Version 1.1

General Certificate of Education (A-level)
January 2013

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

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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**
A	D	D	C	A	D	B	A	B	C	A	B	C
14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	
D	B	B	C	D	C	B	A	C	D	B	A	

Section B

Question	Part	Sub-part	Marking guidance	Mark	Comment
1	a		*Similarity*: momentum is conserved (in both cases) ✓ *Difference*: **kinetic** energy is conserved in an elastic collision but not in an inelastic collision ✓	2	For 2nd mark allow ke is **only** conserved in elastic collision, **or** ke is not conserved in an inelastic collision.
1	b	i	in the Ce nucleus A = 140 Z = 58 and for α A = 4 and Z = 2 ✓	1	All four correct values required
1	b	ii	$0 = 140v - 4 \times 9.3 \times 10^6$ ✓ gives $v = 2.6(6) \times 10^5$ (m s^{-1}) ✓	2	Allow $140v = 4 \times 9.3 \times 10^6$ for 1st mark. Allow ecf from values in (b)(i). Allow inclusion of mass of 58 electrons in recoil atom when shown.

1	b	iii	E_k of α = ½ × 4 × 1.66 × 10^{-27} × $(9.3 \times 10^6)^2$ ✓ (= 2.87 × 10^{-13} J) E_k of Ce = ½ × 140 × 1.66 × 10^{-27} × $(2.66 \times 10^5)^2$ ✓ (= 8.22 × 10^{-15} J) $\frac{E_k \text{ of Ce}}{E_k \text{ of } \alpha} = \frac{8.22\times10^{-15}}{2.87\times10^{-13}}$ = 0.0286 or 2.86% ✓ [**or** $\frac{E_k \text{ of Ce}}{E_k \text{ of } \alpha} = \frac{35 v_d^2}{v_\alpha^2}$ ✓ gives $\frac{35\times(2.66\times10^5)^2}{(9.3\times10^6)^2}$ ✓ = 0.0286 or 2.86% ✓] [**or** $\frac{E_k \text{ of Ce}}{E_k \text{ of } \alpha} = \frac{m_d v_d^2}{m_\alpha v_\alpha^2} = \frac{m_d}{m_\alpha}\times\left(\frac{m_\alpha}{m_d}\right)^2$ ✓ = $\frac{m_\alpha}{m_d} = \frac{1}{35}$ ✓ = 0.0286 or 2.86% ✓]	3	For 3rd mark, answer must be evaluated to at least 2SF (3% alone is insufficient); note that use of v_d = 2.7 × 10^5 m s^{-1} gives 0.0295 or 2.95%. Allow ecf from values in (b)(ii). When ecf is applied, 3rd mark is only available for answers between 2.5% and 3.5%.

2	a	i	$\left(T \propto r^{3/2} \text{ or } \frac{T_E}{T_P} = \left(\frac{r_E}{r_P}\right)^{3/2} \text{ gives}\right)$ $\frac{60\times24}{105} = \left(\frac{r_E}{7370}\right)^{3/2}$ ✓ from which $\frac{r_E}{7370} = \left(\frac{60\times24}{105}\right)^{2/3} = 5.73$ and r_E (= 5.73 × 7370) = 42 200 (km) ✓ height above surface = 42 200 – 6370 = 35 800 or 35 900 (km) ✓ answer to **3SF** only ✓ [**or** Newton's law approach for 1st two marks: $\left(\frac{GMm}{r^2} = m\omega^2 r \text{ and } \omega = \frac{2\pi}{T}\right)$ give $r^3 \left(= \frac{GMT^2}{4\pi^2}\right)$ ∴ $r_E^{\,3} = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times(24\times60\times60)^2}{4\pi^2}$ ✓ (=7.54 × 10^{22}) from which r_E = 42 200 (km) ✓]	4	Full solution derived from Newton's law of gravitation is acceptable for all 4 marks. For 3rd mark, final answer **must** be expressed in km. **3SF** mark is independent.

2	a	ii	centripetal force (= $m\omega^2 r$) = $\dfrac{650 \times 4\pi^2 \times 7.37 \times 10^6}{(105 \times 60)^2}$ ✓ = 4800 (4760) (N) ✓ [**or** centripetal force $\left(= \dfrac{mv^2}{r}\right)$ and $v = \dfrac{2\pi r}{T} = \dfrac{2\pi \times 7.37 \times 10^6}{105 \times 60}$ gives v = 7350 (m s^{-1}) and centripetal force = $\dfrac{650 \times 7350^2}{7.37 \times 10^6}$ ✓ = 4800 (4760) (N) ✓] [**or** centripetal force $\left(= \dfrac{GMm}{r^2}\right) = \dfrac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 650}{(7.37 \times 10^6)^2}$ ✓ = 4800 (4770) (N) ✓]	2	If **both** *T* and *r* values for the **geosynchronous** satellite are substituted, award 0 marks for (ii). If only **one** correct *T* or *r* value for the **polar** satellite is substituted, mark (ii) to max 1.

2	b		**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. *The candidate gives a comprehensive comparison of the principal features of the satellite orbits and explains the consequences for the uses of the two types of satellites. There are clear statements showing good understanding of why the polar satellite is suitable for monitoring, and of why the geosynchronous satellite is useful for communications.* **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's comparison of the principal features of the orbits is less complete and the consequences for the uses of satellites in them are less well understood. The candidate has an acceptable appreciation of why the polar satellite is suitable for monitoring, and of why the geosynchronous satellite is useful for communications.* **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.	max 6	**Four** aspects must be considered in a high level answer:- Features of polar orbit. Features of geosynchronous orbit. Why polar orbit is suitable for monitoring. Why geosynchronous orbit is suitable for communication.

			The candidate has a much weaker knowledge of the principal features of the orbits and very limited knowledge of consequences for the uses of satellites in them. Understanding of why the polar satellite is suitable for monitoring, and why the geosynchronous satellite is suitable for communications, is limited or absent. **The explanation expected in a competent answer should include a coherent selection of the following points.** ***Low polar orbit*** • Orbital period is a few hours • Earth rotates relative to the orbit • Many orbits with different radii and periods are possible • Orbit height is less than geosynchronous satellite • Speed is greater than that of geosynchronous satellite • Satellite scans the whole surface of the Earth • Applications: surveillance of conditions/installations on Earth, mapping, weather observations, environmental monitoring • Gives access to every point on Earth's surface every day • Can collect data from regions inaccessible to man • Contact with transmitting/receiving aerial is intermittent • Aerial is likely to need a tracking facility • Lower signal strength required than that for geosynchronous satellite ***Geosynchronous orbit above Equator*** • Orbital period matches Earth's rotational period exactly • Satellite maintains same position relative to Earth • Only one particular orbit radius is possible • Travels west to east above Equator (in same direction as Earth's rotation) • Orbit height is greater than polar orbit satellite • Speed is less than that of polar orbiting satellite • Scans a restricted (and fixed) area of the Earth's surface only • Applications: telecommunications generally, cable and satellite TV, radio, digital information, etc. • Satellite is in continuous contact with transmitting/receiving aerial • Aerial can be in a fixed position		

			• Higher signal strength required than that for polar satellite		
3	a		$\left(Q = Q_0 e^{-t/RC} \text{ gives}\right)$ 1.0 = 4.0e$^{-300/RC}$ ✓ from which $\frac{300}{RC} = \ln 4$ ✓ and time constant *RC* = 220 (216) (ms) ✓ [***Alternative answer:*** time constant is time for charge to decrease to Q_0/e [**or** 0.37 Q_0] ✓ 4.0/e = 1.47 ✓ reading from graph gives time constant = 216 ± 10 (ms) ✓]	3	In alternative scheme, 4.0/e = 1.47 subsumes 1st mark. Also, accept $T_{½}$ = 0.693 *RC* (or = ln 2 *RC*) for 1st mark.
3	b		current is larger (for given *V*)(because resistance is lower) [**or** correct application of *I* = *V*/*R*] ✓ current is rate of flow of charge [**or** correct application of *I* = Δ*Q*/Δ*t*] ✓ larger rate of flow of charge (implies greater rate of discharge) [**or** causes larger rate of transfer of electrons from one plate back to the other] ✓ [***Alternative answer:*** time constant (or *RC*) is decreased (when *R* is decreased) ✓ explanation using $Q = Q_0 e^{-t/RC}$ **or** time constant explained ✓]	max 2	Use either first or alternative scheme; do not mix and match. Time constant = *RC* is insufficient for time constant explained.
4	a		force between two (point) charges is proportional to (product of) charge**s** ✓ and inversely proportional to the square of their distance apart ✓	2	Formula not acceptable. Accept “charged particles” for charges. Accept separation for distance apart.
4	b	i	lines with arrows radiating outwards from each charge ✓ more lines associated with 6nC charge than with 4nC ✓ lines start radially and become non-radial with correct curvature further away from each charge ✓ correct asymmetric pattern (with neutral pt closer to 4nC charge) ✓	max 3	

4	b	ii	force $\left(=\dfrac{Q_1Q_2}{4\pi\varepsilon_0 r^2}\right)=\dfrac{4.0\times10^{-9}\times6.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(68\times10^{-3})^2}$ ✓ = $4.6(7)\times10^{-5}$ (N) ✓	2	Treat substitution errors such as 10^{-6} (instead of 10^{-9}) as AE with ECF available.
4	c	i	$E_4=\dfrac{4.0\times10^{-9}}{4\pi\varepsilon_0\times(34\times10^{-3})^2}$ (= 3.11×10^4 V m^{-1}) (to the right)✓ $E_6\left(=\dfrac{6.0\times10^{-9}}{4\pi\varepsilon_0\times(34\times10^{-3})^2}\right)$ = (4.67×10^4 V m^{-1}) (to the left) ✓ $E_{resultant}$ = (4.67 – 3.11) × 10^4 = 1.5(6) × 10^4 ✓ Unit: V m^{-1} (or N C^{-1}) ✓	4	For both of 1st two marks to be awarded, substitution for **either** or both of E_4 **or** E_6 (or a substitution in an expression for $E_6 - E_4$) must be shown. If no substitution is shown, but evaluation is correct for E_4 and E_6, award one of 1st two marks. Use of $r = 68\times10^{-3}$ is a physics error with no ECF. Unit mark is independent.
4	c	ii	*direction*: towards 4 nC charge **or** to the left ✓	1	
5	a		direction of induced emf (or current) ✓ opposes change (of magnetic flux) that produces it ✓	2	
5	b	i	(volumes are equal and mass of Q is greater than that of P) density of steel > density of aluminium ✓	1	Allow density of Q greater (than density of P).
5	b	ii	use of $s = \frac{1}{2} g t^2$ gives $t^2=\dfrac{2\times1.0}{9.81}$ (from which t = 0.45 s) ✓ (vertical) acceleration [**or** acceleration due to gravity] is independent of mass of falling object [**or** correct reference to $F = mg = ma$ with m cancelling] ✓	2	Backwards working is acceptable for 1st mark. 2nd mark must refer to mass. Do not allow “both in free fall” for 2nd mark.

5	c	i	moving magnet [**or** magnetic field] passes through tube ✓ there is a change of flux (linkage)(in the tube) [**or** flux lines are cut **or** appropriate reference to $\varepsilon = N(\Delta\Phi/\Delta t)$]✓ [**Alternative:** (conduction) electrons in copper (or tube) acted on by (moving) magnetic field of Q ✓ induced emf (or current) is produced by redistributed electrons ✓]	2	In this part marks can be awarded for answers which mix and match these schemes.
5	c	ii	emf produces current (in copper) ✓ this current [*allow* emf] produces a magnetic field ✓ this field opposes magnetic field (or motion) of Q [**or** acts to reduce relative motion **or** produces upward force] ✓ no emf is induced by P because it is not magnetised (or not magnet) [**or** movement of P is not opposed by an induced emf or current] ✓	max 3	**Alternative** to 3rd mark: current gives heating effect in copper and energy for this comes from ke of Q ✓
5	d		time for P is unaffected because there is still no (induced) emf [**or** because P is not magnetised **or** because there is no repulsive force on P] ✓ time for Q is shorter (than in (c)) ✓ current induced by Q would be smaller ✓ because resistance of brass ∝ resistivity and is therefore higher [**or** resistance of brass is higher because resistivity is greater] ✓ giving weaker (opposing) magnetic field [**or** less opposition to Q's movement] ✓	max 3	Condone "will pass through faster" for 2nd mark. If emf is stated to be smaller for Q, mark (d) to max 2.