Mark schemes

1 (a) Gravitational field lines show the <u>direction</u> (and relative magnitude) of <u>force</u> on a <u>mass</u> (placed in the force field) ✓
Or
The direction a <u>stationary/placed</u> mass would (initially) move.

1

(b) (Lines are closer together so) the field is stronger ✓
(Material forming the Earth) at **K** has a high(er) density (than the surrounding material) ✓

*For second mark allow more mass at **K**.*

'Force is stronger' does not gain first mark.

2

(c) The ball will speed up/accelerate (when moving towards **K**) ✓
(because) the potential is lower at **K** ✓
Or
the angled field lines between **J** and **K** have a component towards the right ie towards **K**) ✓

2

(d) A gravitational field should only show attraction to a body / lines of force should only be going to an object / arrow heads (on the left) should point towards **L**. ✓ (owtte)

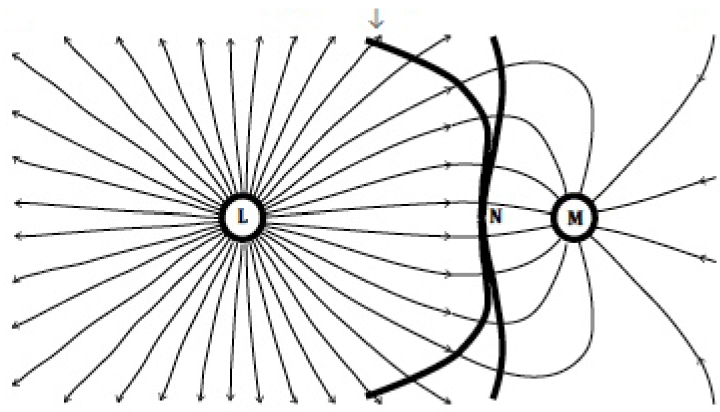
Reference to positive or negative almost <u>always</u> will lose the mark.

1

(e) object = L
object = L ✓

1

(f) The drawn line should approximately cross the field lines at right angles ✓



A mark is given if the line is symmetrical top to bottom and it bends to the left. ✓

First mark:

Only look at the <u>*4 lines*</u> *of force close to N. Essentially the range is from a vertical line to one that curves only slightly in order to cross the 4 field lines close to N at right angles. This mark can also be given if a right angle symbol appears on the diagram at any field crossing of the drawn line.*

Second mark:

There must be some bending of the line to the left (beyond the 4 lines close to N) but no more than that indicated by the arrow above the diagram (For reference the range extends to the position of the second field line that is truncated)

So a very large circle centred on L and leaving the diagram might get 2nd mark but not the 1st.

A vertical line might get the 1st but not the 2nd.

A small circle around M will not score.

If multiple lines are drawn only mark the line that passes through N.

2

[9]

2 (a) $1\text{eV} = 1.6 \times 10^{-19}$ J

kinetic energy = $1.6 \times 10^{-19} \times 4.9 \times 10^{6} = 7.8(4) \times 10^{-13}$ J ✓

ke lost = pe gained = $7.8(4) \times 10^{-13}$ J ✓

2

(b) using $V = Q / 4\pi\varepsilon_0 r$ and $E_p = qV$

$r = qQ/4\pi\varepsilon_0 E_p$ ✓

$= (2 \times 1.6 \times 10^{-19})\ (79 \times 1.6 \times 10^{-19})/4\pi \times 8.85 \times 10^{-12} \times 7.84 \times 10^{-13}$ ✓

$r = 4.67(4.64) \times 10^{-14}$ m ✓

3

(c) $A = (R/R_0)^3$ ✓

$= (7.16 \times 10^{-15} / 1.23 \times 10^{-15}\ \text{m})^3$ ✓

= 197 placed on the dotted line ✓

3

(d) *r* gets smaller ✓

less force so needs to travel further to lose same initial ke ✓

Fewer protons means that r will be smaller when alpha particle has the same electrostatic potential energy (as initial kinetic energy)

2

[10]

3

(a) $t = \sqrt{\frac{2s}{g}}$ or $4.5 = \frac{1}{2} \times 9.81 \times t^2$ ✓

$t = 0.96$ s✓

2

(b) Field strength = 186000V m^{-1}✓

Acceleration = Eq / m

or $186\,000 \times 1.2 \times 10^{-6}$ ✓

0.22 m s^{-2} ✓

3

(c) 0.10(3)m (allow ecf from (i))✓

1

(d) Force on a particle = *mg* and

acceleration = F / m so always = g✓

Time to fall (given distance) depends (only) on the distance and acceleration✓

OR:

$g = GM / r^2$ ✓

Time to fall = $\sqrt{2s / g}$

so no *m* in equations to determine time to fall✓

2

(e) Mass is not constant since particle mass will vary✓

Charge on a particle is not constant✓

Acceleration = Eq / m or $(V / d)(q / m)$ or Vq / dm✓

E or V / d constant but charge and mass are 'random' variables so q / m will vary (or unlikely to be the same)✓

4

[12]

4 (a) force between two (point) charges is

proportional to product of charges ✓

inversely proportional to square of distance between the charges ✓

Mention of force is essential, otherwise no marks.

Condone "proportional to charges".

Do not allow "square of radius" when radius is undefined.

Award full credit for equation with all terms defined.

2

(b) V is inversely proportional to r [**or** $V \propto (-)1 / r$] ✓

(V has negative values) because charge is negative

[**or** because force is attractive on + charge placed near it

or because electric potential is + for + charge and − for − charge] ✓

potential is defined to be zero at infinity ✓

Allow $V \times r$ = constant for 1st mark.

max 2

(c) (i) $Q(= 4\pi\varepsilon_0 rV) = 4\pi\varepsilon_0 \times 0.125 \times 2000$

OR *gradient = $Q / 4\pi\varepsilon_0 = 2000 / 8$* ✓

(for example, using any pair of values from graph) ✓

= 28 (27.8) (± 1) (nC) ✓

(gives Q = 28 (27.8) ±1 (nC) ✓

2

(ii) at r = 0.20m V = −1250V and at r = 0.50m V = −500V
so pd ΔV = −500 − (−1250) = 750 (V) ✓
work done ΔW (= $Q\Delta V$) = 60 × 10^{-9} × 750
= 4.5(0) × 10^{-5} (J) (45 μJ) ✓

(final answer could be between 3.9 and 5.1 × 10^{-5})

Allow tolerance of ± 50V on graph readings.

[Alternative for 1st mark:

$\Delta V = \frac{27.8\times10^{-9}}{4\pi\varepsilon_0}\times\left(\frac{1}{0.2}-\frac{1}{0.5}\right)$(***or** similar substitution using 60 nC*

instead of 27.8 nC:
use of 60 nC gives ΔV = 1620V)]

2

(iii) $E\left(=\frac{Q}{4\pi\varepsilon_0 r^2}\right)=\frac{27.8\times10^{-9}}{4\pi\varepsilon_0\times0.40^2}$ ✓ = 1600 (1560) (V m^{-1}) ✓

[or deduce $E = \frac{V}{r}$ by combining $E = \frac{Q}{4\pi\varepsilon_0 r^2}$ with $V = \frac{Q}{4\pi\varepsilon_0 r}$ ✓

from graph $E = \frac{625\pm50}{0.40}$ = 1600 (1560 ± 130) (V m^{-1}) ✓]

Use of Q = 30 nC gives 1690 (V m^{-1}).

Allow ecf from Q value in (i).

If Q = 60 nC is used here, no marks to be awarded.

2

[10]

5 (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) ✓

Mark sequentially.
Essential to refer to negative charge (or force on + charge is to right) for 2nd mark.

2

(ii) (use of $W = F s$ gives) force $F = \frac{4.0\times10^{-16}}{63\times10^{-3}}$ ✓

= 6.3(5) × 10^{-15} (N) ✓

*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

(iii) electric field strength $E\left(=\frac{F}{Q}\right)=\frac{6.35\times10^{-15}}{3\times1.6\times10^{-19}}$ = 1.3(2) ✓ 10^4 (N C^{-1}) ✓

[**or** $\Delta V\left(=\frac{\Delta W}{Q}\right)=\frac{4.0\times10^{-16}}{3\times1.60\times10^{-19}}$ (833 V)

$E\left(=\frac{\Delta V}{d}\right)=\frac{833}{63\times10^{-3}}$ = 1.3(2) ✓ 10^4 (V m^{-1}) ✓]

Allow ECF from wrong F value in (ii).

1

(b) (i) (vertically) downwards on diagram ✓

reference to Fleming's LH rule **or** equivalent statement ✓

Mark sequentially.

1st point: allow "into the page".

2

(ii) number of free electrons in wire = *A* × *l* × number density

= 5.1 × 10^{-6} × 95 × 10^{-3} × 8.4 × 10^{28} = 4.1 (4.07) × 10^{22} ✓

Provided it is shown correctly to at least 2SF, final answer alone is sufficient for the mark. (Otherwise working is mandatory).

1

(iii) $B\left(=\frac{F}{Qv}\right)=\frac{1.4\times10^{-25}}{1.60\times10^{-19}\times5.5\times10^{-6}}$ ✓ = 0.16 (0.159) (T) ✓

[**or** $B\left(=\frac{F}{I\,l}\right)=\frac{1.4\times10^{-25}\times4.07\times10^{22}}{0.38\times95\times10^{-3}}$ ✓ = 0.16 (0.158) (T) ✓]

In 2nd method allow ECF from wrong number value in (ii).

2

[10]

6 (a) (i) required pd (= 2.5 × 10^{6} × 12 × 10^{-3}) = 3.0(0) × 10^4 (V) ✓

1

(ii) charge required *Q (= CV)* = 3.7 × 10^{-12} × 3.00 × 10^4 ✓

(= 1.11 × 10^{-7} C)

Allow ECF from incorrect V from (a)(i).

time taken $t\left(=\frac{Q}{I}\right)=\frac{1.11\times10^{-7}}{3.2\times10^{-8}}$ = 3.5 (3.47) (s) ✓

2

(b) (i) time increases ✓

(larger C means) more charge required (to reach breakdown pd)

Mark sequentially *i.e. no explanation mark if effect is wrong.*

or $t = \frac{CV}{I}$ **or** time ∝ capacitance ✓

2

(ii) spark is brighter (**or** lasts for a longer time) ✓

more energy (**or** charge) is stored **or** current is larger

Mark sequentially.

or spark has more energy ✓

2

(Total 7 marks)

7 **C**

[1]

8 **D**

[1]

9 **D**

[1]

10 **A**

[1]

Examiner reports

1

(a) A majority of answers simply reinterpreted the words of the question and made no reference to force or mass. So there was a proliferation of answers such as, “They show the direction of the field acts in”. Only a minority of students gave a complete answer. A common misunderstanding that was frequently stated was the idea that a mass will follow the field line when free to move. This may be true for an initial movement, but subsequently, because of the build-up of momentum, it is not generally true.

(b) Many students appreciated that the gravitational field was stronger at K but then did not give a good reason for it. They often referred to the earth not being flat, or stated that K is up a mountain or down a hole. Other students did state that there was a mass at K or it was an area where the Earth’s density is greater, but they did not refer to the field being stronger. Also a few students referred to gravitational force when they were really referring to gravitational field.

(c) Only a small number of students deduced that the field had a component horizontally near K. Therefore very few scored 2 marks. A majority did appreciate that the ball would accelerate, even if their reasoning was sometimes false. Several students misinterpreted the question and thought that the ball was falling, but this would not have excluded the student from scoring both marks. If no direction was stated, the motion was treated as horizontal by examiners. If the students thought the ball was falling, and separated the horizontal and vertical motion, both marks are obtainable. The vertical was ignored and both points in the mark scheme are still true for the horizontal motion.

(d) The idea behind the question was well understood by the vast majority of students. It was only the least able who missed out on the mark.

(e) Most students, 70%, could do this easily.

(f) A majority of students seemed to be unaware how equipotential lines relate to field lines. Very few scored full marks. Common shapes drawn were a line joining L to M, a straight vertical line, and a tight circle around M.

4 Statements of Coulomb's law were generally satisfactory in part (a) and marks were high. Occasionally there was confusion with the law of gravitation (distance between *masses* rather than *charges*) and reference to *indirect* proportion (which was not acceptable) rather than *inverse* proportion.

In part (b), inverse proportion was generally recognised as the relationship between V and r shown on the graph. Many students knew that the negative values of potential were caused by the charge Q being negative. Alternative arguments that approached an answer via the definition of potential usually failed because the positive nature of the charge being moved was not stated. No doubt it was confusion with gravitational potential, which is always attractive, that caused a significant number of students to conclude that electric potential is always negative.

There was a good spread of marks across the three calculations in part (c). Part (c)(i) was usually answered correctly, either by substitution of a data point from the graph or by use of the gradient. Part (c)(ii) was most easily approached by reading the potentials corresponding to r = 0.20 m and r = 0.50 m from the graph, leading to ΔV = 750V, and then applying $\Delta W = Q\Delta V$. The principal failing in the answers that started from first principles, by calculating the two potentials from the Q value in part (i), was to use 60 nC as both the source of the potentials and as the charge being moved. Direct substitution of the charge from part (i) into $E = Q / 4\pi\varepsilon_0 r^2$ gave the most straightforward answer in part (iii). Although the use of $E = V / d$ gave the correct numerical answer here, it should be recognised that this equation is only valid in a uniform field whereas the field in this question is radial. Both marks were therefore awarded for this approach only when the use of $E = V / r$ had been justified.

5 The direction of the force on the negatively charged ion in part (a)(i) was mainly correct. Explanations of the direction of the force were good and marks for this part were high.

At A2 level the students are expected to have retained a comprehensive knowledge of earlier work, which is tested by synoptic components within the questions. Part (a)(ii) was an example of this, because the simplest solution followed directly from "energy gained = work done = force × distance". This eluded most students, many of whom were completely defeated. Many of them became successful after taking a very roundabout route, involving calculation of the pd from $V = W / Q$, the field strength from $E = V / d$ and the force from $F = EQ$. Others produced answers based on the uniform acceleration equations and $F = ma$. When this was done using algebra the mass m of the ion could be cancelled and the answer was accepted. When a numerical value was chosen for m the mark that could be awarded was limited to 1 out of 2. There were fewer difficulties in part (a)(iii), where $E = F / 3e$ gave the most direct answer but where $E = V / d$ offered an alternative method. Incorrect force values from part (a)(ii) were permitted for full credit in part (a)(iii).

In part (b)(i) the successful application of Fleming's left hand rule readily showed the majority that the magnetic force on the wire would be downwards (or into the page). Most students gained both marks. It seemed that some students who thought too deeply about the direction of this force eventually got it wrong: their line of thought was that the force due to the current was downwards, but electrons carry a negative charge so the force on them must act upwards. It had not occurred to them that the force on the complete wire has to act in the same direction as the force on all of the free electrons within it.

The simple calculation that led to the number of free electrons in the section of wire was almost always worked out correctly in part (b)(ii). This was a "show that" question, so students should have realised that a more precise answer than 4×10^{22} (such as 4.07×10^{22}) would be expected before the mark became available. Part (b)(iii) offered two approaches to the value of the flux density B. By considering the average force on a single electron, $F = BQv$ could be used. Alternatively, by considering the force on the section of wire, $F = BIl$ could be used. In the latter method many got into difficulty by forgetting to consider the number of electrons in the wire.

6 Very few candidates experienced any difficulty in (a)(i), where the product of field strength and plate separation readily led to 30,000 V. In the other parts of Question 2 the principal failing of many of the candidates' attempts was to resort to time variations that were exponential. Part (a) puts this question clearly in the context of a charging current that is constant, so any references to exponential changes or time constants showed misunderstanding and were irrelevant. Arithmetical slips sometimes caused the loss of marks in part (a)(ii), but $Q = CV$ and $t = Q / I$ were usually applied correctly to arrive at 3.5 s.

In part (b) it was essential for candidates to realise that both the charging current and the breakdown pd remain constant at their original values when the capacitance is changed. The majority of candidates could see in part (b)(i) that the time between discharges would increase. Many also gave an acceptable explanation, either by stating that the charge stored would have to be larger before the breakdown pd was reached, or by reference to $t = CV / I$, where V and I are both unchanged. A common misconception in part (b)(ii) was to think that the brightness of the spark would be unchanged because the breakdown pd would be the same as it had been originally. It was expected that candidates would know that increased capacitance at the same pd would mean that the energy stored by the capacitor would be greater, so each spark would transfer more energy and would therefore be brighter. Alternatively, explanations in terms of the greater charge stored were also accepted.

7 49.2% correct

8 63.3% correct

9 57.5% correct