M1. C

[1]

M2. (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 (= $Q\Delta V$) = $60 \times 10^{-9} \times 750$

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

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

M3.(a) (i) (Mass change in u=) 1.71×10^{-3} (u)
or (mass Be−7) – (mass He−3) – (mass He−4) seen with numbers

C1

2.84×10^{-30} (kg)
or Converts their mass to kg

Alternative 2nd mark:
Allow conversion of 1.71×10^{-3} (u) to MeV by multiplying by 931 (=1.59 (MeV)) ***seen***

C1

Substitution in $E = mc^2$ *condone their mass* *<u>difference</u> in this sub but must have correct value for c^2 $(3\times10^8)^2$ or 9×10^{16}*

Alternative 3rd mark:
Allow their MeV converted to joules (× 1.6×10^{-13}) ***seen***

C1

2.55×10^{-13} (J) to 2.6×10^{-13} (J)

Alternative 4th mark:

Allow 2.5×10^{-13} (J) for this method

A1 **4**

(ii) Use of *$E = hc / \lambda$* ***ecf***

C1

Correct substitution in rearranged equation with λ *subject* ***ecf***

C1

7.65×10^{-13} (m) to 7.8×10^{-13} (m) ecf

A1 **3**

(b) (i) Use of E_p formula:

C1

Correct charges for the nuclei **<u>and</u>** correct powers of 10

C1

$2.6(3) \times 10^{-13}$ J

A1 **3**

(ii) Uses K*E* = 3 / 2 *kT*: ***or*** *halves KE_T, $KE = 1.3 \times 10^{-13}$ (J)* ***seen ecf***

C1

Correct substitution of data **and** makes T subject **ecf**
Or uses KE_T value **and** divides T by 2

C1

6.35×10^9 (K) or 6.4×10^9 (K) or 6.28×10^9(K) or 6.3×10^9 (K) **ecf**

A1 **3**

(c) (i) Deuteron / deuterium / hydrogen−2

B1

Triton / tritium / hydrogen−3

B1

2

(ii) Electrical heating / electrical discharge / inducing a current in plasma / use of e−m radiation / using radio waves (causing charged particles to resonate)

B1

1

[16]

M4. C

[1]

M5. D

[1]

M6. A

[1]

M7. B

[1]

M8. D

[1]

M9.D

[1]

M10.B

[1]

M11.C

[1]

M12. (a) work done [or energy needed] per unit charge[**or** (change in) electric pe per unit charge] ✓

on [or of] a (small) positive (test) charge ✓

in moving the charge from infinity (to the point) ✓

[**not** from the point to infinity] ✓

3

(b) (i) $V = \frac{Q}{4\pi\varepsilon_0 r}$ gives Q (= $4\pi\varepsilon_0 rV$) = 4π × 8.85 × 10^{-12} × 0.30 × 3.0 ✓

= 1.0 × 10^{-10} (C) ✓

to **2 sf** only ✓

3

(ii) use of $V \propto \frac{1}{r}$ gives $V_M = \frac{V_L}{3}$ ✓ (= (+) 1.0 V)

1

(iii) $E\left(=\frac{Q}{4\pi\varepsilon_0 r^2}\right) = \frac{1.0\times10^{-10}}{4\pi\times8.85\times10^{-12}\times0.60^2}$ ✓ (= 2.50 V m⁻¹)

1

(c) (i) uniformly spaced vertical parallel lines which start and end on plates ✓

relevant lines with arrow(s) pointing only downwards ✓

2

(ii) = 3.3(3) (V m⁻¹) ✓

1

(iii) part (b) is a radial field whilst part (c) is a uniform field ✓

[**or** field lines become further apart between **L** and **M** but are equally spaced between **R** and **S**]

1

[12]