General Certificate of Education (A-level)
June 2013

Physics A PHYA4

(Specification 2450)

Unit 4: Fields and further mechanics

Final

Mark Scheme

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Section A:

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11	**A**	24	**B**
12	**A**	25	**D**
13	**B**		

Section B:

Question	Part	Subpart	Marking guidance	Mark	Comment
1	a		acceleration is proportional to displacement (from equilibrium) ✓ acceleration is in opposite direction to displacement **or** towards a fixed point/equilibrium position✓	2	Acceleration proportional to negative displacement is 1st mark only. Don't accept "restoring force" for accln.
1	b	i	$f\left(=\frac{1}{2\pi}\sqrt{\frac{g}{l}}\right)=\frac{1}{2\pi}\sqrt{\frac{9.81}{0.984}}$ ✓ = 0.503 (0.5025) (Hz) ✓ [**or** $T\left(=2\pi\sqrt{\frac{l}{g}}\right)=2\pi\sqrt{\frac{0.984}{9.81}}$ ✓ (= 1.9(90) (s)) $f\left(=\frac{1}{T}\right)=\frac{1}{1.990}$ = 0.503 (0.5025) (Hz) ✓] answer to **3SF** ✓	3	3SF is an independent mark. When g = 9.81 is used, allow either 0.502 or 0.503 for 2nd and 3rd marks. **Use of g = 9.8** gives 0.502 Hz: award only 1 of first 2 marks if quoted as 0.502, 0.503 0.50 or 0.5 Hz.
1	b	ii	$a\left(=-(2\pi f)^2 x\right)=(-)(2\pi\times0.5025)^2\times42\times10^{-3}$ ✓ = 0.42 (0.419) (m s^{-2}) ✓	2	Allow ECF from **any** incorrect *f* from (b)(i).

1	c		recognition of 20 oscillations of (shorter) pendulum **and/or** 19 oscillations of (longer) pendulum ✓ *Explanation:* difference of 1 oscillation **or** phase change of 2π **or** Δt = 0.1 so *n* = 2/0.1 =20, **or** other acceptable point ✓ time to next in phase condition = 38 (s) ✓ [**or** (T = 1.90 s so) $(n + 1) \times 1.90 = n \times 2.00$ ✓ gives n = 19 (oscillations of longer pendulum) ✓ minimum time between in phase condition = 19×2.00 = 38 (s) ✓]	3	Allow "back in phase (for the first time)" as a valid explanation.

2	a	i	required pd ($= 2.5 \times 10^6 \times 12 \times 10^{-3}$) = $3.0(0) \times 10^4$ (V) ✓	1	

2	a	ii	charge required Q (= CV) = $3.7 \times 10^{-12} \times 3.00 \times 10^4$ ✓ ($= 1.11 \times 10^{-7}$ C) time taken $t\left(=\frac{Q}{I}\right)=\frac{1.11\times10^{-7}}{3.2\times10^{-8}}$ = 3.5 (3.47) (s) ✓	2	Allow ECF from incorrect V from (a)(i).

2	b	i	time increases ✓ (larger C means) more charge required (to reach breakdown pd) **or** $t = \frac{CV}{I}$ **or** time ∝ capacitance ✓	2	**Mark sequentially** i.e. no explanation mark if effect is wrong.

2	b	ii	spark is brighter (**or** lasts for a longer time) ✓ more energy (**or** charge) is stored **or** current is larger **or** spark has more energy ✓	2	**Mark sequentially.**

3	a	i	*Two examples (any order):* • when charged particle is at rest **or** not moving relative to field ✓ • when charged particle moves parallel to magnetic field ✓	2	

3	a	ii	$BQv = \frac{mv^2}{r}$ ✓ (gives $BQr = mv$) B and Q are constant so $r \propto$ momentum (mv) ✓	2	Acceptable answers must include correct force equation (1st point). Insist on a reference to B and Q constant for 2nd mark.

3	b	i	upwards (perpendicular to plane of diagram) ✓	1	Accept "out of the page" etc.

3	b	ii	$v\left(=\frac{BQr}{m}\right)=\frac{0.48\times1.60\times10^{-19}\times0.19}{1.67\times10^{-27}}$ ✓ = 8.7(4) × 10^6 (m s^{-1}) ✓	2	

3	b	iii	length of path followed (= length of semi-circle) = πr ✓ time taken $t\left(=\frac{\pi r}{v}\right)=\frac{\pi\times0.19}{8.74\times10^{6}}$ = 6.8(3) × 10^{-8} (s) ✓ [**or** $\frac{v}{r}=\frac{BQ}{m}$ gives $t=\frac{\pi r}{v}=\frac{\pi m}{BQ}$ ✓ $=\frac{\pi\times1.67\times10^{-27}}{0.48\times1.60\times10^{19}}$ = 6.8(3) × 10^{-8} (s) ✓]	2	Allow ECF from incorrect v from (b)(ii). Max 1 if path length is taken to be $2\pi r$ (gives 1.37 × 10^{-7}s).

3	b	iv	$v \propto r$ (and path length $\propto r$) ✓ t = (path length/ v) **or** (πr / v) so r cancels ($\therefore$ time doesn't depend on r) ✓ [**or** $t\left(=\frac{\pi r}{v}\right)=\frac{\pi rm}{BQr}$ ✓ $=\frac{\pi m}{BQ}$ (because r cancels) ✓] [**or** $BQv = m\omega^2 r$ gives $BQ\omega r = m\omega^2 r$ and $BQ = m\omega = 2\pi fm$ ✓ $\therefore$ frequency is independent of r ✓]	2	

3	c		$v_{\max} = 8.74 \times 10^6 \times \left(\frac{0.47}{0.19}\right)$ = 2.16×10^7 (m s^{-1}) ✓ E_k (= ½ $mv_{\max}^2$) = ½ × 1.67 × 10^{-27} × $(2.16 \times 10^7)^2$ ✓ (= 3.90×10^{-13} J) $= \frac{3.90 \times 10^{-13}}{1.60 \times 10^{-13}}$ = 2.4(4) (MeV) ✓	3	1st mark can be achieved by full substitution, as in (b)(ii), or by use of data from (b)(i) and/or (b)(ii). Allow ECF from incorrect v from (b)(ii), or from incorrect t from (b)(iii).

4			**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 account of the similarities and differences between gravitational and electric fields, referring to both radial and uniform fields. There are clear statements showing good to excellent understanding of the forces between masses/charges, gravitational and electric field strengths, and gravitational and electric potentials and of how aspects of them differ for gravitational and electric effects.* **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.	max 6	A **High Level** answer must refer to at least **two valid** similarities and at least **two valid** differences, and must also contain information about **both** radial and uniform fields. An **Intermediate Level** answer must refer to at least **two valid** similarities and at least **one valid** difference, and must also consider **either** radial or uniform fields, or both.

			The candidate's comparisons are less complete but good understanding is shown of the factors affecting the respective forces and of the definitions of field strength and potential. There may be limited reference to radial and uniform fields. Similarities between gravitational and electric effects are better known than differences. **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 a much weaker ability to convey the similarities and differences between gravitational and electric fields. There is likely to be little or no reference to radial and uniform fields. Factors affecting the respective forces are known, but understanding of field strength is likely to be weaker and understanding of potential may be poor or absent..* **The explanation expected in a competent answer should include a coherent selection of the following points.** ***Forces*** • In a radial field, both gravitational and electric involve an inverse square relationship. • In both cases the force is proportional to a product (masses/charges).		A **Low Level** answer must refer to at least **one valid** similarity but may not identify any **valid** differences. **(D)** = valid difference. Good candidates are likely to mention other valid differences e.g. electrostatic forces depend on the medium whereas gravitational forces don't, possibility of shielding an electric field but impossibility of shielding a gravitational field.

			• In both cases a spherical body may be considered to act as a point mass or charge placed at the centre of the sphere. • In a uniform field the force is constant at all points. • Gravitational forces are always an attraction whilst electric forces may be attraction or repulsion. **(D)** • Gravitational forces are usually much smaller than electric forces (unless very large masses are involved). **(D)** ***Field Strengths*** • Both are defined as a *force per unit* mass or charge. • In both cases the field strength in a radial field is proportional to $1/r^2$. • In both cases the field strength in a radial field is proportional to the magnitude of the mass or charge that produces it. • In a uniform field the field has the same magnitude and same direction at all points. • A gravitational field is always directed towards the mass producing it whereas an electric field is directed towards a negative charge but away from a positive charge. **(D)** • A mass of 1 kg is small in terms of the gravitational field it produces but a charge of 1 C would produce a very strong electric field. **(D)** ***Potentials*** • Definitions of both involve work done in moving a mass or charge from infinity to a point.		

			• Both definitions involve the work done *per unit* mass or charge. • Both types of potential are proportional to 1/*r* in a radial field. • Both types of potential are proportional to the mass or charge producing them. • In a uniform field the potential varies linearly with distance. • The work done in moving a mass or charge across a potential difference is calculated by multiplying the mass or charge by the potential difference. • Gravitational potential is always a negative quantity but electric potential is negative for negative charges and positive for positive charges. **(D)**		

5	a	i	60 (degrees) ✓	1	

5	a	ii	angle required is 150° ✓ which is 5π/6 [**or** 2.6(2)] (radians) ✓	2	Correct answer in radians scores both marks.

5	b	i	(magnitude of the induced) emf ✓	1	Accept “induced voltage” or “rate of change of flux linkage”, but not “voltage” alone.

5	b	ii	frequency $\left(=\frac{1}{T}\right)=\frac{1}{40\times10^{-3}}$ ✓ (= 25 Hz) no of revolutions per minute = 25 × 60 = 1500 ✓	2	1500 scores both marks. Award 1 mark for 40s → 1.5 rev min^{-1}.

5	b	iii	maximum flux linkage (=BAN) = 0.55 (Wb turns) ✓ angular speed $\omega\left(=\frac{2\pi}{T}\right)=\frac{2\pi}{40\times10^{-3}}$ ✓ (= 157 rad s^{-1}) peak emf (= $BAN\omega$) = 0.55 × 157 = 86(.4) (V) ✓ [**or**, less accurately, use of gradient method ✓ {e.g. $\varepsilon\left(=\frac{\Delta(N\Phi)}{\Delta t}\right)=\frac{0.5-(-0.5)}{(16-4)\times10^{-3}}=\frac{1.0}{12\times10^{-3}}$ } = 83 (± 10) (V) ✓ ✓ (max 2 for (iii) for values between 63 and 72 V or 94 and 103V)]	3	

5	c		sinusoidal shape of constant period 40 ms ✓ correct phase (i.e. starts as a minus sin curve) ✓	2	**Mark sequentially.** Graph must cover at least 80ms. For 2nd mark, accept + sin curve. Perfect sin curves are not expected.

5	d		BAN = 0.55 ∴ flux density $B = \dfrac{0.55}{4.0 \times 10^{-3} \times 550}$ ✓ = 0.25(0) (T) ✓	2	**OR** by use of ε from (b)(iii) and f from (b)(ii) substituted in $\varepsilon = BAN\,(2\pi f)$.