Version 1.0

General Certificate of Education (A-level)
January 2011

Physics A PHYA1

(Specification 2450)

Unit 1: Particles, quantum phenomena and electricity

Final

Mark Scheme

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 events which all examiners participate in and is the scheme which was used by them in this examination. The standardisation process 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 standardisation each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, examiners encounter unusual answers which have not been raised 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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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 (eg 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 (ie 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*	**5 – 6**
Modest - Adequate	*see specific mark scheme*	**3 – 4**
Poor - Limited	*see specific mark scheme*	**1 – 2**
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)	(i)	leptons do not experience the strong interaction but hadrons do **or** hadrons not fundamental/made of quarks and leptons are not ✓	**1**
(a)	(ii)	hadron eg proton, neutron, pion ✓ lepton eg electron, neutrino ✓	**2**
(a)	(iii)	baryons ✓ mesons ✓ baryons made from **three quarks** (or **3 antiquarks**), mesons a **quark**, **antiquark** pair **or** baryons, baryon number is **+1 or –1** mesons 0 ✓	**3**
(b)		baryon number, lepton number, charge, strangeness, energy or momentum ✓ demonstration of conservation (before and after considered and number appropriate to particle quoted) ✓	**2**
		Total	**8**

Question 2			
(a)	(i)	88 protons ✓ 140 neutrons ✓ 88 electrons ✓	**3**
(a)	(ii)	electron ✓	**1**
(a)	(iii)	${}^{228}_{88}\mathrm{Ra} \rightarrow {}^{228}_{89}\mathrm{Ac} + {}^{0}_{-1}\mathrm{e} + \bar{\nu}_e$ ✓✓✓✓	**4**
(b)		228 ± 10 ✓ 88 ✓	**2**
		Total	**10**

Question 3			
	(i)	pair production ✓	**1**
	(ii)	conservation law stated (charge or lepton number) ✓ shown to be true eg lepton number +1–1 = 0 ✓	**2**
	(iii)	energy = 2 × 0.510 (ignore sfs) ✓	**1**
	(iv)	$E = (1.02 \times 1.6 \times 10^{-13}) = 1.63 \times 10^{-13}$ ✓ $1.63 \times 10^{-3} = 6.63 \times 10^{-34} \times 3.00 \times 10^{8}/\lambda$ ✓ $\lambda = 6.63 \times 10^{-34} \times 3.00 \times 10^{8}/1.63 \times 10^{-13} = 1.22 \times 10^{-12}$ m ✓ 3 significant figures ✓	**4**
	(v)	will encounter an **electron** and the two particles will annihilate ✓ releasing (two high energy/gamma) **photons**/**quanta** ✓	**2**
		Total	**10**

<table>
<tr><th>Question 4</th><th></th><th></th></tr>
<tr><td>(a)</td><td>
The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.
The candidate's answer will be assessed holistically. The answer will be assigned to one of the three levels according to the following criteria.
High Level (good to excellent) 5 or 6 marks
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.
The candidate provides a comprehensive and coherent description which includes a clear explanation of threshold frequency and why this cannot be explained by the wave theory. The description should include a clear explanation of the photon model of light and this should be linked to the observations such as threshold frequency, the lack of time delay or mentions 1 to 1 interaction, the could not be explained by the wave model.
Intermediate Level (modest to adequate) 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.
The candidate provides an explanation of threshold frequency and work function. The candidate explains the photon model of light and how this can provide an explanation of threshold frequency, eg relates energy of photon to frequency or talks about packets of energy.
Low Level (poor to limited) 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may only be partly appropriate.
States what is meant by photoelectric effect. Knowledge of photons/packets of energy.
The explanation expected in a competent answer should include a coherent account of the significance of threshold frequency and how this supports the particle nature of electromagnetic waves.

threshold frequency minimum frequency for emission of electrons
if frequency below the threshold frequency, no emission even if intensity increased
because the energy of the photon is less than the work function
wave theory can not explain this as energy of wave increases with intensity
light travels as photons
photons have energy that depends on frequency
if frequency is above threshold photon have enough energy
mention of lack of time delay

</td><td>max 6</td></tr>
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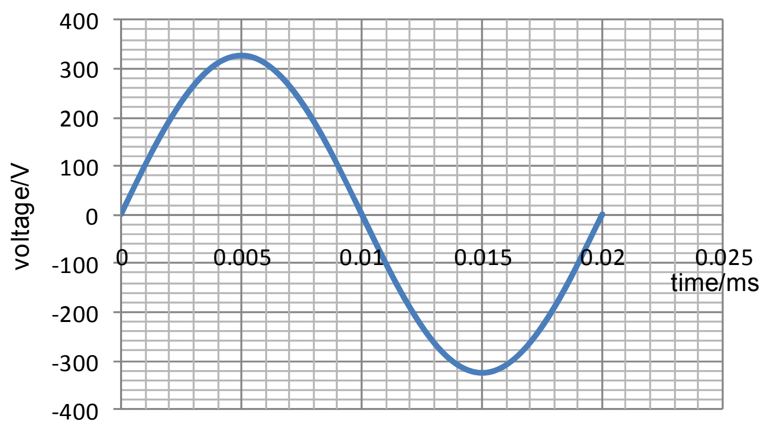
(b)	(i)	use of $E_k = \frac{1}{2}mv^2$ ½ × 6.6 × 10^{-27} ✓ × v^2 = 9.6 × 10^{-13} ✓ v^2 = 2.91 × 10^{-14} (or v = √2.91 × 10^{-14}) ✓ (v = 1.7 × 10^7 m s^{-1})	**3**
(b)	(ii)	(use of $p = mv$) p = 6.6 × 10^{-27} × 1.7 × 10^7 ✓ p = 1.1 × 10^{-19} ✓ kg m s^{-1}/N s ✓	**3**
(b)	(iii)	(use of $\lambda = \frac{h}{mv}$) λ = 6.63 × 10^{-34}/1.1 × 10^{-19} ✓ λ = 5.9 × 10^{-15} m ✓ (6.03 × 10^{-15} m)	**2**
		Total	**14**

Question 5			
(a)		the square root of the mean of the squares of all the values of the voltage in one cycle ✓ **or** the equivalent dc/steady/constant voltage that produces the same **heating effect/power** ✓	**1**
(b)	(i)	peak voltage = 230 × √2 ✓ peak voltage = 325 V (or 324 V) ✓	**2**
(b)	(ii)	average power = 230 × 0.26 = 60 W ✓	**1**
(c)		 shape and symmetrical with consistent values of x at y = 0 and consistent y_{max} (must be at least one cycle) ✓ appropriate scale y-axis ✓ correct peak values (to within one 2 mm square) ✓ correct period (accept 0.02 **or** 20) ✓	**4**
		Total	**8**

Question 6		
(a)	current = 0.40 A ✓	**1**
(b) (i)	resistance = 12/0.2 = 60 Ω ✓	**1**
(b) (ii)	power = 12 × 0.2 = 2.4 W ✓	**1**
(c)	resistance of filament increases **or** more collisions/scattering ✓ as temperature of filament increase **or** filament gets hot/heats (until reaches thermal equilibrium) ✓	**2**
(d) (i)	voltage of supply now shared by lamps **or** resistance increased ✓ hence current reduced ✓	**2**
(d) (ii)	current through the **lamps** unchanged/stays the same ✓ as both connected directly to the supply **or** correct resistance argument ✓	**2**
(e)	resistance of lamps will be lower when first switched on ✓ hence initial current will be larger ✓ sudden rapid change in temperature ✓	**max 2**
	Total	**11**

Question 7			
(a)	(i)	voltage = 0.01 × 540 = 5.4 V ✓	**1**
(a)	(ii)	voltage = 15 – 5.4 = 9.6 V ✓	**1**
(a)	(iii)	(use of resistance = voltage/current) resistance = 9.6/0.01 ✓ = 960 Ω ✓ **or** R_T = 15/0.01 = 1500 Ω ✓ R = 150 – 590 = 960 Ω ✓ **or** potential divider ratio ✓✓	**2**
(a)	(iv)	(use of $1/R = 1/R_1 + 1/R_2$) $1/960 = 1/200 + 1/R_2$ ✓ $1/R_2 = 1/960 – 1/1200$ R_2 = 4800 Ω ✓	**2**
(b)		(voltage of supply constant) (circuit resistance decreases) (supply) current increases or potential divider argument ✓ hence pd across 540 Ω resistor increases ✓ hence pd across 1200 Ω decreases ✓ **or** resistance in parallel combination decreases ✓ pd across parallel resistors decreases ✓ pd across 1200 Ω decreases ✓	**3**
		Total	**9**