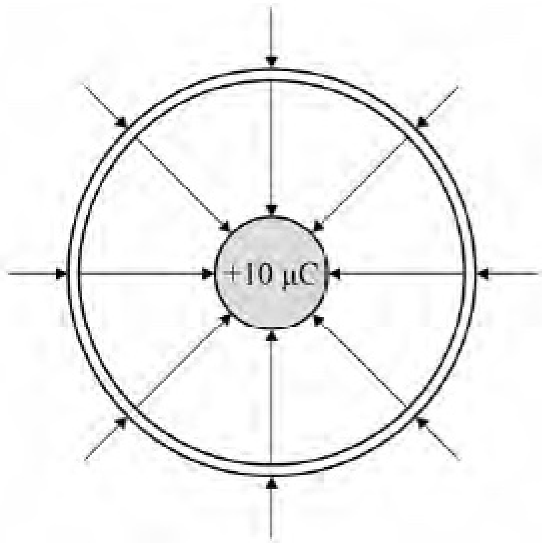
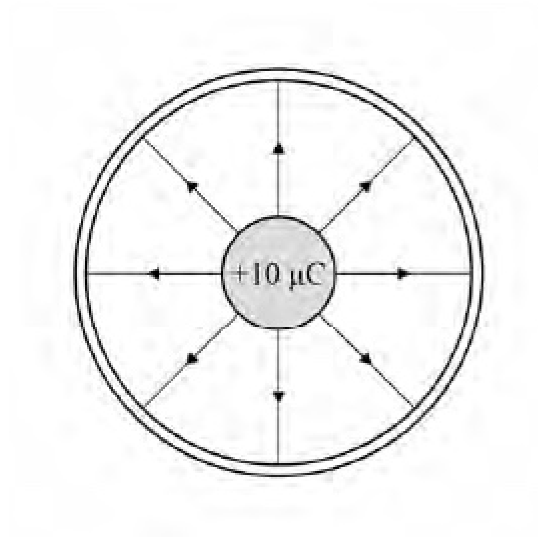
1 A conducting sphere holding a charge of +10 μC is placed centrally inside a second uncharged conducting sphere.

Which diagram shows the electric field lines for the system?

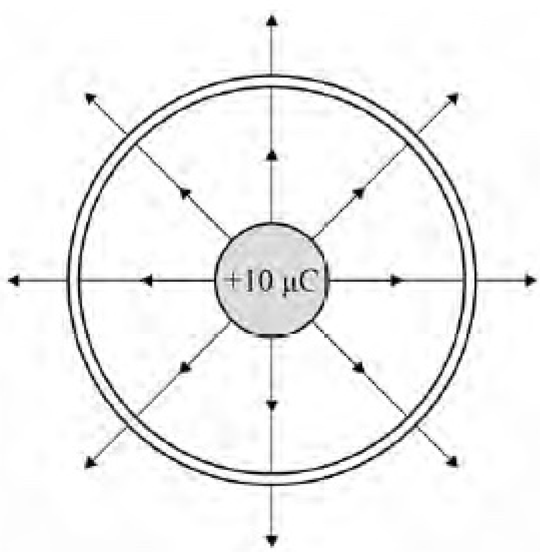
A



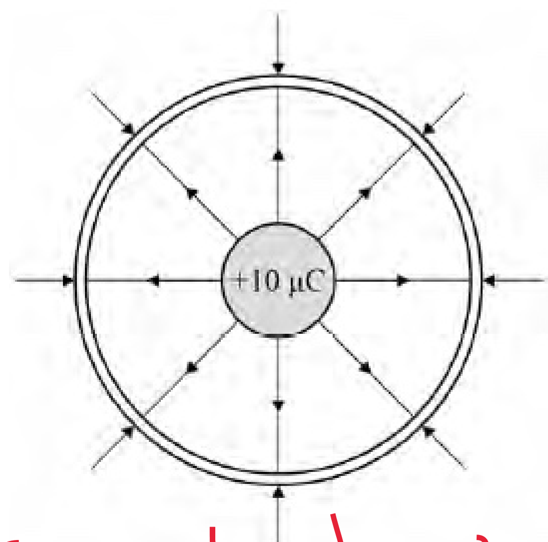
B



C



D



consider how charges in outer sphere move

A ☐

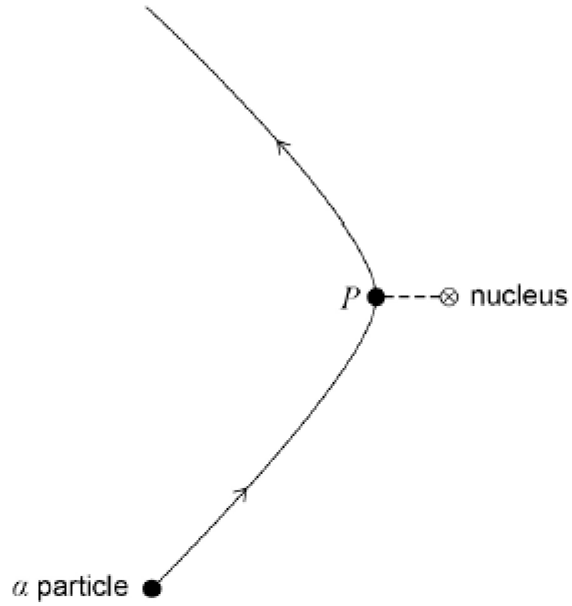
B ☐

C ☐

D ☐

(Total 1 mark)

2 The diagram shows the path of an α particle deflected by the nucleus of an atom. Point P on the path is the point of closest approach of the α particle to the nucleus.



Which of the following statements about the α particle on this path is correct?

A	Its acceleration is zero at P.	⬭
B	Its kinetic energy is greatest at P.	⬭
C	Its potential energy is least at P.	⬭
D	Its speed is least at P.	⬭

(Total 1 mark)

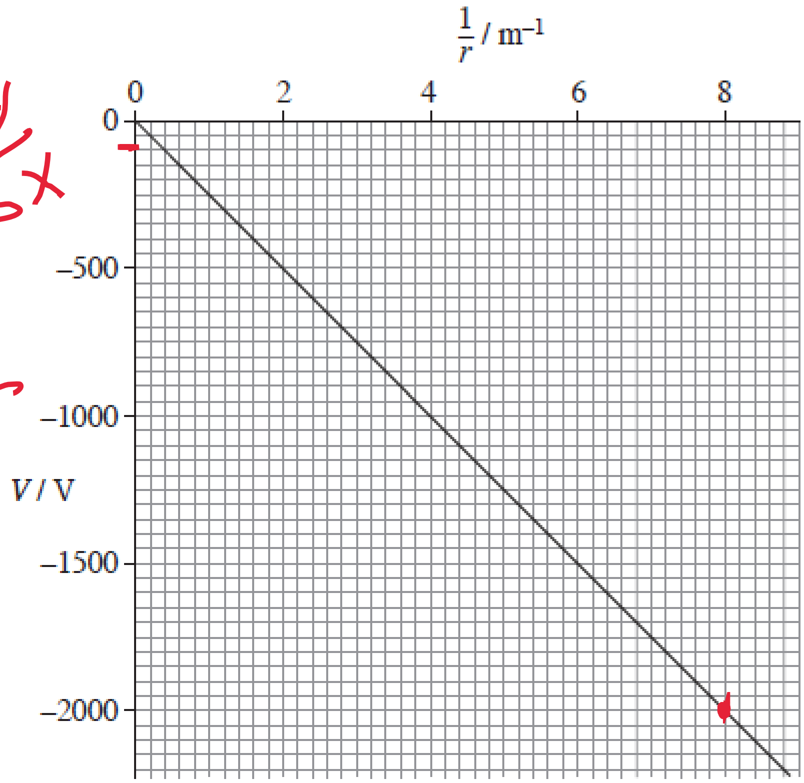
3 (a) State, in words, Coulomb's law.

Force between two point charges is inversely proportional to the separation squared and proportional to the charge multiplied

(2)

(b) The graph shows how the electric potential, V, varies with $\frac{1}{r}$, where r is the distance from a point charge Q.

grad = $\Delta y / \Delta x$ = 2000/8



State what can be deduced from the graph about how V depends on r and explain why all the values of V on the graph are negative.

- $-V \propto \frac{1}{r}$ or V is inversely proportional to 1/r
- at r = ∞ (ie 1/r = 0) the V = 0

(2)

- −ve because charge is −ve so work done to overcome attraction. (the test charge is always +ve)

(c) (i) Use data from the graph to show that the magnitude of Q is about 30 nC.

$V = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r} \Rightarrow Q = Vr \times 4\pi\varepsilon_0 = 2.8\times10^{-8}$ C

≈ 30 nC

(2)

(ii) A +60 nC charge is moved from a point where r = 0.20 m to a point where r = 0.50 m. Calculate the work done.

$\Delta W = Q\Delta V$

$\Delta V = 750$

$r = 2 \Rightarrow \frac{1}{r} = \frac{1}{2} \Rightarrow V = -500$

$\Delta W = 60\times10^{-9} \times 750$

$r = 0.2 \Rightarrow \frac{1}{r} = 5 \Rightarrow V = -1250$

(2)

work done 4.5×10^{-5} J

(iii) Calculate the electric field strength at the point where r = 0.40 m.

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} \leftarrow 28$ nC $= 1600$

electric field strength ____________________ V m^{-1}

(2)

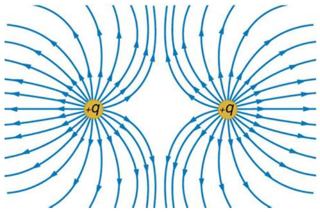
(Total 10 marks)

4 (a) State, in words, Coulomb's law.

As above

(2)

(b) The diagram below shows two point charges of +4.0 nC and +6.0 nC which are 68 mm apart.



like dia but neutral point closer to +4nC, more lines from +6nC

(i) Sketch on the diagram above the pattern of the electric field surrounding the charges.

(3)

(ii) Calculate the magnitude of the electrostatic force acting on the +4.0 nC charge.

$F = \frac{1}{4\pi\varepsilon_0} \frac{4nC \times 6nC}{(68 \times 10^{-3})^2}$

magnitude of force 4.7×10^{-5} N

(2)

(c) (i) Calculate the magnitude of the resultant electric field strength at the mid-point of the line joining the two charges in the diagram above.
State an appropriate unit for your answer.

$E = \frac{1}{4\pi\varepsilon_0} \frac{Q}{r^2}$

Find contribution from each & add with r = 34 mm.

$\frac{1}{4\pi\varepsilon_0 r^2}(Q_6 - Q_4) = 1.5 \times 10^4$

at midpoint 6nC "pushes" left, 4nC push right. ∴ we ~~take~~ the So the contributions to E partially cancel

electric field strength ____________ unit V/m

(4)

(ii) State the direction of the resultant electric field at the mid-point of the line joining the charges.

left

(1)

(Total 12 marks)

Mark schemes

1 **C**

[1]

2 D

[1]

3 (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 $\Delta V = -500 - (-1250) = 750$ (V) ✓

work done $\Delta W (= Q\Delta V) = 60 \times 10^{-9} \times 750$

$= 4.5(0) \times 10^{-5}$ (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:

$\Delta V = \frac{27.8 \times 10^{-9}}{4\pi\varepsilon_0} \times \left(\frac{1}{0.2} - \frac{1}{0.5}\right)$ *(**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 $E = \frac{625 \pm 50}{0.40}$ = 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]

4 (a) force between two (point) charges is proportional to (product of) charges ✓
and inversely proportional to the square of their distance apart ✓

*Formula not acceptable. Accept "charged particles" for charge **s**.*
Accept separation for distance apart.

2

(b) (i) lines with arrows radiating outwards from each charge ✓
more lines associated with 6nC charge than with 4nC ✓
lines start radially and become non-radial with correct curvature further away from each charge ✓ correct asymmetric pattern (with neutral pt closer to 4nC charge) ✓

3 max

(ii) force $\left(=\frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}\right)=\frac{4.0\times10^{-9}\times6.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(68\times10^{-3})^2}$ ✓

= 4.6(7) × 10^{-5} (N) ✓

Treat substitution errors such as 10^{-6}(instead of 10^{-9}) as AE with ECF available.

2

(c) (i) $E_4 = \dfrac{4.0 \times 10^{-9}}{4\pi\varepsilon_0 \times (34 \times 10^{-3})^2}$ (= 3.11×10^4 V m^{-1}) (to the right) ✓

*For both of 1st two marks to be awarded, substitution for **either** or both of E_4 **or** E_6 (or a substitution in an expression for E_6 - E_4) must be shown.*

$E_6 \left(= \dfrac{6.0 \times 10^{-9}}{4\pi\varepsilon_0 \times (34 \times 10^{-3})^2} \right)$ = (4.67×10^4 V m^{-1}) (to the left) ✓

If no substitution is shown, but evaluation is correct for E_4 and E_6, award one of 1 st two marks.

$E_{resultant} = (4.67 - 3.11) \times 10^4 = 1.5(6) \times 10^4$ ✓

Unit: V m^{-1} (or N C^{-1}) ✓

Use of $r = 68 \times 10^{-3}$ is a physics error with no ECF.
Unit mark is independent.

4

(ii) *direction:* towards 4 nC charge **or** to the left ✓

1

[12]