e.g. heat, light, etc
		ii	(some) energy is transferred into thermal energy /lost as heat in (driving charge through) the battery. It behaves as if it has an (internal) resistance/AW **or** there is a voltage drop across/decrease in voltage from the battery (when a current is drawn from it)/AW	**B1**	**allow** any description which uses E = V + Ir but not just the formula alone, e.g. 'lost volts' per unit current is just accepable
		iii	p.d. across each branch is the same/branches in parallel resistance in X branch is 6 Ω, in YZ branch is 12 Ω so current in X branch is twice that in YZ branch/ as V = IR	**B1** **B1** **A0**	 **allow** R in X branch is half that in YZ branch/AW
		iv	V = IR = 0.08 x 6 V = 0.48 (V)	**C1** **A1**	
		v	the p.d. across each 3 Ω resistor is terminal p.d./2 **or** 0.48 V at Z there is 6 Ω either way to the supply/AW so p.d. across each 6 Ω is terminal p.d./2 so p.d. between X and Z is zero	**B1** **B1** **A0**	p.d./voltage across 3 Ω and 6 Ω are equal with justification
		vi	terminal p.d. = 0.96 V current in r = 0.16 + 0.08 = 0.24 A use of E = V + Ir 1.2 = 0.96 + 0.24 r giving r = 1.0 (Ω)	**C1** **C1** **C1** **A1**	**or** V = 0.24 x 4 **or** = 0.08 x 12 **or** 0.16 x 6 **or (iv)** x 2 **alt**: R in parallel gives 4.0 Ω; total R = 1.2/0.24 = 5.0 Ω r = 5.0 - 4.0 = 1.0 (Ω) **allow** 1SF
			Total	**15**	

Question			Answer	Marks	Guidance
3	a		p.d./voltage (across component) divided by current (in it)	B1	**accept** V/I with V and I defined; per (unit) current, etc
	b	i	$R = \rho l/A$ $= 1.7 \times 10^{-8} \times 20 \times d/4d^2 = 1.7 \times 10^{-8} \times 5/3.8 \times 10^{-10}$ $=220$ (Ω)	C1 C1 A1	 **allow** $A = 4\pi r^2 = 4.5 \times 10^{-19}$ giving 285 Ω **accept** 220 to 230 Ω
		ii	$n = 1/d^3 = (1.8 \times 10^{28})$	A1	**accept** alternatives, e.g. 80/volume
		iii	$I = nAev$ $= 1.8 \times 10^{28} \times 4 \times (3.8 \times 10^{-10})^2 \times 1.6 \times 10^{-19} \times 1.9 \times 10^{-5}$ $= 3.2 \times 10^{-14}$ (A)	 C1 A1	 1 mark for substitution into formula, **ecf** n, A values accept 3.16 and 3.5 (using $n = 2 \times 10^{28}$) accept 2.48 and 2.76 (for 285 Ω)
		iv	$P = I^2R$ $= (3.2 \times 10^{-14})^2 \times 200 \times 10^9$ $= 2.0 \times 10^{-16}$ (W)	C1 C1 A1	**ecf b(i) & (iii)** **accept** 1 SF as estimate; can obtain 1.2 to 2.8 using all values possible in **(iii)**
	c		electron moves at drift velocity signal travels at/close to the speed of light	B1 B1	**accept** answers explaining idea of drift velocity
			Total	**12**	

Question			Answer	Marks	Guidance
4	a	i	ammeter in series voltmeter in parallel with LED	B1	both correct to score 1 mark
		ii	(at 20 mA) V_{led} = 4.0 V V_R = 0.020 x 100 = 2.0 V so p.d. = 6.0 V	B1 C1 A1	**allow** R_{led} = (4.0/ 0.02) = 200 Ω p.d. = 0.020 (200 + 100) **allow** answer to 1 SF
	b	i	energy in eV = 4.1 x 10^{-19}/1.6 x 10^{-19} = 2.6 (eV)	B1	**expect** 2.56 eV
		ii	LED strikes at 2.6 V/ only conducts above 2.6 V an electron must pass through a p.d. of 2.6 V to lose energy as a photon of blue light/AW.	M1 A1	
	c	i	n = I/e = 0.02/1.6 x 10^{-19} = 1.3 x 10^{17}	C1 A1	**expect** 1.25 x 10^{17}
		ii	energy/s = 1.25 x 10^{17} x 4.1 x 10^{-19} or 2.6 V x 0.020 A = 0.051 to 0.053 (J s^{-1})	C1 A1	**ecf (c)(i); NOT** 4.0 x 0.020 answer is 0.053 using 1.3 x 10^{17}
		iii	efficiency = 0.052/(4.0 x 20 x 10^{-3}) = 0.64	C1 A1	**ecf (c)(ii)** **accept** $V_{strike}/V_{operate}$ = 2.6/4.0 or any other correct (P or W out)/ (P or W in) calculation **accept** 64 %
	d		shape similar to the curve drawn leaving x-axis at close to 2.0 V and passing through (3.4, 20)	B1 B1	Within half a square
			Total	**15**	

Question			Answer	Marks	Guidance
5	a		<u>constant</u> phase difference/relationship (between the waves) **or** <u>always</u> at π radians/180^o **or** because they are generated by the same source/AW	B1	**allow** fixed **NOT** same
	b		(for a minimum) the two oscillations/amplitudes add in antiphase/ are π (rad) out of phase/<u>completely</u> out of phase there is a resultant <u>amplitude</u> (of 2.0 μm) so a sound will still be heard	B1 B1	for zero intensity the two oscillations must have equal amplitudes/AW and be in antiphase **allow** the word waves for oscillations
	c		**B** π/2 radians/90^o **C** 3π/4 radians/135^o	B1 B1	**max** 1 out of 2 marks if unit omitted
	d	i	f = 10^3/0.8 = 1.25 kHz **or** T = 0.8 x 10^{-3} s λ = v/f **or** vT = 340 x 0.8 x 10^{-3} λ = 0.27 m	C1 C1 A1	if T value from graph incorrect **ecf** with max 2/3
		ii	select λ = ax/D D = 0.4 x 4.8/ 0.27 D = 7.1 (m)	C1 C1 A1	**ecf (d)(i)** **expect** 7.06 m if using λ = 0.272 m 3.5 m or 3.6 m scores 2 marks
	e	i	energy per unit time/power per unit area (perpendicular to the direction of energy transfer)	B1	**accept** per second as a special case
		ii	ratio of amplitudes = 3 intensity is proportional to (amplitude)^2 ratio of intensities = 9 so intensity at **O** = 4.0 x 10^{-6} x 9 I = 3.6 x 10^{-5} (W m^{-2})	C1 C1 A1	**or** A at **P** = 2.0 μm and A at **O** = 6.0 μm clearly stated **allow** I α A^2 i.e. symbols only
			Total	**15**	

Question			Answer	Marks	Guidance
6	a		all travel at speed of light through a vacuum are oscillating E and B fields **or** are caused by accelerating charges/AW	B1 B1	**max** 2 marks from 3 marking points if 3 properties are given withhold one mark for each incorrect property so 2 correct and 1 incorrect would score 1 mark ;1 correct and 2 incorrect would score zero, etc
	b	i	oscillations (of particles/e-m fields along the wave) are in one direction only perpendicular to the direction of wave propagation/of travel of the wave/of energy transfer	B1 B1	
		ii	light passing through polariser 1 is vertically polarised/ only vertical oscillations of the light exist beyond the polariser 1/AW only (the component of) light in the horizontal plane can pass through polariser 2 so no light reaches the eye	B1 B1	**allow** any words indicating vertical, e.g. up and down; for horizontal, e.g. at 90° to vertical or crossed polarisers **accept** using Malus' law $I_{trans} = I_{incident}\cos^2\theta$ with $\theta = 90°$ gives $I_{trans} = 0$
		iii	after polariser 1 the component of the vertically polarised light at 45° passes through polariser 3 the polarised light beyond polariser 3 has a component at 45° which passes through polariser 2 so light reaches the eye **or mark a typical answer of the form (max 2) as follows** some of the vertically polarised light passes through polariser 3 and some of this passes through polariser 2 because in each case the polarised light is not at right angles to the transmission axis of the polariser	B1 B1 B1	**QWC** statement to the effect that component of light along polarising axis of filter is transmitted **accept** using Malus' law $I_{trans} = I_{incident}\cos^2\theta$ with $\theta = 45°$ gives $I_{trans} = I_{incident}/2$ same process gives $I_{trans} = I_{incident}/2$ again so ¼ of light after polariser 1 reaches eye (assuming no absorption) accept answers in terms of amplitudes rather than intensities, i.e. $A = A_0 \cos\theta$, etc.
			Total	9	

Question			Answer	Marks	Guidance
7	a		(micro)waves are reflected (at the metal walls) reflected waves interfere/superpose with the incident waves to produce nodes and antinodes (– a stationary wave pattern)	**B1** **B1** **B1**	 **allow** points of constructive and destructive interference
	b		X are the points of maximum energy/intensity/amplitude so are antinodes	**M1** **A1**	**allow** displacement in this case
	c		measurement = 3 cm **or** $\lambda/2$ = 6 cm so λ = 0.12 m $c = f\lambda = 2.5 \times 10^9 \times 0.12$ $= 3.0 \times 10^8$ (m s^{-1})	**B1** **C1** **M1** **A1**	measurement to within ± 1 mm **ecf** measurement, i.e. λ = 4 x measurement there must be a valid calculation shown scores 1 out of final 3 for answer of 1.5×10^8 **allow** 1 SF, i.e. 3×10^8
			Total	**9**	

Question			Answer	Marks	Guidance
8	a	i	energy φ required for an electron to escape from metal surface the minimum energy........	M1 A1	 inclusion of the word minimum in the sentence scores the second mark
		ii	a photon with less than the threshold frequency f_0 cannot cause electron emission/AW so work function = h (threshold frequency)	 B1 B1	 **allow** $\varphi = hf_0$ when the symbols φ and f_0 have been defined somewhere in the question
		iii	$\varphi = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/550 \times 10^{-9}$ $= 3.6 \times 10^{-19}$ (J)	 C1 A1	
	b	i	$KE_{max} = hf - \varphi$ or $hf = \varphi + KE_{max}$ $hf = 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/440 \times 10^{-9} = 4.5 \times 10^{-19}$ J $½mv^2 = 9 \times 10^{-20}$ giving $v^2 = 1.8 \times 10^{-19}/9.1 \times 10^{-31}$ $v = 4.45 \times 10^{5}$ (m s^{-1})	C1 B1 B1 A0	 **ecf (a)(iii)** allow 4.5 or 4.4 x 10^5
		ii	$\lambda = h/mv = 6.63 \times 10^{-34} / 9.1 \times 10^{-31} \times 4.5 \times 10^{5}$ $\lambda = 1.6 \times 10^{-9}$ (m)	C1 A1	 allow 1.7×10^{-9} for $v = 4.4 \times 10^5$
	c	i	n = 3 to n = 2	B1	**allow** between **or** and **when** there is a downward arrow on Fig. 8.1
		ii	$E_{32} + E_{21} = E_{31}$ $hc/\lambda_{32} + hc/\lambda_{21} = hc/\lambda_{31}$ $1/590 + 1/440 = 1/252$ so $\lambda_{31} = 250 \times 10^{-9}$ (m)	C1 C1 A1	 **accept** equation using 1/λ **or** $1/590 + 1/440 = 1/\lambda_{31}$ **allow** 2 or 3 sf **allow** 2/3 for using 550 for 590 nm giving 244 nm
			Total	**15**	

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