CAMBRIDGE INTERNATIONAL AS & A LEVEL PHYSICS · 9702

PHYSICS



MARK SCHEME

18 ELECTRIC FIELDS

SCORE	PERCENTAGE
/	%

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Paper 1 Multiple Choice Answers: Electric Fields

Question	Paper	Q. No.	Answer
1008	9702_m20_qp_12	30	A
1009	9702_s20_qp_11	31	D
1010	9702_s20_qp_12	31	D
1011	9702_s20_qp_13	31	D
1012	9702_m19_qp_12	31	B
1013	9702_s19_qp_11	31	A
1014	9702_s19_qp_11	32	D
1015	9702_s19_qp_13	31	D
1016	9702_w19_qp_12	29	C
1017	9702_w19_qp_13	31	D
1018	9702_s18_qp_12	31	A
1019	9702_w18_qp_11	30	B
1020	9702_w18_qp_12	31	C
1021	9702_w18_qp_13	30	B
1022	9702_m17_qp_12	30	A
1023	9702_s17_qp_11	30	A
1024	9702_s17_qp_12	30	C
1025	9702_s17_qp_13	29	D
1026	9702_s16_qp_11	29	D
1027	9702_s16_qp_12	29	B
1028	9702_s16_qp_13	29	D
1029	9702_s15_qp_12	29	B
1030	9702_s15_qp_13	31	D
1031	9702_m20_qp_12	31	D
1032	9702_s20_qp_11	32	A
1033	9702_s20_qp_12	32	A
1034	9702_s20_qp_13	32	D
1035	9702_m19_qp_12	30	A
1036	9702_s19_qp_12	13	C
1037	9702_s19_qp_12	32	A
1038	9702_w19_qp_12	30	B
1039	9702_w19_qp_13	32	D
1040	9702_m18_qp_12	30	D
1041	9702_m18_qp_12	31	D
1042	9702_s18_qp_11	28	D
1043	9702_s18_qp_11	29	B
1044	9702_s18_qp_12	30	D
1045	9702_s18_qp_13	27	A
1046	9702_s18_qp_13	28	B
1047	9702_w18_qp_11	31	B
1048	9702_w18_qp_11	32	D
1049	9702_w18_qp_12	32	D
1050	9702_w18_qp_13	31	D
1051	9702_m17_qp_12	31	D
1052	9702_s17_qp_11	31	B
1053	9702_s17_qp_12	31	C

Paper 1 Multiple Choice Answers: Electric Fields (continued)

Question	Paper	Q. No.	Answer
1054	9702_s17_qp_13	30	D
1055	9702_w17_qp_11	31	C
1056	9702_w17_qp_11	32	C
1057	9702_w17_qp_12	31	A
1058	9702_w17_qp_12	32	B
1059	9702_w17_qp_13	31	A
1060	9702_w17_qp_13	32	C
1061	9702_m16_qp_12	27	D
1062	9702_m16_qp_12	28	A
1063	9702_m16_qp_12	29	A
1064	9702_s16_qp_11	28	A
1065	9702_s16_qp_12	30	C
1066	9702_s16_qp_12	31	C
1067	9702_s16_qp_13	30	A
1068	9702_w16_qp_11	30	A
1069	9702_w16_qp_11	32	A
1070	9702_w16_qp_12	30	B
1071	9702_w16_qp_12	31	A
1072	9702_w16_qp_13	30	A
1073	9702_w16_qp_13	32	A
1074	9702_s15_qp_11	31	D
1075	9702_s15_qp_11	32	B
1076	9702_s15_qp_12	30	B
1077	9702_s15_qp_13	30	B
1078	9702_w16_qp_11	31	B
1079	9702_w16_qp_13	31	B

185. 9702_s15_qp_21 Q: 6

(a) diffraction is the spreading of a wave as it passes through a slit or past an edge B1

when two (or more) waves superpose/meet/overlap M1
resultant displacement is the sum of the displacement of each wave A1 [3]

(b) $n\lambda = d \sin\theta$ and $v = f\lambda$ C1

max order number for $\theta = 90°$
hence n (= f/vN) = $7.06 \times 10^{14} / (3 \times 10^8 \times 650 \times 10^3)$ M1

$n = 3.6$
hence number of orders = 3 A1 [3]

(c) greater wavelength so fewer orders seen A1 [1]

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186. 9702_m17_qp_22 Q: 5

	Answer	Mark
(a)	to the right / from the left / from A to B / in the same direction as electron velocity	**B1**
(b)	$v^2 = u^2 + 2as$ $a = (1.5 \times 10^7)^2 / (2 \times 2.0 \times 10^{-2})$ Other alternative calculations for the C1 mark: e.g. $a = 1.5\times10^7 / 2.67\times10^{-9}$ e.g. $a = [(1.5\times10^7 \times 2.67\times10^{-9}) - 2.0\times10^{-2}] \times [2 / (2.67\times10^{-9})^2]$ e.g. $a = (2.0\times10^{-2} \times 2) / (2.67\times10^{-9})^2$	**C1**
	$= 5.6 \times 10^{15}\ \text{m s}^{-2}$	**A1**
(c)	$E = F/Q$	**C1**
	$= (9.1 \times 10^{-31} \times 5.6 \times 10^{15}) / 1.6 \times 10^{-19}$	**C1**
	$= 3.2 \times 10^4\ \text{V m}^{-1}$	**A1**
(d)	straight line with negative gradient starting at an intercept on the *v*-axis and ending at an intercept on the *t*-axis.	**B1**

187. 9702_s17_qp_23 Q: 3

	Answer	Mark
(a)	force per unit (positive) charge	B1
(b)(i)	$a = (v^2 - u^2) / 2s$ $= [(18 \times 10^6)^2 - (2.5 \times 10^3)^2] / (2 \times 12 \times 10^{-3})$	B1
	$= 1.3\ (1.35) \times 10^{16}\ m\ s^{-2}$	A1
(b)(ii)	KE = $\frac{1}{2} mv^2$ **or** $\frac{1}{2} m(v^2 - u^2)$	C1
	change in KE $= 0.5 \times 9.11 \times 10^{-31} \times [(18 \times 10^6)^2 - (2.5 \times 10^3)^2]$	B1
	$= 1.5\ (1.48) \times 10^{-16}$ J	A1
(b)(iii)	$E = F / e = ma / e$ **or** $eV = \Delta$KE so $E = \Delta$KE $/ (e \times d)$	C1
	$E = (9.11 \times 10^{-31} \times 1.35 \times 10^{16}) / 1.60 \times 10^{-19}$ **or** $E = (1.48 \times 10^{-16}) / (12 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1
	$= 7.7\ (7.69) \times 10^4\ V\ m^{-1}$	A1
(c)	charge on α opposite to electron/charge on α is positive	B1
	ΔKE is negative/KE reduced	B1
	charge of α greater/twice that of electron causes larger/twice ΔKE (in magnitude)	B1

188. 9702_m19_qp_22 Q: 4

	Answer	Mark
(a)	force per unit positive charge	B1
(b)(i)	1 $E = V / d$ or $E = \Delta V / \Delta d$ $d = 4.0 \times 10^3 / 5.0 \times 10^4$	C1
	$= 8.0 \times 10^{-2}$ m	A1
	2 plates are (in) horizontal (plane) (above and below the rod)	B1
	top (plate) negative and bottom (plate) positive	B1
(b)(ii)	magnitude $= 5.0 \times 10^4 \times 3 \times 1.6 \times 10^{-19}$ $= 2.4 \times 10^{-14}$ N	A1
	direction is (vertically) downwards / down	B1

	Answer	Mark
(b)(iii)	$6.2 \times 10^{-16} = 2.4 \times 10^{-14} \times 72 \times 10^{-3} \times \cos\theta$	C1
	$\theta = 69°$	A1

189. 9702_s19_qp_21 Q: 4

	Answer	Mark
(a)(i)	$m = \rho \times V$	C1
	$= (4 / 3) \times \pi \times (1.2 \times 10^{-6})^3 \times 940 = 6.8 \times 10^{-15}$ (kg)	A1
(a)(ii)	minimum charge (on drop) is 1.6×10^{-19} C	B1
(b)(i)	$V = Ed$	C1
	$V = 2.1 \times 10^5 \times 8.0 \times 10^{-3}$ $= 1.7 \times 10^3$ V	A1
(b)(ii)	constant velocity so no resultant force (so in equilibrium)	B1
(b)(iii)	$mg = Eq$ **or** $mg = (V / d)q$ **or** $F = mg$ **and** $F = Eq$	C1
	$q = (6.8 \times 10^{-15} \times 9.81) / 2.1 \times 10^5$ $= 3.2 \times 10^{-19}$ C	A1
	sign of charge is negative	A1
(c)(i)	electric force decreases	B1
	weight > electric force **or** resultant force acts downwards	B1
(c)(ii)	(field line) separation increases	B1
(d)(i)	upthrust (force)	B1
(d)(ii)	air resistance/drag/viscous (force)	B1

190. 9702_s19_qp_23 Q: 4

	Answer	Mark
(a)	straight (horizontal) lines **and** from the +0.90 kV plate/to the 0 V plate	B1
	(lines are) equally spaced	B1
(b)	weight/gravitational force **and** electric force	B1
(c)	$s = ½at^2$ **or** $s = ut + ½at^2$ **and** $u = 0$	C1
	$2.0 = ½ \times 9.81 \times t^2$ so $t = 0.64$ s	A1
(d)	$0.080 = ½ \times a \times 0.64^2$	C1
	$a = 0.39$ m s^{-2}	A1
(e)(i)	$E = (\Delta)V / (\Delta)d$	C1
	$E = 0.90 \times 10^3 / 0.12$ $= 7.5 \times 10^3$ N C^{-1}	A1
(e)(ii)	$ma = Eq$ **or** $F = ma$ **and** $F = Eq$	C1
	$q / m = 0.39 / 7.5 \times 10^3$ $= 5.2 \times 10^{-5}$ C kg^{-1}	A1
(f)(i)	no effect	B1
(f)(ii)	decreases/smaller	B1

191. 9702_w19_qp_21 Q: 2

	Answer	Mark
(a)	the (two) plates are vertical (and separated)	B1
	left plate positively charged **and** right plate negatively charged/earthed **or** right plate negatively charged **and** left plate positively charged/earthed	B1
(b)	$F = Eq$	C1
	$= 1.3 \times 10^4 \times 3.7 \times 10^{-9}$ $= 4.8 \times 10^{-5}$ N	A1
(c)	$F^2 = (4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2$ so $F = 7.2 \times 10^{-5}$ N **or** $F = [(4.8 \times 10^{-5})^2 + (5.4 \times 10^{-5})^2]^{0.5}$ so $F = 7.2 \times 10^{-5}$ N	A1
(d)	electric force is constant (because field strength/E is constant)	B1
	weight is constant (and so resultant force constant)	B1
(e)(i)	$m = 5.4 \times 10^{-5} / 9.81$ (= 5.5×10^{-6})	C1
	$a = 7.2 \times 10^{-5} / (5.5 \times 10^{-6})$ $=13$ m s^{-2}	A1
(e)(ii)	$v^2 = u^2 + 2as$ $v^2 = 2 \times 13 \times 0.58$	C1
	$v = 3.9$ m s^{-1}	A1

192. 9702_w19_qp_23 Q: 3

	Answer	Mark
(a)(i)	mass	B1
(a)(ii)	charge	B1
(b)(i)	$E = V/d$ **or** $E = F/q$	C1
	$F = (1.2 \times 10^3 \times 4.2 \times 10^{-9}) / 3.6 \times 10^{-2}$	C1
	$= 1.4 \times 10^{-4}$ N	A1
(b)(ii)	$W = mg$	C1
	$= 5.9 \times 10^{-6} \times 9.81$ resultant force = $1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)$	C1
	$a = F/m$	C1
	$a = [1.4 \times 10^{-4} - (5.9 \times 10^{-6} \times 9.81)] / [5.9 \times 10^{-6}] = 14$ m s^{-2}	A1
(b)(iii)	**1.** $s = ut + ½at^2$ $1.8 \times 10^{-2} = ½ \times 14 \times t^2$	C1
	$t = 0.051$ s	A1
	2. $p = 0.75 \times 0.051$ $= 0.038$ m	A1

193. 9702_w17_qp_21 Q: 6

	Answer	Mark
(a)	force per unit positive charge	B1
(b)(i)	$E_K = ½mv^2$	C1
	$2.4 \times 10^{-16} = ½ \times 1.7 \times 10^{-27} \times v^2$ $v = 5.3 \times 10^5 \text{ m s}^{-1}$	A1
(b)(ii)	work done $= 2.4 \times 10^{-16}$ J	A1
(b)(iii)	$W = Fs$	C1
	$F = 2.4 \times 10^{-16} / 15 \times 10^{-3}$ $= 1.6 \times 10^{-14}$ N	A1
(b)(iv)	$V = Fd / Q$ **or** $V = W / Q$ **or** $E = V / d$ **and** $E = F / Q$	C1
	$V = (1.6 \times 10^{-14} \times 15 \times 10^{-3}) / 1.6 \times 10^{-19}$ **or** $2.4 \times 10^{-16} / 1.6 \times 10^{-19}$	C1
	$= 1500$ V	A1
(b)(v)	straight line with positive gradient starting at the origin and going as far as $x = 15$ mm	B1

194. 9702_w17_qp_23 Q: 5

	Answer	Mark
(a)	force per unit positive charge	B1
(b)(i)	$s = ½at^2$	C1
	$a = (2 \times 0.045) / (1.5 \times 10^{-7})^2 = 4(.0) \times 10^{12} \text{ m s}^{-2}$	A1
(b)(ii)	$F = 1.67 \times 10^{-27} \times 4.0 \times 10^{12} = 6.7\ (6.68) \times 10^{-15}$ N	A1
(b)(iii)	**1.** $E = F / Q$	C1
	$= 6.68 \times 10^{-15} / 1.6 \times 10^{-19}$ $= 4.2\ (4.18) \times 10^4 \text{ N C}^{-1}$	A1
	2. $E = V / d$	C1
	$V = 4.18 \times 10^4 \times 0.045$ $= 1.9 \times 10^3$ V	A1

	Answer	Mark
(c)	$a = Eq / m$ **or** $F = ma$ **and** $F = Eq$	C1
	ratio $= \frac{(2 \times 1.6 \times 10^{-19}) \times (1.67 \times 10^{-27})}{(1.6 \times 10^{-19}) \times (4 \times 1.66 \times 10^{-27})}$ **or** $\frac{2 \times 1}{1 \times 4}$ $= 0.50$	A1

195. 9702_s16_qp_22 Q: 6

(a) at least six horizontal lines equally spaced and arrow to the right B1 [1]

(b) charge used $2e$ C1

gain in KE = $15 \times 1.6 \times 10^{-19} \times 10^3 = 2 \times 1.6 \times 10^{-19} \times V$ (p.d.across plates)
or
F (= W/d) = $15 \times 1.6 \times 10^{-19} \times 10^3 / 16 \times 10^{-3}$ C1

(hence V = 7500 V or $F = 1.5 \times 10^{-13}$ N)

$E = V/d$ or $E = F/Q$ C1

$E = (7500 / 16 \times 10^{-3})$ or $E = (1.5 \times 10^{-13} / 3.2 \times 10^{-19})$

$E = 4.7 \times 10^5$ (468 750) V m^{-1} A1 [4]

or

KE (= ½mv^2) = $15 \times 10^3 \times 1.6 \times 10^{-19}$

$v = [(2 \times 15 \times 10^3 \times 1.6 \times 10^{-19}) / (6.68 \times 10^{-27})]^{1/2} = 8.5 \times 10^5$ m s^{-1} (C1)

a (= $v^2/2s$) = $(8.5 \times 10^5)^2 / 2 \times 16 \times 10^{-3} = 2.25 \times 10^{13}$ m s^{-2}

F (= $6.68 \times 10^{-27} \times 2.25 \times 10^{-13}$) = 1.5×10^{-13} N

$E = F/Q$ (C1)

$Q = 2e$ (C1)

$E = 4.7 \times 10^5$ V m^{-1} (A1)

196. 9702_w16_qp_21 Q: 2

(a) force per unit positive charge B1 [1]

(b) (i) time $= 5.9 \times 10^{-2} / 3.7 \times 10^{7}$
$= 1.6 \times 10^{-9}$ s (1.59×10^{-9} s) A1 [1]

(ii) $E = V/d$ C1

$= 2500 / 4.0 \times 10^{-2}$

$= 6.3 \times 10^{4}$ N C^{-1} (6.25×10^{4} or 62500 N C^{-1}) A1 [2]

(iii) $a = Eq/m$ *or* $F = ma$ *and* $F = Eq$ C1

$= (6.3 \times 10^{4} \times 1.60 \times 10^{-19}) / 9.11 \times 10^{-31} = 1.1 \times 10^{16}$ m s^{-2} A1 [2]

(iv) $s = ut + ½at^2$

$= ½ \times 1.1 \times 10^{16} \times (1.6 \times 10^{-9})^2$ C1

$= 1.4 \times 10^{-2}$ (m) C1

distance from plate $= 2.0 - 1.4$
$= 0.6$ cm (*allow 1 or more s.f.*) A1 [3]

(v) electric force ≫ gravitational force (on electron)/weight
or
acceleration due to electric field ≫ acceleration due to gravitational field B1 [1]

(vi) v_X–t graph: horizontal line at a non-zero value of v_X B1

v_Y–t graph: straight line through the origin with positive gradient B1 [2]

197. 9702_w16_qp_23 Q: 2

(a) force per unit positive charge — B1 [1]

(b) (i) time $= 5.9 \times 10^{-2} / 3.7 \times 10^{7}$
$= 1.6 \times 10^{-9}$ s (1.59×10^{-9} s) — A1 [1]

(ii) $E = V/d$ — C1

$= 2500 / 4.0 \times 10^{-2}$

$= 6.3 \times 10^{4}$ N C^{-1} (6.25×10^{4} or 62500 N C^{-1}) — A1 [2]

(iii) $a = Eq/m$ *or* $F = ma$ *and* $F = Eq$ — C1

$= (6.3 \times 10^{4} \times 1.60 \times 10^{-19}) / 9.11 \times 10^{-31} = 1.1 \times 10^{16}$ m s^{-2} — A1 [2]

(iv) $s = ut + ½at^2$

$= ½ \times 1.1 \times 10^{16} \times (1.6 \times 10^{-9})^2$ — C1

$= 1.4 \times 10^{-2}$ (m) — C1

distance from plate $= 2.0 - 1.4$
$= 0.6$ cm (*allow 1 or more s.f.*) — A1 [3]

(v) electric force ≫ gravitational force (on electron)/weight
or
acceleration due to electric field ≫ acceleration due to gravitational field — B1 [1]

(vi) v_X–t graph: horizontal line at a non-zero value of v_X — B1

v_Y–t graph: straight line through the origin with positive gradient — B1 [2]

198. 9702_s15_qp_21 Q: 7

(a) a region/space/area where a (stationary) charge experiences an (electric) force B1 [1]

(b) (i) at least four parallel equally spaced straight lines perpendicular to plates B1

consistent direction of an arrow on line(s) from left to right B1 [2]

(ii) electric field strength $E = V/d$ C1

$E = (450/16 \times 10^{-3})$
$= 28 \times 10^3$ (28 125) V m^{-1} A1 [2]

(iii) $W = Eqd$ or Vq C1

$q = 3.2 \times 10^{-19}$ (C) C1

$W = 28\,125 \times 3.2 \times 10^{-19} \times 16 \times 10^{-3}$ or $450 \times 3.2 \times 10^{-19}$

$= 1.4(4) \times 10^{-16}$ J A1 [3]

(iv) ratio $= \dfrac{450 \times 3.2 \times 10^{-19}}{450 \times -1.6 \times 10^{-19}}$ *(evidence of working required)*

= (–) 2 A1 [1]

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199. 9702_s20_qp_23 Q: 6

	Answer	Mark
(a)	A: cross-sectional area	**B1**
	n: number density of free electrons	**B1**
(b)	units of I: A **and** units of A: m^2 **and** units of v: m s^{-1}	**B1**
	units of e: A / (m^2 m^{-3} m s^{-1}) = A s	**A1**
(c)	ratio = A_Q / A_P	**C1**
	= [πr^2] / [$\pi(2r^2)$] = 0.25	**A1**

200. 9702_w18_qp_22 Q: 7

	Answer	Mark
(a)	A: (cross-sectional) area (of wire)	**B1**
	n: number of free electrons per unit volume **or** number density of free electrons	**B1**
(b)	line drawn between (X, v_x) and (Y, $4v_x$)	**M1**
	line has increasing gradient	**A1**

(b) (i) gain/dB = $10 \lg (P_2 / P_1)$

$32 = 10 \lg [P_{MIN} / (0.38 \times 10^{-6})]$
or
$-32 = 10 \lg (0.38 \times 10^{-6} / P_{MIN})$ C1

$P_{MIN} = 6.0 \times 10^{-4}$ W A1 [2]

(ii) attenuation $= 10 \lg [(9.5 \times 10^{-3}) / (6.02 \times 10^{-4})]$ C1

$= 12$ dB

attenuation per unit length (= 12/58) = 0.21 dB km^{-1} A1 [2]

172. 9702_s17_MS_41 Q: 5

	Answer	Marks
(a)	(loss in) kinetic energy of α-particle = $Qq / 4\pi\varepsilon_0 r$ **or** $7.7 \times 10^{-13} = Qq / 4\pi\varepsilon_0 r$	**C1**
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$	**M1**
	$r = 4.7 \times 10^{-14}$ m r is closest distance of approach so radius less than this	**A1**
(b)	force = $Qq / 4\pi\varepsilon_0 r^2 = 4\text{u} \times a$	**C1**
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$	**C1**
	$a = 2.5 \times 10^{27}$ m s^{-2}	**A1**
(c)	so that single interactions between nucleus and α-particle can be studied **or** so that multiple deflections with nucleus do not occur	**B1**

173. 9702_s20_MS_41 Q: 5

	Answer	Marks
(a)	similarity: both are radial **or** both have inverse square (variations)	**B1**
	difference: direction is always/only towards the mass **or** direction can be towards or away from charge	**B1**
(b)	field strength = $Q / 4\pi\varepsilon_0 x^2$	**C1**
	$E = Q / 36\pi\varepsilon_0 R^2$	**A1**
(c)(i)	fields (due to each sphere) are in same direction	**B1**
(c)(ii)	charges on spheres attract/affect each other **or** charge distribution on each sphere distorted by the other sphere **or** charges on the surface of the spheres move	**B1**
	spheres are not point charges (at their centres)	**B1**

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174. 9702_s20_MS_42 Q: 7

	Answer	Marks
(a)	force per unit charge	M1
	(force on) positive charge	A1
(b)(i)	no electric field inside a conductor	B1
	R = 4.5 cm	A1
(b)(ii)	$E = Q / (4\pi\varepsilon_0 x^2)$	C1
	clear correct read-off of a pair of values of E and x	C1
	e.g. $Q = 18 \times 10^5 \times 4\pi \times 8.85 \times 10^{-12} \times (4.5 \times 10^{-2})^2$ $= 4.0 \times 10^{-7}$ C **or** 4.1×10^{-7} C	A1
(c)	At 8.0 cm, $E = 5.75 \times 10^5$ V m^{-1}	C1
	$F = Eq$ **and** $a = F / m$	C1
	$F = (5.75 \times 10^5 \times 2 \times 1.6 \times 10^{-19}) / (4 \times 1.66 \times 10^{-27})$ $= 2.8 \times 10^{13}$ m s^{-2}	A1

175. 9702_s20_MS_43 Q: 5

	Answer	Marks
(a)	similarity: both are radial **or** both have inverse square (variations)	B1
	difference: direction is always/only towards the mass **or** direction can be towards or away from charge	B1
(b)	field strength = $Q / 4\pi\varepsilon_0 x^2$	C1
	$E = Q / 36\pi\varepsilon_0 R^2$	A1
(c)(i)	fields (due to each sphere) are in same direction	B1
(c)(ii)	charges on spheres attract/affect each other **or** charge distribution on each sphere distorted by the other sphere **or** charges on the surface of the spheres move	B1
	spheres are not point charges (at their centres)	B1

176. 9702_m19_MS_42 Q: 5

	Answer	Marks
(a)	region where charge experiences an (electric) force	B1
(b)	graph: field strength zero from x = 0 to $x = R$	B1
	curve with negative gradient, decreasing from $x = R$ to $x = 3R$	B1
	line passes through field strength E at $x = R$,	B1
	line passes through field strength $0.25E$ at $x = 2R$ and field strength $0.11E$ at $x = 3R$	B1

	Answer	Marks
(c)	field strength = $q / 4\pi\epsilon_0 x^2$	C1
	$2.0 \times 10^6 = q / (4 \times \pi \times 8.85 \times 10^{-12} \times 0.26^2)$	C1
	$q = 1.5 \times 10^{-5}$ C	A1

177. 9702_s19_MS_41 Q: 5

	Answer	Marks
(a)	force per unit charge	B1
	(force on) positive charge	B1
(b)(i)	field changes direction (between A and B)/field is zero at a point (between A and B)	M1
	so charges have same sign	A1
(b)(ii)	Any one from: • field is (also) influenced by charge B • charge A is not isolated/is not the only charge present • field is due to two/both charges • field is the resultant of two fields	B1
(b)(iii)	$E = Q / (4\pi\varepsilon_0 x^2)$	C1
	at x = 10 cm, $E_A = E_B$	C1
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	A1

178. 9702_s19_MS_43 Q: 5

	Answer	Marks
(a)	force per unit charge	B1
	(force on) positive charge	B1
(b)(i)	field changes direction (between A and B)/field is zero at a point (between A and B)	M1
	so charges have same sign	A1
(b)(ii)	Any one from: • field is (also) influenced by charge B • charge A is not isolated/is not the only charge present • field is due to two/both charges • field is the resultant of two fields	B1
(b)(iii)	$E = Q / (4\pi\varepsilon_0 x^2)$	C1
	at x = 10 cm, $E_A = E_B$	C1
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	A1

179. 9702_w19_MS_41 Q: 6

	Answer	Marks
(a)	(E =) $Q / 4\pi\varepsilon_0 r^2$	M1
	where ε_0 is permittivity (of free space)	A1
(b)(i)	field does not change direction/field does not become zero	M1
	so (charges have) opposite (sign)	A1
(b)(ii)	minimum is at the midpoint (between the charges)	M1
	so (magnitudes are the) same	A1
(c)	force = field strength × charge **and** force = mass × acceleration **or** acceleration is proportional to field strength	B1
	(from x = 3.0 cm) to x = 5.0 cm: acceleration decreases	B1
	at x = 5.0 cm: acceleration is a minimum	B1
	from x = 5.0 cm (to x = 7.0 cm): acceleration increases	B1

180. 9702_w19_MS_43 Q: 6

	Answer	Marks
(a)	(E =) $Q / 4\pi\varepsilon_0 r^2$	M1
	where ε_0 is permittivity (of free space)	A1
(b)(i)	field does not change direction/field does not become zero	M1
	so (charges have) opposite (sign)	A1
(b)(ii)	minimum is at the midpoint (between the charges)	M1
	so (magnitudes are the) same	A1
(c)	force = field strength × charge **and** force = mass × acceleration **or** acceleration is proportional to field strength	B1
	(from x = 3.0 cm) to x = 5.0 cm: acceleration decreases	B1
	at x = 5.0 cm: acceleration is a minimum	B1
	from x = 5.0 cm (to x = 7.0 cm): acceleration increases	B1

181. 9702_s18_MS_41 Q: 6

	Answer	Marks
(a)	force per unit charge	B1
(b)	$E = Q/(4\pi\varepsilon_0 r^2)$	C1
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge = 1.5×10^{-7} C	A1
(c)	charge (= $Q\,[52/26]^2$) = $4Q$	C1
	additional charge = 3Q	A1

182. 9702_s18_MS_43 Q: 6

	Answer	Marks
(a)	force per unit charge	B1
(b)	$E = Q/(4\pi\varepsilon_0 r^2)$	C1
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge = 1.5×10^{-7} C	A1
(c)	charge (= $Q\,[52/26]^2$) = $4Q$	C1
	additional charge = 3Q	A1

183. 9702_m17_MS_42 Q: 6

	Answer	Marks
(a)	similarity: lines are radial / greater separation of lines with increased distance from the sphere	B1
	difference: gravitational lines directed towards sphere and electric lines directed away from sphere	B1
(b)(i)	$E = Q / 4\pi\varepsilon_0 r^2$ or $E = kQ / r^2$ with k defined / substituted in	C1
	$4.1 \times 10^{-5} = [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.025^2)] - [Q / (4\pi \times 8.85 \times 10^{-12} \times 0.075^2)]$	C1
	$Q = 3.2 \times 10^{-18}$ C	A1
(b)(ii)	smooth curve with gradient decreasing starting at $(0, 4.1 \times 10^{-5})$ to d-axis at (2.5, 0)	B1
	smooth curve with gradient increasing from (2.5, 0) ending at $(5, -4.1 \times 10^{-5})$	B1
(b)(iii)	acceleration decreases (to zero at mid-point)	B1
	then acceleration increases in the opposite direction / increasing negative acceleration	B1

184. 9702_s19_MS_42 Q: 6

	Answer	Marks
(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity	B1
(b)	straight line with non-zero gradient from $x = 0$ to $x = d$	B1
	line with gradient of constant sign and end-points between which $\Delta V = V_0$ and $\Delta x = d$	B1
	line passes through $(d, 0)$ and $(0, +V_0)$ with negative gradient throughout	B1
(c)	V constant (and non-zero) from $0 \rightarrow R$ and from $(D - R) \rightarrow D$	B1
	equal (non-zero) values of (magnitude of) V at R and $(D - R)$.	B1
	curve (with a minimum) from R to $(D - R)$ with V always positive	B1
	minimum at mid-point of curve	B1

185. 9702_w19_MS_42 Q: 9

	Answer	Marks
(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity	B1
(b)(i)	energy $= 4.8 \times 1.60 \times 10^{-13}$ $= 7.7 \times 10^{-13}$ J	A1
(b)(ii)	$E_P = Qq / 4\pi\varepsilon_0 d$	C1
	$Q = 79e$ **and** $q = 2e$	C1
	$7.68 \times 10^{-13} = (79 \times 2 \times \{1.60 \times 10^{-19}\}^2 / (4\pi \times 8.85 \times 10^{-12} \times d)$	C1
	$d = 4.7 \times 10^{-14}$ m	A1
(c)	(diameter must be) less than/equal to 10^{-13} or 10^{-14} m	B1

186. 9702_m18_MS_42 Q: 7

	Answer	Marks
(a)	work done per unit charge	B1
	(work done) moving positive charge from infinity (to the point)	B1
(b)(i)	potential always same sign / potential is always positive so same sign of charge	B1

	Answer	Marks
(b)(ii)	1 *from x = 12 cm to x = 25 cm:* speed increases and *from x = 27 cm to x = 31 cm*: speed decreases	B1
	(*from x = 12 cm to x = 25 cm:* speed increases) at decreasing rate or (*from x = 27 cm to x = 31 cm*: speed decreases) at increasing rate	B1
	at x = 26 cm: speed maximum	B1
	at 32 cm: speed still decreasing	B1
	2 $q\Delta V = \frac{1}{2}mv^2$ $3.2 \times 10^{-19} \times (2.14 - 1.43) \times 10^4 = \frac{1}{2} \times 6.6 \times 10^{-27} \times v^2$ $v^2 = 6.88 \times 10^{11}$	C1
	$v = \mathbf{8.3 \times 10^5}$ m s^{-1} (8.30)	A1

187. 9702_w18_MS_41 Q: 6

	Answer	Marks
(b)(ii)	(at $x = 0.40$ cm), potential $= (-) 75 \times 0.40 / 1.2$ $(= (-) 25$ V)	C1
	$\frac{1}{2}mv^2 = qV$ $\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$	C1
	or	
	$a = Vq/dm$ **and** $v^2 = 2as$	(C1)
	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$	(C1)
	$v = 4.9 \times 10^4$ m s^{-1}	A1

188. 9702_w18_MS_42 Q: 6

	Answer	Marks
(a)(i)	work done per unit charge	**B1**
	work done moving positive charge from infinity (to the point)	**B1**
(a)(ii)	field strength = potential gradient	**M1**
	negative sign included **or** directions discussed	**A1**
(b)	horizontal straight lines, at non-zero potential, within the spheres	**B1**
	magnitude of potential greater at surface of sphere A than at surface of sphere B	**B1**
	concave curve between A and B, with a minimum nearer to B	**B1**
	lines show *V* positive all the way from 0 to *D*	**B1**

189. 9702_w18_MS_43 Q: 6

	Answer	Marks
(a)(i)	work done per unit charge	**B1**
	work done moving positive charge from infinity (to the point)	**B1**
(a)(ii)	field strength = potential gradient	**M1**
	'–' sign included **or** directions discussed	**A1**
(b)(i)	gain in kinetic energy (= loss in potential energy) = charge × p.d. **or** $qV = ½mv^2$	**M1**
	so *v* is independent of separation (because separation not in expressions)	**A1**

	Answer	Marks
(b)(ii)	(at x = 0.40 cm), potential = (–) 75 × 0.40 / 1.2 (= (–) 25 V)	C1
	$½mv^2 = qV$ $½ \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 25$	C1
	or	
	$a = Vq/dm$ **and** $v^2 = 2as$	(C1)
	$v^2 = (2 \times 75 \times 2 \times 1.60 \times 10^{-19} \times 0.40 \times 10^{-2}) / (1.2 \times 10^{-2} \times 4 \times 1.66 \times 10^{-27})$	(C1)
	$v = 4.9 \times 10^4$ m s^{-1}	A1

190. 9702_s17_MS_42 Q: 6

	Answer	Marks
(a)	force proportional to product of charges and inversely proportional to the square of the separation	M1
	reference to point charges	A1
(b)(i)	(near to each sphere,) fields are in opposite directions **or** point (between spheres) where fields are equal and opposite **or** point (between spheres) where field strength is zero	M1
	so same (sign of charge)	A1
(b)(ii)	(at x = 5.0 cm,) $E = 3.0 \times 10^3$ V m^{-1} **and** $a = qE/m$	C1
	$E = (1.60 \times 10^{-19} \times 3.0 \times 10^3) / (1.67 \times 10^{-27})$	C1
	$= 2.9 \times 10^{11}$ m s^{-2}	A1
(c)	field strength or E is potential gradient **or** field strength is rate of change of (electric) potential	M1
	(field strength) maximum at x = 6 cm	A1

191. 9702_s17_MS_43 Q: 5

	Answer	Marks
(a)	(loss in) kinetic energy of α-particle = $Qq / 4\pi\varepsilon_0 r$ **or** $7.7 \times 10^{-13} = Qq / 4\pi\varepsilon_0 r$	C1
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$	M1
	$r = 4.7 \times 10^{-14}$ m r is closest distance of approach so radius less than this	A1
(b)	force = $Qq / 4\pi\varepsilon_0 r^2 = 4u \times a$	C1
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$	C1
	$a = 2.5 \times 10^{27}$ m s^{-2}	A1
(c)	so that single interactions between nucleus and α-particle can be studied **or** so that multiple deflections with nucleus do not occur	B1

192. 9702_w17_MS_42 Q: 6

	Answer	Marks
(a)	electric field lines are radial/normal to surface (of sphere)	B1
	electric field lines appear to originate from centre (of sphere)	B1
(b)(i)	tangent drawn at x = 6.0 cm and gradient calculation attempted	C1
	$E = 9.0 \times 10^4\,\text{NC}^{-1}$ (*1 mark if in range ±1.2; 2 marks if in range ±0.6*)	A2
	or	
	correct pair of values of V and x read from curved part of graph and substituted into $V = q/4\pi\varepsilon_0 x$	(C1)
	to give $q = 3.6 \times 10^{-8}\,\text{C}$	(C1)
	(then $E = q/4\pi\varepsilon_0 x^2$ and x = 6 cm gives) $E = 9.0 \times 10^4\,\text{NC}^{-1}$	(A1)
	or	
	($E = q/4\pi\varepsilon_0 x^2$ and $V = q/4\pi\varepsilon_0 x$ and so) $E = V/x$	(C1)
	giving $E = 5.4 \times 10^3/0.060$	(C1)
	$= 9.0 \times 10^4\,\text{NC}^{-1}$	(A1)
(b)(ii)	(R =) 2.5 cm	B1
	potential inside a conductor is constant **or** field strength inside a conductor zero (so gradient is zero)	B1

193. 9702_w16_MS_41 Q: 5

(a) in an electric field, charges (in a conductor) would move — B1

no movement of charge so zero field strength
or
charge moves until $F = 0$ / $E = 0$ — B1 [2]

or

charges in metal do not move — (B1)
no (resultant) force on charges so no (electric) field — (B1)

(b) at P, $E_A = (3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2]$ $(= 10.79\,\text{N C}^{-1})$ — M1

at P, $E_B = (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2]$ $(= 10.79\,\text{N C}^{-1})$ — M1

or

$(3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2] = 0$
or
$(3.0 \times 10^{-12}) / [4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12}) / [4\pi\varepsilon_0(10 \times 10^{-2})^2]$ — (M2)

fields due to charged spheres are (equal and) opposite in direction, so $E = 0$ — A1 [3]

(c) potential $= 8.99 \times 10^9 \{(3.0 \times 10^{-12}) / (5.0 \times 10^{-2}) + (12 \times 10^{-12}) / (10 \times 10^{-2})\}$ — C1

$= 1.62\,\text{V}$ — A1 [2]

(d) $\frac{1}{2}mv^2 = qV$

$E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2$ — C1

$qV = 47 \times 1.60 \times 10^{-19} \times 1.62$ — C1

$v^2 = 1.37 \times 10^8$

$v = 1.2 \times 10^4\,\text{m s}^{-1}$ — A1 [3]

194. 9702_w16_MS_42 Q: 6

(a) $E = 0$ *or* $E_A = (-)E_B$ (at $x = 11$ cm) — B1

$Q_A / x^2 = Q_B / (20 - x)^2 = 11^2 / 9^2$ — C1

Q_A / Q_B or ratio $= 1.5$ — A1 [3]

or

$E \propto Q$ because r same *or* $E = Q / 4\pi\varepsilon_0 r^2$ and r same — (B1)

$Q_A / Q_B = 48 / 32$ — (C1)

Q_A / Q_B or ratio $= 1.5$ — (A1)

(b) (i) for max. speed, $\Delta V = (0.76 - 0.18)$ V or $\Delta V = 0.58$ V C1

$q\Delta V = \frac{1}{2}mv^2$

$2 \times (1.60 \times 10^{-19}) \times 0.58 = \frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2$ C1

$v^2 = 5.59 \times 10^7$

$v = 7.5 \times 10^3\,\text{m s}^{-1}$ A1 [3]

(ii) $\Delta V = 0.22$ V C1

$2 \times (1.60 \times 10^{-19}) \times 0.22 = \frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2$

$v^2 = 2.12 \times 10^7$

$v = 4.6 \times 10^3\,\text{m s}^{-1}$ A1 [2]

195. 9702_w16_MS_43 Q: 5

(a) in an electric field, charges (in a conductor) would move B1

no movement of charge so zero field strength
or
charge moves until $F = 0$ / $E = 0$ B1 [2]

or

charges in metal do not move (B1)
no (resultant) force on charges so no (electric) field (B1)

(b) at P, $E_A = (3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2]$ $(= 10.79\,\text{N C}^{-1})$ M1

at P, $E_B = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]$ $(= 10.79\,\text{N C}^{-1})$ M1

or

$(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2] = 0$
or
$(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]$ (M2)

fields due to charged spheres are (equal and) opposite in direction, so $E = 0$ A1 [3]

(c) potential $= 8.99 \times 10^9\,\{(3.0 \times 10^{-12})/(5.0 \times 10^{-2}) + (12 \times 10^{-12})/(10 \times 10^{-2})\}$ C1

$= 1.62\,\text{V}$ A1 [2]

(d) $\frac{1}{2}mv^2 = qV$

$E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2$ C1

$qV = 47 \times 1.60 \times 10^{-19} \times 1.62$ C1

$v^2 = 1.37 \times 10^8$

$v = 1.2 \times 10^4\,\text{m s}^{-1}$ A1 [3]

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Electric Field

Q.No	Answers
1	**A**
2	**A**
3	**B**
4	**B**
5	**C**
6	**D**
7	**B**
8	**D**
9	**B**
10	**D**
11	**B**
12	**D**
13	**A**
14	**A**
15	**D**
16	**C**
17	**D**
18	**D**
19	**C**
20	**A**
21	**A**
22	**C**
23	**B**
24	**A**
25	**A**
26	**B**
27	**C**
28	**A**
29	**D**
30	**A**
31	**B**
32	**C**
33	**A**
34	**D**
35	**B**
36	**A**
37	**B**
38	**A**
39	**D**
40	**B**
41	**D**
42	**B**
43	**A**
44	**C**
45	**D**
46	**D**
47	**D**
48	**D**
49	**A**
50	**C**
51	**C**
52	**C**
53	**A**
54	**D**
55	**A**
56	**C**
57	**A**
58	**C**
59	**D**
60	**B**
61	**C**
62	**A**
63	**A**
64	**D**
65	**B**
66	**A**
67	**A**
68	**A**
69	**C**
70	**D**
71	**A**
72	**B**
73	**D**
74	**A**
75	**C**
76	**A**
77	**C**
78	**D**
79	**C**
80	**C**
81	**A**
82	**A**
83	**C**
84	**D**
85	**C**
86	**B**
87	**B**
88	**B**
89	**A**
90	**A**
91	**B**
92	**D**
93	**D**
94	**A**
95	**C**
96	**D**
97	**D**
98	**C**
99	**B**
100	**D**
101	**D**
102	**A**
103	**C**
104	**A**
105	**A**
106	**C**
107	**B**
108	**A**
109	**A**
110	**D**
111	**C**
112	**C**
113	**B**
114	**D**
115	**D**
116	**B**
117	**B**
118	**B**

Q1.

4	(a)		field causes forces on the electrons ..... M1 and the nucleus in opposite directions ..... A1 (field causes) electrons (to be) stripped off the atom..... B1	[3]
	(b)	(i)	$E = Q/4\pi\varepsilon_0 r^2$ ..... C1 $20 \times 10^3 \times 10^2 = Q/(4\pi \times 8.85 \times 10^{-12} \times 0.21^2$ ..... C1 charge = 9.8×10^{-6} C A1	[3]

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		(ii)	$V = Q/4\pi\varepsilon_0 r$ $= (9.8 \times 10^{-6})/(4\pi \times 8.85 \times 10^{-12} \times 0.21)$ ..... C1 $= 4.2 \times 10^5$ V..... A1	[2]
	(c)		e.g. sphere not smooth, humid air, etc B1	[1]

Q2.

1	(a)		charge is quantised/enabled electron charge to be measured B1	[1]
	(b)		all are (approximately) $n \times (1.6 \times 10^{-19}$ C) so $e = 1.6 \times 10^{-19}$ C (allow 2 sig. fig. only *summing charges and dividing ten, without explanation scores 1/2* Total	M1 A1 [2] [3]

Q3.

5	(a)	field strength = potential gradient [- sign not required] [allow $E = \Delta V/\Delta x$ but not $E = V/d$]	B1 [1]
	(b)	No field for $x < r$ for $x > r$, curve in correct direction, not going to zero discontinuity at $x = r$ (vertical line required)	B1 B1 B1 [3]

Q4.

5 (a) (i) force per unit positive charge (ratio idea essential) B1 [1]

(ii) $E = Q / 4\pi\varepsilon_0 r^2$ M1
ε_0 being the permittivity of free space A1 [2]

(b) (i) $2.0 \times 10^6 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.35^2)$ C1
$Q = 2.7 \times 10^{-5}$ C A1 [2]

(ii) $V = (2.7 \times 10^{-5}) / (4\pi \times 8.85 \times 10^{-12} \times 0.35)$ C1
$= 7.0 \times 10^5$ V A1 [2]

(c) electrons are stripped off the atoms B1
electrons and positive ions move in opposite directions,
(giving rise to a current) B1 [2]

Q5.

3 (a) field strength = potential gradient M1
correct sign OR directions discussed A1 [2]

(b) area is 21.2 $cm^2 \pm 0.4$ cm^2 C2
(if outside ± 0.4 cm^2 but within ± 0.8 cm^2, allow 1 mark)
1.0 cm^2 represents ($1.0 \times 10^{-2} \times 2.5 \times 10^3$ =) 25 V C1
potential difference = 530 V A1 [4]

(c) $\frac{1}{2}mv^2 = qV$
$\frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 1.6 \times 10^{-19} \times 530$ C1
$v = 1.37 \times 10^7$ ms^{-1} A1 [2]

(d) (i) $d = 0$ B1 [1]

(ii) acceleration decreases then increases B1
some quantitative analysis (e.g. minimum at 4.0 cm) B1 [2]
(any suggestion that acceleration becomes zero or that there is a deceleration scores 0/2)

Q6.

4 (a) work done moving unit positive charge M1
from infinity to the point A1 [2]

(b) (i) x = 18 cm A1 [1]

(ii) $V_A + V_B = 0$ C1
$(3.6 \times 10^{-9}) / (4\pi\varepsilon_0 \times 18 \times 10^{-2}) + q / (4\pi\varepsilon_0 \times 12 \times 10^{-2}) = 0$ C1
$q = -2.4 \times 10^{-9}$ C A1 [3]
(use of $V_A = V_B$ giving 2.4×10^{-9} C scores one mark)

(c) field strength = (–) gradient of graph B1
force = charge × gradient / field strength *or* *force ∝ gradient* B1
force largest at x = 27 cm B1 [3]

Q7.

4	(a)	ability to do work	B1	
		as a result of the position/shape, etc. of an object	B1	[2]
	(b) (i) 1	$\Delta E_{gpe} = GMm / r$	C1	
		$= (6.67 \times 10^{-11} \times \{2 \times 1.66 \times 10^{-27}\}^2) / (3.8 \times 10^{-15})$	C1	
		$= 1.93 \times 10^{-49}$ J	A1	[3]
	2	$\Delta E_{epe} = Qq / 4\pi\varepsilon_0 r$	C1	
		$= (1.6 \times 10^{-19})^2 / (4\pi \times 8.85 \times 10^{-12} \times 3.8 \times 10^{-15})$	C1	
		$= 6.06 \times 10^{-14}$ J	A1	[3]
	(ii)	idea that $2E_K = \Delta E_{epe} - \Delta E_{gpe}$	B1	
		$E_K = 3.03 \times 10^{-14}$ J		
		$= (3.03 \times 10^{-14}) / 1.6 \times 10^{-13}$	M1	
		= 0.19 MeV	A0	[2]
	(iii)	fusion may occur / may break into sub-nuclear particles	B1	[1]

Q8.

4	(a)	force $= q_1q_2 / 4\pi\varepsilon_0x^2$	C1	
		$= (6.4 \times 10^{-19})^2 / (4\pi \times 8.85 \times 10^{-12} \times \{12 \times 10^{-6}\}^2)$	C1	
		$= 2.56 \times 10^{-17}$ N	A1	[3]
	(b)	potential at P is same as potential at Q	B1	
		work done $= q\Delta V$	M1	
		$\Delta V = 0$ so zero work done	A0	[2]
	(c)	at midpoint, potential is $2 \times (6.4 \times 10^{-19}) / (4\pi\varepsilon_0 \times 6 \times 10^{-6})$	C1	
		at P, potential is $(6.4 \times 10^{-19}) / (4\pi\varepsilon_0 \times 3 \times 10^{-6}) + (6.4 \times 10^{-19}) / (4\pi\varepsilon_0 \times 9 \times 10^{-6})$	C1	
		change in potential $= (6.4 \times 10^{-19}) / (4\pi\varepsilon_0 \times 9 \times 10^{-6})$		
		energy $= 1.6 \times 10^{-19} \times (6.4 \times 10^{-19}) / (4\pi\varepsilon_0 \times 9 \times 10^{-6})$	C1	
		$= 1.0 \times 10^{-22}$ J	A1	[4]

Q9.

4	(a)	work done in bringing unit positive charge	M1	
		from infinity (to that point)	A1	[2]
	(b) (i)	field strength is potential gradient	B1	[1]
	(ii)	field strength proportional to force (on particle Q)	B1	
		potential gradient proportional to gradient of (potential energy) graph	B1	
		so force is proportional to the gradient of the graph	A0	[2]

(c) energy = $5.1 \times 1.6 \times 10^{-19}$ (J) C1
potential energy = $Q_1Q_2 / 4\pi\varepsilon_0 r$ C1
$5.1 \times 1.6 \times 10^{-19} = (1.6 \times 10^{-19})^2 / 4\pi \times 8.85 \times 10^{-12} \times r$ C1
$r = 2.8 \times 10^{-10}$ m A1 [4]

(d) (i) work is got out as x decreases M1
so opposite sign A1 [2]

(ii) energy would be doubled B1
gradient would be increased B1 [2]

Q10.

5 (a) force per unit positive charge acting on a stationary charge B1 [1]

(b) (i) $E = Q / 4\pi\varepsilon_0 r^2$ C1
$Q = 1.8 \times 10^4 \times 10^2 \times 4\pi \times 8.85 \times 10^{-12} \times (25 \times 10^{-2})^2$ M1
$Q = 1.25 \times 10^{-5}$ C $= 12.5\,\mu$C A0 [2]

(ii) $V = Q / 4\pi\varepsilon_0 r$
$= (1.25 \times 10^{-5}) / (4\pi \times 8.85 \times 10^{-12} \times 25 \times 10^{-2})$ C1
$= 4.5 \times 10^5$ V A1 [2]
(Do not allow use of V = Er unless explained)

Q11.

4 (a) (i) as r decreases, energy decreases/work got out (due to) M1
attraction so point mass is negatively charged A1 [2]

(ii) electric potential energy = charge × electric potential B1
electric field strength is potential gradient B1
field strength = gradient of potential energy graph/charge A0 [2]

(b) tangent drawn at (4.0, 14.5) B1
gradient = 3.6×10^{-24} A2
(for < ±0.3 allow 2 marks, for < ±0.6 allow 1 mark)
field strength= $(3.6 \times 10^{-24}) / (1.6 \times 10^{-19})$
$= 2.3 \times 10^{-5}$ V m^{-1} *(allow ecf from gradient value)* A1 [4]
(one point solution for gradient leading to 2.3×10^{-5} Vm^{-1} scores 1 mark only)

Q12.

4	(a)	work done moving unit positive charge from infinity (to the point)		M1 A1	[2]
	(b)	(gain in) kinetic energy = change in potential energy $\frac{1}{2}mv^2 = qV$ leading to $v = (2Vq/m)^{\frac{1}{2}}$		B1 B1	[2]
	(c)	*either*	$(2.5 \times 10^5)^2 = 2 \times V \times 9.58 \times 10^7$ $V = 330\,V$ this is less than 470 V and so 'no'	C1 M1 A1	[3]
		or	$v = (2 \times 470 \times 9.58 \times 10^7)$ $v = 3.0 \times 10^5\,m\,s^{-1}$ this is greater than $2.5 \times 10^5\,m\,s^{-1}$ and so 'no'	(C1) (M1) (A1)	
		or	$(2.5 \times 10^5)^2 = 2 \times 470 \times (q/m)$ $(q/m) = 6.6 \times 10^7\,C\,kg^{-1}$ this is less than $9.58 \times 10^7\,C\,kg^{-1}$ and so 'no'	(C1) (M1) (A1)	

Q13.

4	(a)	(i)	$V = q / 4\pi\varepsilon_0 R$	B1	[1]
		(ii)	(capacitance is) ratio of charge and potential or q/V $C = q/V = 4\pi\varepsilon_0 R$	M1 A0	[1]
	(b)	(i)	$C = 4\pi \times 8.85 \times 10^{-12} \times 0.45$ $= 50$ pF	C1 A1	[2]
		(ii)	either energy = $\frac{1}{2}\,CV^2$ or energy = $\frac{1}{2}\,QV$ and $Q = CV$ energy of spark = $\frac{1}{2} \times 50 \times 10^{-12}\,\{(9.0 \times 10^5)^2 - (3.6 \times 10^5)^2\}$ $= 17$ J	C1 C1 A1	[3]

Q14.

2	(a)	(i)	grav. pot. energy = GM_1M_2/R energy = $\{6.67 \times 10^{-11} \times 197 \times 4 \times (1.66 \times 10^{-27})^2\}/9.6 \times 10^{-15}$ $= 1.51 \times 10^{-47}$ J	1 1 1	**[3]**
		(ii)	elec. pot. energy = $Q_1Q_2/4\pi\,\varepsilon_0 R$ energy = $\{79 \times 2 \times (1.6 \times 10^{-19})^2\}/4\pi \times 8.85 \times 10^{-12} \times 9.6 \times 10^{-15}$ $= 3.79 \times 10^{-12}$ J	1 1 1	**[3]**
			*(For the substitution, -1 each error or omission to max 2 in **(i)** and in **(ii)**)*		
	(b)		electric potential <u>energy</u> >> gravitational potential <u>energy</u>	1	**[1]**
	(c)		*either* 6 MeV = 9.6×10^{-13} J or 3.79×10^{-12} J = 24 MeV not enough energy to get close to the nucleus	1 1	**[2]**

Q15.

4 (a) (i) *either* lines directed away from sphere
or lines go from positive to negative
or line shows direction of force on positive charge M1
so positively charged ..... A1 [2]

(ii) *either* all lines (appear to) radiate from centre
or all lines are normal to surface of sphere ..... B1 [1]

(b) tangent to curve B1
in correct position and direction ..... B1 [2]

(c) (i) $V = (0.76 \times 10^{-9}) / (4\pi \times 8.85 \times 10^{-12} \times 0.024)$ C1
$= 285$ V ..... A1 [2]

(ii) negative charge is induced on (inside of) box M1
formula applies to isolated (point) charge
OR less work done moving test charge from infinity A1
so potential is lower ..... A1 [3]

(d) *either* gravitational field is <u>always</u> attractive
or field lines must be directed towards both box and sphere ..... B1 [1]

Q16.

5 (a) work done per / on unit positive charge M1
moving charge from infinity to the point ..... A1 [2]

(b) (i) α-particle and gold nucleus repel each other B1
<u>all</u> kinetic energy of α-particle converted into electric potential energy ..... B1 [2]

(ii) **1** potential energy $= (79 \times 2 \times \{1.6 \times 10^{-19}\}^2) / (4\pi \times 8.85 \times 10^{-12} \times d)$ C1
kinetic energy $= 4.8 \times 1.6 \times 10^{-13} = 7.68 \times 10^{-13}$ J C1
equating to give $d = 4.7 \times 10^{-14}$ m ..... A1 [3]

(ii) **2** $F = Qq / 4\pi\varepsilon_0 d \times 1 / d = 7.68 \times 10^{-13} \times 1 / (4.7 \times 10^{-14})$ C1
$= 16$ N ..... A1 [2]

[Total: 9]

Q17.

4	(a)	(i)	zero field (strength) inside spheres	B1	[1]
		(ii)	*either* field strength is zero		
			or the fields are in opposite directions	M1	
			at a point between the spheres	A1	[2]
	(b)	(i)	field strength is (–) potential gradient *(not V/x)*	B1	[1]
		(ii)	**1.** field strength has maximum value	B1	
			at x = 11.4 cm	B1	[2]
			2. field strength is zero	B1	
			either at x = 7.9 cm *(allow ±0.3 cm)*		
			or at 0 to 1.4 cm *or* 11.4 cm to 12 cm	B1	[2]

Q18.

3	(a)	(i)	(tangent to line gives) direction of force on a (small test) mass	B1	[1]
		(ii)	(tangent to line gives) direction of force on a (small test) charge	M1	
			charge is positive	A1	[2]
	(b)		similarity:		
			e.g. radial fields		
			lines normal to surface		
			greater separation of lines with increased distance from sphere		
			field strength $\propto$ 1 / (distance to centre of sphere)^2		
			(*allow any sensible answer*)	B1	
			difference:		
			e.g. gravitational force (always) towards sphere	B1	
			electric force direction depends on sign of charge on sphere / towards or away from sphere	B1	
			e.g. gravitational field/force is attractive	(B1)	
			electric field/force is attractive or repulsive	(B1)	
			(*allow any sensible comparison*)		[3]
	(c)		gravitational force = $1.67 \times 10^{-27} \times 9.81$		
			$= 1.6 \times 10^{-26}$ N	A1	
			electric force = $1.6 \times 10^{-19} \times 270 / (1.8 \times 10^{-2})$	C1	
			$= 2.4 \times 10^{-15}$ N	A1	
			electric force very much greater than gravitational force	B1	[4]

Q19.

4	(a) (i)	force proportional to product of (two) charges and inversely proportional to square of separation	M1	
		reference to point charges	A1	[2]
	(ii)	$F = 2 \times (1.6 \times 10^{-19})^2 / \{4\pi \times 8.85 \times 10^{-12} \times (20 \times 10^{-6})^2\}$	C1	
		$= 1.15 \times 10^{-18}$ N	A1	[2]
	(b) (i)	force per unit charge on *either* a stationary charge *or* a positive charge	M1 A1	[2]
	(ii)	1. electric field is a vector quantity electric fields are in opposite directions charges repel *Any two of the above, 1 each*	B2	[2]
		2. graph: line always between given lines	M1	
		crosses *x*-axis between 11.0 μm and 12.3 μm	A1	
		reasonable shape for curve	A1	[3]

Q20.

3	(a)	work done bringing unit positive charge from infinity (to the point)	M1 A1	[2]
	(b) (i)	*either* both potentials are positive/same sign	M1	
		so same sign	A1	[2]
		or gradients are positive & negative (so fields in opposite directions)	(M1)	
		so same sign	(A1)	
	(ii)	the individual potentials are summed	B1	[1]
	(iii)	allow value of *x* between 10 nm and 13 nm	A1	[1]
	(iv)	$V = 0.43$ V (*allow 0.42 V → 0.44 V*)	M1	
		energy $= 2 \times 1.6 \times 10^{-19} \times 0.43$	A1	
		$= 1.4 \times 10^{-19}$ J	A1	[3]

Q21.

5	(a)	graph: straight line at constant potential = V_0 from $x = 0$ to $x = r$	B1	
		curve with decreasing gradient	M1	
		passing through $(2r, 0.50V_0)$ and $(4r, 0.25V_0)$	A1	[3]
	(b)	graph: straight line at $E = 0$ from $x = 0$ to $x = r$	B1	
		curve with decreasing gradient from (r, E_0)	M1	
		passing through $(2r, ¼E_0)$	A1	[3]
		(*for 3rd mark line must be drawn to x = 4r and must not touch x-axis*)		

Q22.

4 (a) (i) $F_E = Q_1Q_2/4\pi\varepsilon_0 r^2$ C1

$= 8.99 \times 10^9 \times (1.6 \times 10^{-19})^2 / (2.0 \times 10^{-15})^2$

$= 58$ N A1 [2]

(ii) $F_G = Gm_1m_2/r^2$ C1

$= 6.67 \times 10^{-11} \times (1.67 \times 10^{-27})^2 / (2.0 \times 10^{-15})^2$

$= 4.7 \times 10^{-35}$ N A1 [2]

(b) (i) force of repulsion (much) greater than force of attraction B1

must be some other force of attraction M1

to hold nucleus together A1 [3]

(*Do not allow if $F_G > F_E$ in* ***(a)*** *or one of the forces not calculated in* ***(a)***)

(ii) outside nucleus there is repulsion between protons B1

either attractive force must act only in nucleus

or if not short range, all nuclei would stick together B1 [2]

Q23.

5 (a) work done in moving unit positive charge M1

from infinity (to the point) A1 [2]

(b) (i) inside the sphere, the potential would be constant B1 [1]

(ii) for point charge, Vx is constant B1

co-ordinates clear and determines two values of Vx at least 4 cm apart M1

conclusion made clear A1 [3]

(c) $q = 4\pi\varepsilon_0 Vx$

$q = 4\pi \times 8.85 \times 10^{-12} \times 180 \times 1.0 \times 10^{-2}$ M1

$= 2.0 \times 10^{-10}$ C A1 [2]

Q24.

5 **(a)** work done / energy in moving unit positive charge from infinity (to the point) — M1 A1 [2]

(b) **(i)** $V = q / 4\pi\varepsilon_0 r$
at 16 kV, $q = 3.0 \times 10^{-8}$ C

$r = (3.0 \times 10^{-8}) / (4\pi \times 8.85 \times 10^{-12} \times 16 \times 10^{3})$ — C1
$= 1.69 \times 10^{-2}$ m (*allow 2 s.f.*) — A1 [2]
(*allow any answer which rounds to 1.7 × 10^{-2}*)

(ii) energy is / represented by area 'below' line — C1
energy $= \frac{1}{2} qV$
$= \frac{1}{2} \times 24 \times 10^{3} \times 4.5 \times 10^{-8}$ — C1
$= 5.4 \times 10^{-4}$ J — A1 [3]

(c) $V = q / 4\pi\varepsilon_0 r$ and $E = q / 4\pi\varepsilon_0 r^2$ giving $Er = V$ — B1
$2.0 \times 10^{6} \times 1.7 \times 10^{-2} = V$ — C1
$V = 3.4 \times 10^{4}$ V — A1 [3]