A-LEVEL
PHYSICS A

PHYA4 – Fields and Further Mechanics
Mark scheme

2450
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Mark schemes are prepared by the Lead Assessment Writer 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 associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' 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

Section A:

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

Section B:

Question	Part	Sub-part	Marking guidance	Mark	Comment
1	a	i	force per unit mass ✓ a vector quantity ✓	2	Accept force on 1 kg (or a unit mass).
1	a	ii	force on body of mass *m* is given by $F = \frac{GMm}{(R+h)^2}$ ✓ gravitational field strength $g\left(=\frac{F}{m}\right) = \frac{GM}{(R+h)^2}$ ✓	2	For both marks to be awarded, correct symbols must be used for *M* and *m*.
1	b	i	$F\left(=\frac{GMm}{(R+h)^2}\right) = \frac{6.67\times10^{-11}\times5.98\times10^{24}\times2520}{\left(\left(6.37\times10^{6}\right)+\left(1.39\times10^{7}\right)\right)^2}$ ✓ $= 2.45 \times 10^3$ (N) ✓ to **3SF** ✓	3	1st mark: all substituted numbers must be to at least 3SF. If 1.39×10^7 is used as the complete denominator, treat as AE with ECF available. 3rd mark: **SF mark is independent**.

1	b	ii	$F = m\omega^2(R+h)$ gives $\omega^2 = \dfrac{2450}{2520\times 2.03\times 10^7}$ ✓ from which $\omega = 2.19 \times 10^{-4}$ (rad s^{-1}) ✓ time period $T\left(=\dfrac{2\pi}{\omega}\right) = \dfrac{2\pi}{2.19\times 10^{-4}}$ **or** $= 2.87 \times 10^4$ s ✓ [**or** $F = \dfrac{mv^2}{R+h}$ gives $v^2 = \dfrac{2.45\times 10^3 \times ((6.37\times 10^6)+(13.9\times 10^6))}{2520}$ ✓ from which $v = 4.40 \times 10^3$ (m s^{-1}) ✓ time period $T\left(=\dfrac{2\pi(R+h)}{v}\right) = \dfrac{2\pi\times 2.03\times 10^7}{4.40\times 10^3}$ **or** $= 2.87 \times 10^4$ s ✓] [**or** $T^2 = \dfrac{4\pi^2 (R+h)^3}{GM}$ ✓ $= \dfrac{4\pi^2((6.37\times 10^6)+(13.9\times 10^6))^3}{6.67\times 10^{-11}\times 5.98\times 10^{24}}$ ✓ gives time period $T = 2.87 \times 10^4$s ✓] $= \dfrac{2.87\times 10^4}{3600} = 7.97$ (hours) ✓ number of transits in 1 day = $\dfrac{24}{7.97} = 3.01$ (≈ 3) ✓	5	Allow ECF from wrong *F* value in (b)(i) but mark to max 4 (because final answer won't agree with value to be *shown*). First 3 marks are for determining time period (or frequency). Last 2 marks are for relating this to the number of transits. Determination of $f = 3.46 \times 10^{-5}$ (s^{-1}) is equivalent to finding *T* by any of the methods.

1	c		acceptable use ✓ satisfactory explanation ✓ e.g. monitoring weather **or** surveillance: whole Earth may be scanned **or** Earth rotates under orbit **or** information can be updated regularly **or** communications: limited by intermittent contact **or** gps: several satellites needed to fix position on Earth	2	Any reference to equatorial satellite should be awarded 0 marks.

2	a	i	force acts towards left **or** in opposite direction to field lines ✓ because ion (or electron) has negative charge (∴ experiences force in opposite direction to field) ✓	2	Mark sequentially. Essential to refer to negative charge (or force on + charge is to right) for 2nd mark.
2	a	ii	(use of $W = F s$ gives) force $F = \dfrac{4.0\times10^{-16}}{63\times10^{-3}}$ ✓ $= 6.3(5) \times 10^{-15}$ (N) ✓	2	If mass of ion m is used correctly **using algebra** with $F = ma$, allow both marks (since m will cancel). If numerical value for m is used, max 1.
2	a	iii	electric field strength $E\left(=\dfrac{F}{Q}\right)=\dfrac{6.35\times10^{-15}}{3\times1.6\times10^{-19}}$ $= 1.3(2) \times 10^{4}$ (N C^{-1}) ✓ [**or** $\Delta V\left(=\dfrac{\Delta W}{Q}\right)=\dfrac{4.0\times10^{-16}}{3\times1.60\times10^{-19}}$ (833 V) $E\left(=\dfrac{\Delta V}{d}\right)=\dfrac{833}{63\times10^{-3}}$ $= 1.3(2) \times 10^{4}$ (V m^{-1}) ✓]	1	Allow ECF from wrong F value in (a)(ii).
2	b	i	(vertically) downwards on diagram ✓ reference to Fleming's LH rule **or** equivalent statement ✓	2	Mark sequentially. 1st point: allow "into the page".
2	b	ii	number of free electrons in wire = $A \times l \times$ number density $= 5.1 \times 10^{-6} \times 95 \times 10^{-3} \times 8.4 \times 10^{28} = 4.1\ (4.07) \times 10^{22}$ ✓	1	Provided it is shown correctly to at least 2SF, final answer alone is sufficient for the mark. (Otherwise working is mandatory).
2	b	iii	$B\left(=\dfrac{F}{Qv}\right)=\dfrac{1.4\times10^{-25}}{1.60\times10^{-19}\times5.5\times10^{-6}}$ ✓ = 0.16 (0.159) (T) ✓ [**or** $B\left(=\dfrac{F}{I\,l}\right)=\dfrac{1.4\times10^{-25}\times4.07\times10^{22}}{0.38\times95\times10^{-3}}$ ✓ = 0.16 (0.158) (T) ✓]	2	In 2nd method allow ECF from wrong number value in (b)(ii).

3	a	i	elastic potential energy **and** gravitational potential energy ✓	1	For elastic pe allow "pe due to tension", or "strain energy" etc
3	a	ii	elastic pe → kinetic energy → gravitational pe → kinetic energy → elastic pe ✓✓ [**or** pe→ke→pe→ke→pe is ✓ only] [**or** elastic pe → kinetic energy → gravitational pe is ✓ only]	2	If kinetic energy is not mentioned, no marks. Types of potential energy must be identified for full credit.
3	b	i	period = 0.80 s ✓ during one oscillation there are two energy transfer cycles (or elastic pe→ke→gravitational pe→ke→elastic pe in 1 cycle) **or** there are two potential energy maxima per complete oscillation ✓	2	Mark sequentially.
3	b	ii	sinusoidal curve of period 0.80 s ✓ – cosine curve starting at t = 0 continuing to t = 1.2s ✓	2	For 1st mark allow ECF from T value given in 3(b)(i).
3	c	i	use of $T = 2\pi\sqrt{\frac{m}{k}}$ gives $0.80 = 2\pi\sqrt{\frac{0.35}{k}}$ ✓ $\therefore\ k \left(= \frac{4\pi^2 \times 0.35}{0.80^2}\right)$ = 22 (21.6) ✓ N m^{-1} ✓	3	Unit mark is independent: insist on N m^{-1}. Allow ECF from wrong T value from (b)(i): use of 0.40s gives 86.4 (N m^{-1}).
3	c	ii	maximum ke = (½ mv_{max}^2) = 2.0 × 10^{-2} gives $v_{max}{}^2 = \frac{2.0\times10^{-2}}{0.5\times0.35}$ ✓ (= 0.114 m^{2}s^{-2}) and v_{max} = 0.338 (m s^{-1}) ✓ $v_{max} = 2\pi fA$ gives $A = \frac{0.338}{2\pi\times1.25}$ ✓ and A = 4.3(0) × 10^{-2} m ✓ i.e. about 40 mm [**or** maximum ke = (½ mv_{max}^2) = ½ m (2πfA)^2 ✓ ½ × 0.35 × 4π^2 × 1.25^2 × A^2 = 2.0 × 10^{-2} ✓	4	First two schemes include recognition that f = 1/T i.e. f = 1/0.80 = 1.25 (Hz). Allow ECF from wrong T value from (b)(i) – 0.40s gives A = 2.15 × 10^{-2}m but mark to max 3. Allow ECF from wrong k value from (c)(i) –

			$\therefore\ A^2 = \dfrac{2\times 2.0\times 10^{-2}}{4\pi^2 \times 0.35\times 1.25^2}$ ✓ (= 1.85 × 10^{-3}) and A = 4.3(0) × 10^{-2} m ✓ i.e. about 40 mm] [**or** maximum ke = maximum pe = 2.0 × 10^{-2} (J) maximum pe = ½ k A^2 ✓ ∴ 2.0 × 10^{-2} = ½ × 21.6 × A^2 ✓ from which $A^2 = \dfrac{2\times 2.0\times 10^{-2}}{21.6}$ ✓ (= 1.85 × 10^{-3}) and A = 4.3(0) × 10^{-2} m ✓ i.e. about 40 mm]		86.4Nm^{-1} gives A = 2.15 × 10^{-2}m but mark to max 3.
4	a	i	$Q(=It) = 4.5\times 10^{-6} \times 60$ **or** = 2.70 × 10^{-4} (C) ✓ $C\left(=\dfrac{Q}{V}\right) = \dfrac{2.70\times 10^{-4}}{4.4}$ ✓ = 6.1(4) × 10^{-5} = 61 (μF) ✓	3	
4	a	ii	since V_C was 4.4V after 60s, when t = 30s V_C = 2.2 (V) ✓ [**or** by use of $Q = It$ and $V_C = Q/C$] ∴ pd across R is (6.0 – 2.2) = 3.8 (V) ✓ $R\left(=\dfrac{V}{I}\right) = \dfrac{3.8}{4.5\times 10^{-6}}$ = 8.4(4) × 10^5 (Ω) ✓ (=844 kΩ)	3	In alternative method, Q = 4.5 × 10^{-6} × 30 = 1.35 × 10^{-4} (C) V_C = 1.35 × 10^{-4} / 6.14 × 10^{-5} = 2.2 (V) (allow ECF from wrong values in (a)(i))

4	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 coherent and logical description of the flow of electrons taking place during the charging and discharging processes, indicating the correct directions of flow and the correct time variations. There is clear understanding of how the pds change with time during charging and during discharging. The candidate also gives a coherent account of energy transfers that take place during charging and during discharging, naming the types of energy involved. They recognise that the time constant is the same for both charging and discharging.* **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 has a fair understanding of how the flow of electrons varies with time, but may not be entirely clear about the directions of flow. Description of the variation of pds with time is likely to be only partially correct and may not be complete. The candidate may show reasonable understanding of the energy transfers.*	max 6	A **High Level** answer must contain correct physical statements about at least **two** of the following for **both** the charging and the discharging positions of the switch:- • the direction of electron flow in the circuit • how the flow of electrons (or current) changes with time • how V_R and/or V_C change with time • energy changes in the circuit An **Intermediate Level** answer must contain correct physical statements about at least **two** of the above for **either** the charging or the discharging positions of the switch. A **Low Level** answer must contain a correct physical statement about at least **one** of the above for **either** the charging or the discharging positions of the switch. Any answer which does not satisfy the requirement for a Low Level answer should be awarded 0 marks.

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 is likely to confuse electron flow with current and is therefore unlikely to make effective progress in describing electron flow. Understanding of the variation of pds with time is likely to be quite poor. The candidate may show some understanding of the energy transfers that take place.

Incorrect, inappropriate or no response: 0 marks
No answer, or answer refers to unrelated, incorrect or inappropriate physics.

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.

Charging

- electrons flow from plate **P** to terminal **A** and from terminal **B** to plate **Q** (ie. from plate **P** to plate **Q** via **A** and **B**)
- electrons flow in the opposite direction to current
- plate **P** becomes + and plate **Q** becomes –
- the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully charged
- V_R decreases from E to zero whilst V_C increases from zero to E.
- at any time $V_R + V_C = E$
- time variations are exponential decrease for V_R and exponential increase for V_C
- chemical energy of the battery is changed into electric potential energy stored in the capacitor, and into thermal energy by the resistor (which passes to the surroundings)
- half of the energy supplied by the battery is converted into thermal energy and half is stored in the capacitor

			Discharging • electrons flow back from plate **Q** via the shorting wire to plate **P** • at the end of the process the plates are uncharged • the rate of flow of electrons is greatest at the start, and decreases to zero when the capacitor is fully discharged • V_C decreases from $-E$ to zero and V_R decreases from E to zero • at any time $V_C = -V_R$ • both V_C and V_R decrease exponentially with time • electrical energy stored by the capacitor is all converted to thermal energy by the resistor as the electrons flow through it and this energy passes to the surroundings • time constant of the circuit is the same for discharging as for charging		