M1.(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 × 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 (= $Q\Delta V$) = $60 \times 10^{-9} \times 750$

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

$\Delta V = \dfrac{27.8\times10^{-9}}{4\pi\varepsilon_0}\times\left(\dfrac{1}{0.2}-\dfrac{1}{0.5}\right)$ *(**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]

M2.D

[1]

M3.A

[1]

M4.B

[1]

M5.D

[1]

M6.(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 $\left(= \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}\right) = \frac{4.0\times10^{-9}\times6.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(68\times10^{-3})^2}$ ✓

$= 4.6(7)\times10^{-5}$ (N) ✓

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

2

(c) (i) $E_4 = \frac{4.0\times10^{-9}}{4\pi\varepsilon_0\times(34\times10^{-3})^2}$ (= 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.*

$E_6 \left(= \frac{6.0\times10^{-9}}{4\pi\varepsilon_0\times(34\times10^{-3})^2}\right)$ = (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.

$E_{resultant} = (4.67 - 3.11)\times10^4 = 1.5(6)\times10^4$ ✓

Unit: V m^{-1} (or N C^{-1}) ✓

Use of $r = 68\times10^{-3}$ is a physics error with no ECF. Unit mark is independent.

4

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

1

[12]

M7. D

[1]

M8. C

[1]

M9. D

[1]

M10. D

[1]

M11. C

[1]

M12. A

[1]

M13. (a) (i) force per unit charge **(1)**
acting on a positive charge **(1)**

(ii) vector **(1)**

3

(b) (i) $F\left(=\frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}\right)=\frac{4.0\times10^{-9}\times8.0\times10^{-9}}{4\pi\times8.85\times10^{-12}\times(80\times10^{-3})^2}$ **(1)**

$=4.5(0)\times10^{-5}$ N **(1)**

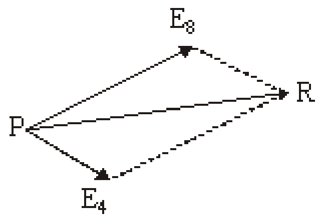
(ii) (use of $V=\frac{Q}{4\pi\varepsilon_0 x}$ gives) $0=\left(\frac{4.0\times10^{-9}}{4\pi\varepsilon_0 x}\right)-\left(\frac{8.0\times10^{-9}}{4\pi\varepsilon_0(80\times10^{-3}-x)}\right)$

or $\frac{4}{x}=\frac{8}{80-x}$ **(1)**

x = 26.7mm **(1)**

4

(c) correct directions for E_4 and E_8 **(1)**
E_8 approx twice as long as E_4 **(1)**
correct direction of resultant R shown **(1)**



3

[10]

M14. D

[1]

M15. D

[1]

M16. A

[1]

M17. D

[1]