Oxford Cambridge and RSA

# GCE

# Physics A

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

Advanced Subsidiary GCE

# Mark Scheme for June 2015

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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.

## Annotations

Available in Scoris

| Annotation | Meaning |
|---|---|
| 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 repeat error |
| SF | Error in number of significant figures |
| ✓ | Correct response |
| AE | Arithmetic error |
| ? | Wrong physics or equation |

The abbreviations, annotations and conventions used in the detailed Mark Scheme are:

| 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 |

**Subject-specific Marking Instructions**

## CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

**B** marks: These are awarded as <u>independent</u> 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.

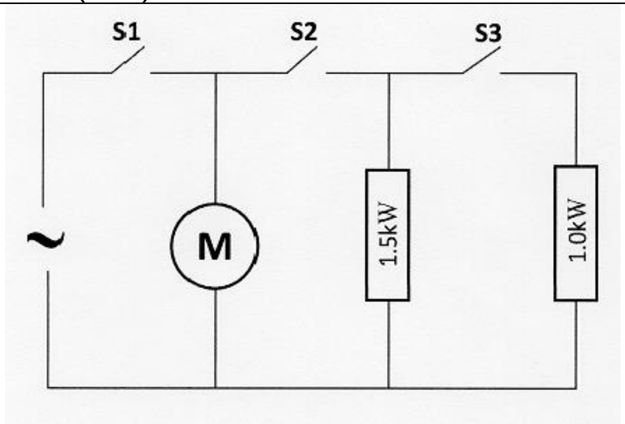
**M** marks: These are <u>method</u> marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

**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.

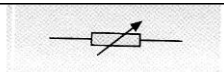
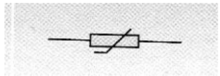
**A** marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

**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. **N.B.** Also penalise RE only once per paper.
Any exception to this rule will be mentioned in the Guidance.

**A tick should be placed in the body of the script at the point where each mark is awarded.**

| Question | | | Answer | M | Guidance |
|---|---|---|---|---|---|
| 1 | | | | | |
| | a | i | $P = V^2/R = 230^2/R = 1500$<br>$R = 35.3\ \Omega$ | C1<br>A1 | **accept** I = P/V = 6.52 A and R = 230/6.52<br>**allow** 52900/1500 = 35 Ω, i.e. some working shown |
| | | ii | use of $\rho = RA/l$ or $R = \rho l/A$<br>$l = 35 \times 7.8 \times 10^{-8}/1.1 \times 10^{-6}$<br>l = 2.5 (m) | C1<br>C1<br>A1 | formula<br>correct substitution<br>answer (2.48) |
| | b | | resistors and motor wired in parallel to supply<br>switches correctly placed (open or closed)<br>any suitably labelled symbols; components in correct order | B1<br>M1<br>A1 | <br>do not expect switches to be labelled |
| | c | i | power is inversely proportional resistance (for same V)<br><br>resistance of wire is inversely proportional to c-s area/diameter squared (as l and ρ are fixed/same) | B1<br><br>B1 | **accept**: (same V so for) larger/smaller power need (larger/smaller I and so) smaller/larger resistance<br>**accept** smaller c-s area/diameter (of wire) causes larger resistance or vice versa |
| | | ii | $P \propto A$ (because $P = V^2/R = V^2A/\rho l$)<br>**or** $P \propto d^2$ (because $A = \pi d^2/4$)<br>$1.0/1.5 = (d/D)^2 = 2/3$<br>so d = 0.82 D | B1<br><br>M1<br>A1 | **accept** $R_{1000} = 52.9\ \Omega$ and $R \propto 1/A$<br>[ where $A_d = 5.2 \times 10^{-8}$ & $A_D = 7.8 \times 10^{-8}$ ]<br>so $35.3 / 52.9 = [(d/D)^2$ or $A_d/A_D] = 2/3$<br>[ where $d = 2.57 \times 10^{-4}$ & $D = 3.15 \times 10^{-4}$ ] |

| Question | | | Answer | M | Guidance |
|---|---|---|---|---|---|
| | **d** | | total current in circuit = 2600/230 = 11.3 A<br>so 13 A fuse required | M1<br>A1 | **accept** I = 2500/230 = 10.9 A |
| | **e** | **i** | (a unit of) <u>energy</u> equal to 3.6 MJ **or** 1 kW for 1 h/AW | B1 | **e.g.** 1000 W for 3600 s or similar;<br>**NOT** 1 kW **per** hour |
| | | **ii** | 1.6 x 4 x 18<br>115 (p) | C1<br>A1 | **allow** 1 mark for 108 p; i.e. using 1.5 x 4 x 18<br>**or** 1 mark for 79 p; i.e. using 1.1 x 4 x 18<br>**NOT** 72 p |
| | | | **Total question 1** | **18** | |

| Question | | | Answer | M | Guidance |
|---|---|---|---|---|---|
| **2** | | | | | |
| | **a** | |  for $R_1$<br> for $R_2$ | B1<br>B1 | |
| | **b** | **i** | 500 Ω | B1 | **accept** ± 20 Ω |
| | | **ii** | 7.0 = I x 500; I  0.014 (A) | B1 | **ecf b(i)** |
| | | **iii** | 5.0 = 0.014 x R or 12 = 0.014(500 + R)<br>R = 360 Ω | M1<br>A1 | **ecf b(i)(ii)**<br>**allow** R = 500 x 5/7 = 360 Ω |
| | | **iv** | (at 200°C) $R_{th}$ = 250 Ω<br>V across thermistor =12 x 250/(250 + 350) = 5.0 V<br>**alt** 5.0 = 12 x R/(R + 350)<br>**or** I = 7.0/350 = 0.02 A; $V_{th}$ = 5.0 = 0.02 x R<br>R = 250 Ω which occurs at 200°C | B1<br>B1 | **allow** $R_{th}$ = 250 ± 10 giving 4.8 to 5.1 V<br>**expect** 350 or 360; **allow** 1 SF where answer is 5.0<br>**NOT** 250 x 0.02 = 5.0 V; 0.02 A must be justified<br>**allow** 7.0 = 12 x 350/(350 + R) |
| | **c** | | **switch on** 5.0 = 12 x 250/(250 + R ) or 7.0 = 12 x R/(250 + R )<br>giving R = 350 Ω which is 190°C<br>**switch off** 7.0 = 12 x 250/(250 + R) or 5.0 = 12 x R/(250 + R )<br>giving R = 180 Ω which is 210°C<br>**or** Switch on, R2 / R1 = 7/5 giving R2 - 250 x 7/5 = 350 ohm<br>Switch off, R2 / R1 = 5/7 giving R2 = 250 x 5/7 = 179 ohm | M1<br>A1<br>M1<br>A1 | **accept** solution in 2 stages first calculating currents<br>on I = 0.02 and R = 7/0.02<br>off I = 0.028 and R = 5/0.028<br>**allow** ± 5°C in reading from graph<br>**N.B.** zero marks for correct temperatures quoted without some correct working/justification |
| | | | **Total question 2** | **12** | |

| Question | | | Answer | M | Guidance |
|---|---|---|---|---|---|
| 3 | | | | | |
| | a | i | Q = It= 0.45 x 4.67 x 60 x 60<br>= 7600<br>C or As | C1<br>A1<br>B1 | <br>**accept** 7560 or 7570 |
| | | ii 1,2 | **1** positive; **2** clockwise<br><br>energy must be transferred to the cell<br>**or** current in opposite direction transfers energy from the cell to the circuit/AW | M1<br><br>A1 | positive plus correct direction of arrow for first mark; do not penalise if arrow not labelled I.<br>**allow** (conventional) current is from positive to negative ; **or** electron flow from **–** to + [but current must be clockwise in **1**] |
| | | 3 | $V_{XY}$ = 1.5 + 0.45 x 0.90<br>$V_{XY}$ = 1.9 (V) | C1<br>A1 | <br>**accept** 1.905 or 1.91 |
| | | 4 | P = VI = 0.45 x 1.5<br>P = 0.675 (J $s^{-1}$) | C1<br>A1 | **allow** QV/t with **ecf a(i)** if necessary (11340/16800)<br>**allow** 0.7 as final line if 0.675 appears above |
| | b | | **1.**cell across variable resistor R ammeter in series and voltmeter in parallel across R or cell<br>**2.**Take (set of) readings of V and I for different positions/values of the variable resistor<br>**3.**plot a graph of V against I<br>**4.**(find) y-intercept = E<br>**5.**(find) the gradient of the V against I graph which equals the internal resistance in magnitude<br>**or 4 or 5** take one pair of values of V,I and substitute into equation E = V + Ir to find r or E | B1<br><br>B1<br>B1<br>B1<br><br>B1 | QWC last marking point needed for full marks<br><br>**allow** use (digital) voltmeter across <u>unloaded</u> cell to find E; add R and find one value of V and I; then use equation to find r (points 2 to 5)<br>**ignore** sign of gradient in determining r<br>**allow** for no graph plot, using 2 pairs of values of V and I substituted into equation allows r and E to be found.(points 2 to 5) |
| | c | i | 4 x 1.5 V cells gives 6.0 V with r of 3.6 Ω<br>so current is 6.0/(3.6 + 18) = 0.28 A<br>requires (2 W/6 V = ) 0.33 A to light normally<br>or power delivered = ($0.28^2$ x 18 or 5.0 x 0.28 )= 1.4 W<br>**alt**: use 0.33 A & 6 V to show need emf of 7.2 V (1.8 V per cell) | B1<br>B1<br>B1 | **allow** AW such as: 6 V but total R now 21.6 Ω;<br>6 V across 21.6 Ω gives 5 V across 18 Ω;<br>requires 6 V to light normally<br>**allow** P = 1.(6)7 W for 2 marks; only give the third mark if P labelled as power delivered by cell |
| | | ii | 1.5 n = 0.33 (18 + 0.9 n) **or** 1.5n = 6 + 0.3n<br>so 3.6 n = 18 **or** 1.2n = 6 giving n = 5 | M1<br>A1 | **alt:** lamp needs V = 6V and I = 0.33 A<br>terminal p.d per cell is 1.5 = V + 0.9 x 0.33<br>giving V = 1.2 V so n = 6/1.2 = 5<br>**allow** trial and error method but working must be shown to score any marks |
| | | | **Total question 3** | **19** | |

| Question | | | Answer | M | Guidance |
|---|---|---|---|---|---|
| 4 | | | | | |
| | a | i 1<br>2<br><br><br>3 | the maximum displacement <u>from equilibrium</u> or <u>rest position</u><br>number of oscillations/vibrations (at a point) <u>per</u> unit time<br><br><br>how far 'out of step' (out of sync) the oscillations <u>at two points</u> on the wave/string are/AW | B1<br>B1<br><br><br>B1 | **allow** *zero* or *undisturbed* for *equilibrium*<br>number of <u>wavelengths</u> passing a point or produced by the wave source <u>per</u> unit time<br>**allow** <u>per</u> second **NOT** *amount* for *number*<br>**alt e.g.** the fraction of a cycle between the oscillations at the two points |
| | | ii 1<br>2 | all have same frequency **or** same amplitude<br>all have different phases/ phase differences | B1<br>B1 | **N.B.** withhold mark if extra incorrect answers given<br>**allow** *not in phase* or *all out of phase* |
| | b | i | *progressive* a wave which transfers energy<br>*stationary* a wave which <u>traps/stores</u> energy (in pockets)<br>**or** *progressive* : transfers shape/information from one place to another<br>*stationary* where the shape does not move along/which has nodes and antinodes/AW | B1<br>B1 | **accept** phase relationship descriptions between different points on wave;<br><br>must be a comparison for same property to score both marks |
| | | ii | the wave <u>reflected</u> (at the fixed end of the wire)<br><u>interferes/superposes</u> with the incident wave<br>to produce a resultant wave with nodes and antinodes/no energy transfer | B1<br>B1<br><br>B1 | |
| | | iii 1<br><br>2 | (**all** points have) same frequency<br>**P** and **Q** have same amplitude <u>and</u> (are in) phase<br>**S** has larger amplitude than **P** <u>and</u> **Q**<br>**S** has a phase difference of π/in antiphase to **P** <u>and</u> **Q** | B1<br>B1<br>B1<br>B1 | <br>**allow** *same phase difference* here<br>**allow** *different to*<br>**or** $180^o$ **max** any 3 out of 4 marking points |
| | | iv 1<br><br><br>2 | 15 Hz<br>as all points in the fundamental/first harmonic mode move in phase<br>120 Hz<br>for every 10 cm to be at rest λ = 20 cm (so 4 x frequency of Fig. 4.2) | B1<br><br>B1<br>B1<br><br>B1 | <br>**accept** string is ½ λ long/between ends<br><br><br>**accept** as all points are nodes **or** $f = 8f_0$ **or** is $8^{th}$ harmonic |
| | | | **Total question 4** | **17** | |

| Question | | | Answer | M | Guidance |
|---|---|---|---|---|---|
| 5 | | | | | |
| | a | i | when two (or more) waves meet/superpose/overlap (at a point)<br>there is a change in overall displacement | M1<br>A1 | **NOT** interact,combine, join, connect, collide, hit**,** intersect, pass through, etc.<br>**allow** the resultant displacement equals the sum of the individual displacements |
| | | ii | constant phase difference/relationship (between the waves) | B1 | **allow** fixed **not** same |
| | b | | $\lambda = c/f = 3.0 \times 10^8 / 1.0 \times 10^{10}$<br>$\lambda = 3.0 \times 10^{-2}$ so aerial length = $1.5 \times 10^{-2}$ (m) | M1<br>A1 | <br>**accept** 1.5 c(m) |
| | c | i1 | the path difference between the signals (from the two transmitters) changes (along OP)<br>causing the detected signal to vary between maximum and minimum values/AW<br>**or** when signals (at the point on OP) are in phase there is a maximum<br>when (π) out of phase there is a minimum | B1<br><br>B1 | **give** 1 mark out of 2 for maxima <u>and</u> minima occur (because of interference) |
| | | 2 | $x = \lambda D/a = 3.0 \times 10^{-2} \times 4.0/0.20$ (= 0.60)<br>so distance = x/2 = 0.30 (m) | C1<br>A1 | **ecf (b)** 20 times answer to **(b)**<br>**allow** 1 SF answer here |
| | | ii | amplitude of signal decreases (inversely) with distance<br>because energy emitted by the transmitters spreads out (so less is collected by the receiver the further away it is ) | B1<br><br>B1 | **allow** intensity; **no mark if** any suspicion of decrease being caused by interference effect<br>**accept** any statement which conveys the idea of energy spreading correctly,e.g. $I \propto 1/d^2$ |
| | | iii | when AO – BO = λ/2 a minimum occurs/AW **or** phase difference of π (180°) between detected signals from A and B<br>so distance = $\lambda/2 = 1.5 \times 10^{-2}$ (m) | B1<br><br>B1 | idea that movement of λ/2 will change maximum to minimum or vice versa<br>**ecf (b)** same answer as **(b); accept** 1.5 c(m) |
| | d | i | intensity increases by factor of 4<br>as intensity α $(\text{amplitude})^2$ | B1<br>B1 | |
| | | ii | intensity falls to zero<br>(emitted) signal is (vertically) <u>polarised</u><br>receiver in position only to detect horizontally polarised signal | B1<br>B1<br>B1 | <br><br>**allow** transmitter and detector act like ‘crossed polarisers’ or quoting Malus' law correctly |
| | | | **Total question 5** | **18** | |

| Question | | | Answer | M | Guidance |
|---|---|---|---|---|---|
| **6** | | | | | |
| | **a** | | photoelectric effect | B1 | |
| | **b** | **i** | **1.**Individual photons are absorbed by individual electrons ( in the metal surface)/ one to one interaction/AW<br>**2.**Only photon with energy above the work function energy will cause photoelectron emission/idea of threshold frequency<br>**3.**Photon energy is proportional to frequency<br>**4.**(therefore) blue photons with higher f/shorter *λ* will cause photoemission but red photons will not.<br>**5.**hf – ϕ = $KE_{max}$ is the equation resulting from conservation of energy **or** resulting from the meaning of each term<br>**6.**A wave model does not explain instantaneous emission | B1<br>B1<br>B1<br>B1<br>B1<br>B1 | **max** 4 from 6 marking points<br>**allow** work function (of a metal surface) is minimum energy for photoemission<br>**allow** shorter wavelength light has higher energy (hc/ *λ)* or higher frequency higher energy (hf)<br>**or** ….red photons with lower f/longer *λ.....*<br>*max* must be present to score mark; equation stated in words: photon e. – w.f. = max ke of *e*<br>to score full marks (4) the answer **must include** two terms out of *photon, work function* and *threshold frequency/wavelength* (QWC mark) |
| | **c** | **i** | work function = ϕ = hc/*λ*<br>$\varphi = 6.6 \times 10^{-34} \times 3.0 \times 10^{8} / 4.8 \times 10^{-7}$<br>$= 4.1(4) \times 10^{-19}$ (J) | C1<br>M1<br>A1 | allow ϕ = hf ($f = 6.25 \times 10^{14}$) and f = c/*λ*<br>must show answer <u>initially</u> to 2 or 3 SF; ignore any <u>final</u> rounding down to 1 SF |
| | | **ii** | $E - \phi = ½ mv^2$<br>$(5.2 – 4.1) \times 10^{-19} = 1.1 \times 10^{-19} = ½ mv^2$<br>$v = \sqrt{(2 \times 1.1 \times 10^{-19} / 9.1 \times 10^{-31})}$<br>$v = 4.9 \times 10^{5}$ (m $s^{-1}$) | C1<br>C1<br>A1 | can use 4.14 or 4 instead of 4.1<br>**allow** $5.1 \times 10^{5}$ (m $s^{-1}$) using $\phi = 4 \times 10^{-19}$ or $4.8 \times 10^{5}$ (m $s^{-1}$) using $\phi = 4.14 \times 10^{-19}$ |
| | **d** | **i** | electrons passing through a thin sheet of graphite<br>are diffracted/produce diffraction rings on a fluorescent screen | M1<br>A1 | any suitable/reasonably plausible situation<br>what is observed/ interpretation |
| | | **ii** | λ = h/mv<br>$\lambda = 6.63 \times 10^{-34} / 5.0 \times 10^{5} \times 9.1 \times 10^{-31}$<br>$\lambda = 1.5 \times 10^{-9}$ (m) | C1<br>C1<br>A1 | 1.46 to 3 SF |
| | | | **Total question 6** | **16** | |

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