18. Electric Fields

18.5 Electric potential

Paper 4

Marking Scheme

Q1.

(a)	work done per unit charge	**B1**
	work (done) moving positive charge from infinity (to the point)	**B1**
(b)	*Any three points from*: *Up to 2 points from*: • radius of sphere X is 0.30 m • radius of sphere Y is 0.10 m • radius of X is treble the radius of Y *Up to 2 points from*: • charge on X is positive • charge on Y is positive • spheres X and Y carry charges of the same sign *Up to 1 point from*: • (magnitudes of) charges on the spheres are equal • charges on the spheres have the same magnitude	**B3**
(c)	proton remains at rest (in the position of release)	**M1**
	potential energy of proton is (already) at its minimum **or** (electric) forces (from spheres) on proton are equal and opposite **or** no resultant (electric) force on proton **or** resultant electric field strength (at proton) is zero	**A1**

Q2.

(a)	(electric) field equals (electric) potential gradient	**M1**
	reference to minus sign	**A1**
(b)	• for potential to be zero, one potential must be positive and the other potential must be negative • for potential to be zero, the charges must have opposite sign • for field to be zero, the fields (due to X and Y) must be in opposite directions • for field to be zero, the charges must have the same sign • the signs of the charges cannot (simultaneously) be both the same and opposite (so not possible) *Any three points, 1 mark each*	**B3**
(c)(i)	$V_X = (-)\ Q / 4\pi\varepsilon_0 x$ **and** $V_Y = (-)\ 2Q / 4\pi\varepsilon_0 y$	**C1**
	($V_X + V_Y = 0$ so) $Q / 4\pi\varepsilon_0 x = 2Q / 4\pi\varepsilon_0 y$ leading to $y = 2x$	**A1**

Q3.

(a)	work done per unit charge	**B1**
	work (done on charge) moving positive charge from infinity (to the point)	**B1**
(b)	*Any three points from*: *Up to 2 points from*: • radius of sphere X is 2.0 m • radius of sphere Y is 4.0 m • radius of Y is double the radius of X *Up to 2 points from*: • charge on X is negative • charge on Y is positive • spheres carry opposite charges *Up to 1 point from*: • magnitudes of charges on the spheres are equal	**B3**
(c)	particle is attracted to X or repelled from Y **or** resultant force on particle is towards X / away from Y / to the left	**B1**
	particle accelerates towards X / away from Y / to the left	**B1**
	(magnitude of) acceleration of particle increases	**B1**

Q4.

(a)	work done per unit charge	**B1**
	work done (on charge) in moving positive charge from infinity (to the point)	**B1**
(b)(i)	radius = 0.060 m	**A1**
(b)(ii)	$V = Q / 4\pi\varepsilon_0 x$ $Q = (-)\ 850 \times 4\pi \times 8.85 \times 10^{-12} \times 0.060$ **or** $Q = (-)\ 850 \times 0.060 / 8.99 \times 10^{9}$ (*any correct pair of V and x values from curve*)	**C1**
	$Q = -5.7 \times 10^{-9}$ C	**A1**
(c)(i)	$E_P = Q^2 / 4\pi\varepsilon_0 x$ $= (5.67 \times 10^{-9})^2 / (4\pi \times 8.85 \times 10^{-12} \times 0.46)$	**C1**
	$= 6.3 \times 10^{-7}$ J	**A1**
(c)(ii)	• force is repulsive so spheres move apart • force in direction of motion so speed increases • potential energy converted to kinetic energy so speed increases • force decreases with distance so acceleration decreases • momentum is conserved (at zero) (and masses are equal) so velocities are always equal and opposite *Any three points, 1 mark each*	**B3**

Q5.

(a)	from $x = 0$ to $x = r$: horizontal line at $V = 1.0V_0$	**B1**
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude starting at $(r, 1.0V_0)$	**B1**
	line passing through $(2r, \frac{1}{2}V_0)$ and $(3r, \frac{1}{3}V_0)$	**B1**

Q6.

(b)	change in potential energy = change in kinetic energy **or** $qV = \frac{1}{2}mv^2$	**B1**
	$v = \sqrt{(2qV / m)}$	**A1**

Q7.

(c)(i)	$\frac{1}{2}mv^2 = eV$	**C1**
	$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 1.60 \times 10^{-19} \times 4800$ so $v = 4.1 \times 10^{7}$ m s^{-1}	**A1**

Q8.

(a)	work done per unit charge	**B1**
	(work done in) moving positive charge from infinity	**B1**

Q9.

(a)	work done per unit charge	**B1**
	(work done on charge) moving positive charge from infinity	**B1**
(b)(i)	$(2.0 \times 10^{-9}) / 4\pi\varepsilon_0(4.0 \times 10^{-2}) + Q / 4\pi\varepsilon_0(8.0 \times 10^{-2}) = 0$	**C1**
	$Q = 4.0 \times 10^{-9}$ C	**A1**
	Q given with negative sign	**B1**
(b)(ii)	change = 1200 V	**A1**
(c)	$\frac{1}{2}mv^2 = qV$	**C1**
	$\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 1200$	**C1**
	$v = 3.4 \times 10^5$ m s^{-1}	**A1**

Q10.

(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**

Q11.

(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**

Q12.

(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**
(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)**
	$v = 4.9 \times 10^4\ \text{m s}^{-1}$	**A1**

Q13.

(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**