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ASSESSMENT and QUALIFICATIONS ALLIANCE

## General Certificate of Education

# Physics 1451

*Specification A*

## PHYA1 Particles, Quantum Phenomena and Electricity

# Mark Scheme

*2009 examination - January series*

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.



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*Dr Michael Cresswell Director General*

## Instructions to Examiners

1 Give due credit for alternative treatments which are correct. Give marks for what is correct in accordance with the mark scheme; do not deduct marks because the attempt falls short of some ideal answer. Where marks are to be deducted for particular errors, specific instructions are given in the marking scheme.

2 Do not deduct marks for poor written communication. Refer the scripts to the Awards meeting if poor presentation forbids a proper assessment. In each paper, candidates are assessed on their quality of written communication (QWC) in designated questions (or part-questions) that require explanations or descriptions. The criteria for the award of marks on each such question are set out in the mark scheme in three bands in the following format. The descriptor for each band sets out the expected level of the quality of written communication of physics for each band. Such quality covers the scope (e.g. relevance, correctness), sequence and presentation of the answer. Amplification of the level of physics expected in a good answer is set out in the last row of the table. To arrive at the mark for a candidate, their work should first be assessed holistically (i.e. in terms of scope, sequence and presentation) to determine which band is appropriate then in terms of the degree to which the candidate's work meets the expected level for the band.

| **QWC** | **descriptor** | **mark range** |
|---|---|---|
| Good - Excellent | *see specific mark scheme* | |
| Modest - Adequate | *see specific mark scheme* | |
| Poor - Limited | *see specific mark scheme* | |
| The description and/or explanation expected in a good answer should include a coherent account of the following points: *see specific mark scheme* | | |

Answers given as bullet points should be considered in the above terms. Such answers without an 'overview' paragraph in the answer would be unlikely to score in the top band.

3 An arithmetical error in an answer will cause the candidate to lose one mark and should be annotated AE if possible. The candidate's incorrect value should be carried through all subsequent calculations for the question and, if there are no subsequent errors, the candidate can score all remaining marks.

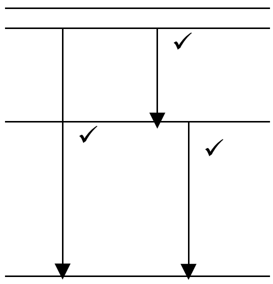
4 The use of significant figures is tested **once** on each paper in a designated question or part-question. The numerical answer on the designated question should be given to the same number of significant figures as there are in the data given in the question or to one more than this number. All other numerical answers should not be considered in terms of significant figures.

5 Numerical answers **presented** in non-standard form are undesirable but should not be penalised. Arithmetical errors by candidates resulting from use of non-standard form in a candidate's working should be penalised as in point 3 above. Incorrect numerical prefixes and the use of a given diameter in a geometrical formula as the radius should be treated as arithmetical errors.

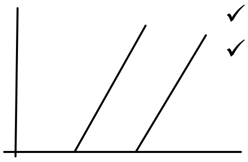
6 Knowledge of units is tested on designated questions or parts of questions in each a paper. On each such question or part-question, unless otherwise stated in the mark scheme, the mark scheme will show a mark to be awarded for the numerical value of the answer and a further mark for the correct unit. No penalties are imposed for incorrect or omitted units at intermediate stages in a calculation or at the final stage of a non-designated 'unit' question.

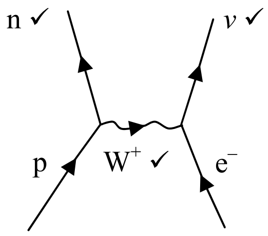
7 All other procedures including recording of marks and dealing with missing parts of answers will be clarified in the standardising procedures.

## GCE Physics, Specification A, PHYA1, Particles, Quantum Phenomena and Electricity

| **Question 1** | | |
|---|---|---|
| (a) | ionisation energy = 13.6 eV ✓ | **1** |
| (b) (i) |  | **8** |
| (ii) | energy in Joules = 1.90 ✓ $\times$ 1.6 $\times 10^{-19}$ = 3.04 $\times 10^{-19}$ (J) ✓<br>(use of $E = hc/\lambda$)<br><br>3.04 $\times 10^{-19}$ = 6.63 $\times 10^{-34}$ $\times$ 3 $\times 10^{8}/\lambda$ ✓<br>(working/equation must be shown)<br><br>$\lambda$ = 6.54 $\times 10^{-7}$ m ✓✓ (2 or 3 sf for second mark)<br>(accept 0.65 which gives an answer of $\lambda$ = 1.91 $\times 10^{-6}$ m) | |
| | **Total** | **9** |

| **Question 2** | | |
|---|---|---|
| (a)<br><br>**QWC** | **descriptor** | **mark range** |
| good - excellent | The candidate provides a comprehensive and logical explanation which recognises that light consists of photons of energy $hf$ and that an electron at or near the metal surface can only gain the energy of a single photon when it interacts with a photon. In addition, the candidate should recognise the significance of the work function (of the metal) in this context in relation to the maximum kinetic energy that an emitted electron can have. The candidate should also provide some indication of why the kinetic energy of an emitted electron may be less than the maximum kinetic energy. Although the term 'work function' might not be defined or used, the candidate's explanation should clearly state that each electron needs a minimum amount of energy to escape from the metal. | **5 - 6** |
| modest - adequate | The candidate provides a logical and coherent explanation which includes the key ideas including recognition that light consists of photons of energy $hf$ and that an electron at or near the metal surface can only gain the energy of a single photon when it interacts with a photon. In addition, the candidate should be aware that each electron needs a minimum amount of energy to escape from the metal. They should appreciate that the kinetic energy of an emitted electron is equal to the difference between the energy it gains from a photon and the energy it needs (or uses) to escape from the metal. However, the explanation may lack a key element such as why the kinetic energy of the emitted electrons varies. | **3 - 4** |
| poor - limited | The candidate provides some correct ideas including recognition that light consists of photons of energy *hf* and that electrons in the metal (or at its surface) absorb photons and thereby gain energy. Their ideas lack coherence and they fail to recognise or use in their explanation the key idea that one photon is absorbed by one electron. | **1 – 2** |
| | **The explanations expected in a good answer should include most of the following physics ideas**<br><br>energy is needed to remove an electron from the surface<br><br>work function $\varphi$ (of the metal) is the minimum energy needed by an electron to escape from the surface<br><br>light consists of photons , each of energy $E = hf$<br><br>one photon is absorbed by one electron<br><br>an electron can escape (from the surface) if $hf > \varphi$<br><br>kinetic energy of an emitted electron cannot be greater than $hf - \varphi$<br><br>an electron below the surface needs to do work/uses energy to reach the surface<br><br>kinetic energy of such an electron will be less than $hf - \varphi$ | |

| | | | |
|---|---|---|---|
| (b) | (i) |  ✓<br>✓<br>$f_0$ ✓ | 4 |
| | (ii) | parallel line, higher threshold frequency ✓✓ | |
| | (iii) | Planck's constant ✓ | |
| (c) | | (use of $hf_0 = \phi$)<br>$hf = 6.63 \times 10^{-34} \times 2 \times 5.6 \times 10^{14}$ ✓<br>$\phi = 3.7(1) \times 10^{-19}$ J ✓<br>$E_k = 2 \times 3.7 \times 10^{-19} - 3.7 \times 10^{-19} = 3.7 \times 10^{-19}$ J ✓ | 3 |
| | | **Total** | **13** |

| **Question 3** | | |
|---|---|---|
| (a) (i) | electromagnetic ✓<br>photon (or γ) ✓ | |
| (ii) | charge<br>mass<br>lepton number<br>baryon number<br>strangeness any two ✓✓ | **4** |
| (b) (i) |  | |
| (ii) | weak ✓ | |
| (iii) | charge ✓<br>charge before = + and – = 0 same after ✓<br>baryon number ✓<br>+1 before (p) and +1 after (n) ✓<br>lepton number ✓<br>+1 before and +1 after ✓<br>**or** strangeness | **7** |
| (iv) | if a reliable experiment does not support a hypothesis **or** experiment proves/disproves/checks theory ✓<br>the hypothesis must be changed/rejected **or** hypothesis/theory can be extended to other areas ✓ | |
| | **Total** | **11** |

| Question 4 | | |
|---|---|---|
| (a) | electrons can have wavelike properties and particle like properties ✓ | **1** |
| (b) (i) | (use of $\lambda = h/mv$)<br>$mv = 6.63 \times 10^{-34}/1.2 \times 10^{-10}$ ✓<br>$mv = 5.5 \times 10^{-24}$ ✓ $kg\,m\,s^{-1}$ ✓ (or N s) | **7** |
| (ii) | $v = 5.5 \times 10^{-24}/9.11 \times 10^{-31}$ ✓<br>$v = 6.1 \times 10^{6}\,m\,s^{-1}$ ✓ | |
| (iii) | (use of $E = ½mv^2$)<br>$E = ½ \times 9.11 \times 10^{-31} \times (6.1 \times 10^{6})^2$ ✓ (must see working or equation)<br>$E = 1.6(9) \times 10^{-17}$ J ✓ (no working max 1) | |
| | **Total** | **8** |

| Question 5 | | |
|---|---|---|
| (a) | superconductivity means a material has zero resistivity/resistance ✓<br>resistivity decreases with temperature **or** idea of cooling ✓<br>becomes superconducting when you reach the critical/certain/transition temperature ✓ | **3** |
| (b) (i) | (use of $R = \rho l/A$)<br>$0.075 = \rho \times 1/(2.28 \times 10^{-7})$ ✓ (must see working or equation)<br>$R = 1.7 \times 10^{-8}$ ✓ Ω m ✓ | **6** |
| (ii) | **max 3 from**<br>the resistance decreases (to zero) ✓<br>copper still has resistance ✓<br>but this is in parallel with filaments (which have zero resistance) ✓<br>hence **total** resistance is zero ✓<br>current goes through filaments ✓ | |
| | **Total** | **9** |

| Question 6 | | |
|---|---|---|
| (a) | (use of $1/R_{total} = 1/R_1 + 1/R_2$)<br>$1/R_{total}$ = 1/400 + 1/400 = 2/400<br>$R_{total}$ = 200 Ω ✓ (working does not need to be shown)<br>hence total resistance = 25 + 200 = 225 Ω ✓ | **2** |
| (b) (i) | (use of $P = V^2/R$)<br>1 = $V^2$/400 ✓<br>$V^2$ = 400 (working does not need to be shown)<br>$V$ = 20 V ✓ | **6** |
| (ii) | (use of $I = V/R$)<br>$I$ = 20/400 = 0.05 A ✓ (working does not need to be shown)<br>hence current = 2 × 0.05 = 0.10 A ✓ | |
| (iii) | (use of $V = IR$)<br>pd across 25 Ω resistor = 25 × 0.10 = 2.5 V ✓ (working does not need to be shown)<br>hence maximum applied pd = 20 + 2.5 = 22.5 V ✓ | |
| | **Total** | **8** |

| Question 7 | | |
|---|---|---|
| (a) (i) | work done (by the battery) per unit charge ✓<br>**or** (electrical) energy per unit charge<br>**or** pd/voltage when open circuit/no current | **2** |
| (ii) | the resistance of the materials within the battery ✓<br>**or** hindrance to flow of charge **in** battery<br>**or** loss of pd/voltage per unit current | |
| (b) (i) | (use of $E = V + Ir$)<br>12 = $V$ + 800 × 0.005 ✓ (working/equation needs to be shown)<br>$V$ = 12 – 4 = 8.0 V ✓ | **5** |
| (ii) | (use of $P = I^2r$)<br>$P = 800^2 \times 0.005$ ✓ (working/equation needs to be shown)<br>$P$ = 3200 ✓ W ✓ **or** J $s^{-1}$ | |
| (c) | car will probably **not** start ✓<br>battery will not be able to provide enough current ✓<br>**or** less current<br>**or** lower terminal pd/voltage | **2** |
| | **Total** | **9** |