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General Certificate of Education (A-level)
June 2012

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

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.

Further copies of this Mark Scheme are available from: aqa.org.uk

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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.

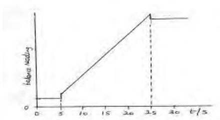
GCE Physics, Specification A, PHYA4, Fields and Further Mechanics

Section A

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

Keys to Objective Test Questions												
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
C	A	A	D	C	C	A	A	C	B	D	B	C
14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
A	D	C	B	D	B	B	A	D	D	C	A	

Section B

1	a		force is equal to (**or** proportional to) rate of <u>change of</u> momentum ✓ [**or** impulse = force × time = <u>change of</u> momentum] [Answer should **not** be in symbols unless all the symbols are explained]	1
1	b	i	use of $mg\Delta h = \frac{1}{2} mv^2$ gives v = $\sqrt{2gh} = \sqrt{2 \times 9.81 \times 1.6}$ ✓ (= 5.60 m s^{-1})	1
1	b	ii	momentum per second (= 0.30 × 5.60) = 1.68 (Ns) ✓	1
1	b	iii	mass of sand falling in 10s = (0.30 × 10) (= 3.00 kg) ✓ force due to arriving sand = momentum arriving per second = 1.68 (N) equivalent mass reading = $\frac{1.68}{9.81}$ ✓ (= 0.17 kg) so balance reading is 3.00 + 0.65 + 0.17 ✓ (= 3.82 kg)	3
1	c		horizontal lines up to 5 s and beyond 25 s ✓ line of constant positive gradient between 5 s and 25 s ✓  (near) vertical steps up at 5 s and down at 25 s ✓	3
2	a	i	horizontal arrow to the left ✓	1
2	a	ii	the electrostatic force is unchanged ✓	2

			because electric field strength is constant ✓	
2	b	i	forces are equal in magnitude but opposite in direction ✓ (*E* is the same for both and) *Q* has same magnitude but opposite sign ✓	2
2	b	ii	acceleration of proton is (much) smaller (than acceleration of electron) ✓ because mass of proton is (much) greater (than mass of electron) ✓	2
2	b	iii	acceleration of proton increases and acceleration of electron decreases ✓ correct reference to changing strength of electric field (for either or both) ✓	2
2	c	i	energy of photon $E\left(=\frac{hc}{\lambda}\right)=\frac{6.63\times10^{-34}\times3.00\times10^{8}}{650\times10^{-9}}$ ✓ $= 3.06 \times 10^{-19}$ (J) ✓ energy required = $=\frac{3.06\times10^{-19}}{1.60\times10^{-19}}$ = 1.91 (eV) ✓	3
2	c	ii	electric field strength $\left(=\frac{V}{d}\right)=\frac{4500}{180\times10^{-3}}$ $= 2.50 \times 10^{4}$ (V m^{-1}) ✓ distance = $\left(\frac{V}{E}\right)=\frac{1.91}{2.50\times10^{4}}$ $\left[\text{or}=\left(\frac{W}{F}\right)=\frac{3.06\times10^{-19}}{4.0\times10^{-15}}\right]$ ✓ $= 7.64 \times 10^{-5}$ (m) ✓	3
3	a		(magnetic) <u>field</u> is applied perpendicular to path **or** direction **or** velocity of charged particles ✓ (magnetic) <u>force</u> acts perpendicular to path **or** direction **or** velocity of charged particles ✓ force depends on speed of particle **or** on *B* [or $F \propto v$ or $F = BQv$ explained] ✓ force provides (centripetal) acceleration towards centre of circle [**or** (magnetic) force is a centripetal force] ✓ $BQv=\frac{mv^2}{r}$ **or** $r=\frac{mv}{BQ}$ shows that *r* is constant when *B* and *v* are constant ✓	max 4
3	b	i	radius *r* of path = $\frac{\text{circumference}}{2\pi}=\frac{27\times10^{3}}{2\pi}$ $= 4.30 \times 10^{3}$ (m) (allow 4.3 km) ✓	3

			centripetal force $\left(=\frac{mv^2}{r}\right)=\frac{1.67\times10^{-27}\times\left(3.00\times10^{7}\right)^2}{4.30\times10^{3}}$ ✓ $= 3.50\times10^{-16}$ (N) ✓	
3	b	ii	magnetic flux density $B\left(=\frac{F}{Qv}\right)=\frac{3.50\times10^{-16}}{1.60\times10^{-19}\times3.00\times10^{7}}$ ✓ $= 7.29\times10^{-5}$ ✓ T ✓	3
3	c		magnetic field must be increased ✓ to increase (centripetal) force **or** in order to keep *r* constant ✓ [**or** otherwise protons would attempt to travel in a path of larger radius] [**or**, referring to $r=\frac{mv}{BQ}$, *B* must increase when *v* increases to keep r constant]	2
4	a		work done (**or** energy required) per unit mass ✓ in moving a mass from infinity to the point ✓	2
4	b	i	ΔV (= –1.3 – (–62.6)) = 61.3 (MJ kg^{-1}) ✓ energy required (= $m\Delta V$) = $1.2\times10^{4}\times61.3\times10^{6}$ $= 7.4\times10^{11}$ (J) ✓ to **2SF** only ✓	3
4	b	ii	beyond **X**, gravitational potential decreases as Moon is approached [**or** gravitational field (or force) of Moon will now attract the probe] ✓	1
4	b	iii	distance from Earth to Sun » distance from Earth to Moon ✓ <u>change in</u> V_{sun} (**or** in g_{sun}) over Earth to Moon distance is negligible ✓ value of V_{sun} (**or** g_{sun}) is not (significantly) changed by relative positions of E+M ✓	max 2
4	c		**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 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.	Max 6

The candidate discusses the forces of attraction due to the Earth and due to the Moon, appreciates that they act in opposite directions, and that the former is generally much greater than the latter.
The candidate discusses the resultant gravitational field between E and M, understands that there is a 'neutral' point at which the resultant field strength is zero and that this point is much closer to M than E. It is recognised that this point has to be passed for the journey to be completed in either direction.
There is a discussion of gravitational potential, in which it is pointed out that the resultant potential rises to a maximum at the neutral point. There is a reference to the much greater amount of work that has to be done on the spacecraft to reach this point from E than from M.

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 discusses the forces of attraction due to the Earth and the Moon, and appreciates either that they act in opposite directions, or that the former is much greater than the latter. There is a relevant discussion of field strength or potential. The significance of the neutral point may not be appreciated. The candidate is likely to make some reference to the work that has to be done on the spacecraft.

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 be only partly appropriate.
The candidate has some understanding of the forces that act during the journey but makes very limited references to the significance of the variation of the gravitational field. Discussions of gravitational potential and/or work done are likely to be superficial and may be absent.

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.

Gravitational forces

- The spacecraft experiences gravitational attractions to both the Earth and the Moon during its journey.
- These forces pull in opposite directions on the spacecraft.
- Because E is much more massive than M, for most of the outward journey the force towards E is greater than that towards M.
- Only in the later stages of the outward journey is the

			resultant force directed towards M. • On the return journey the resultant force is predominantly towards E. **Gravitational field strength** • During the outward journey E's gravitational field becomes weaker and M's becomes stronger. • The resultant field is the vector sum of those due to E and M separately. • A point (X) is reached at which these two component fields are equal and opposite, giving zero resultant. • X is much closer to M than to E. • Once X has been passed, the spacecraft will be attracted to M by M's gravitational field. • On the return journey the spacecraft will 'fall' to E once it is beyond X. **Gravitational potential** • The gravitational potential due E increases (i.e. becomes less negative) as the spacecraft moves away from E. • The resultant gravitational potential is the (scalar) sum of those due to E and M separately. • At X the gravitational potential reaches a maximum value before decreasing as M is approached. • In order to reach M on the outward journey, the spacecraft has to be given at least enough energy to reach X, and vice-versa for the return. • Much more work is needed to move the spacecraft from E to X than from M to X, since a larger force has to be overcome over a larger distance.	

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