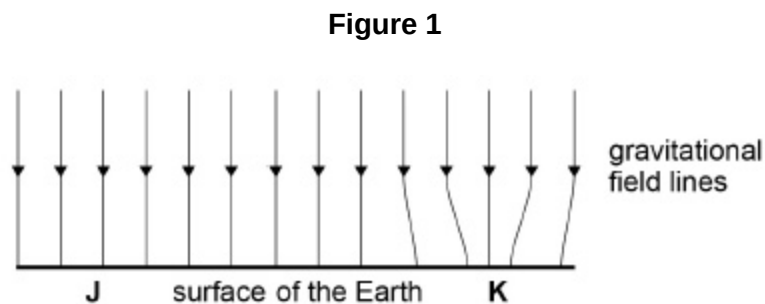


1.

- (a) State what is represented by gravitational field lines.

(1)

- (b) **Figure 1** shows the gravitational field above a small horizontal region on the surface of the Earth.



Suggest why the field lines converge over a small area at **K**.

(2)

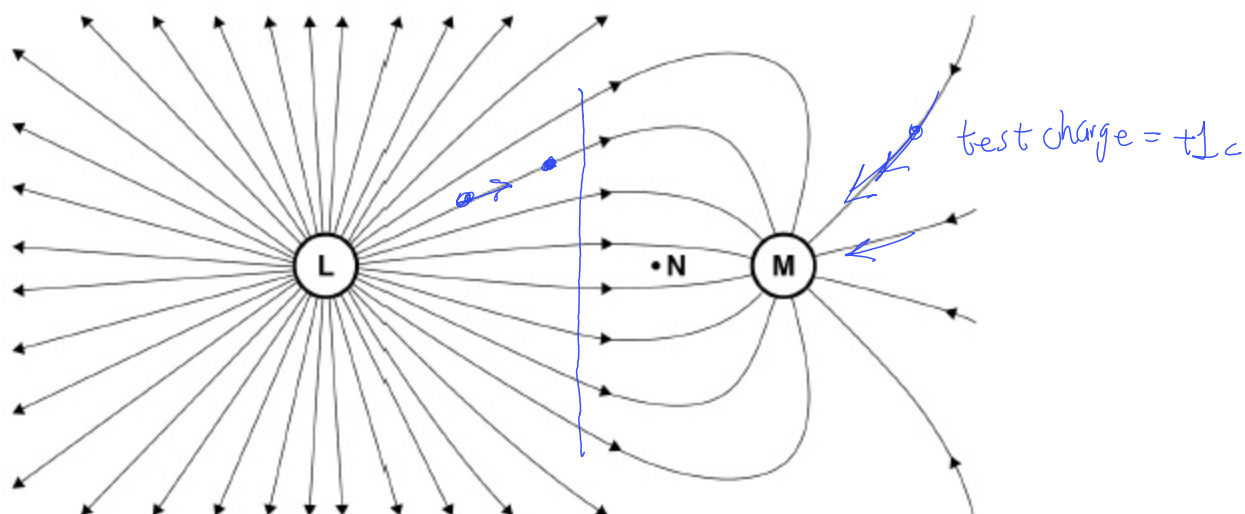
- (c) A ball travelling at constant speed passes position **J** moving towards position **K** in **Figure 1**. Assume friction is negligible.

Explain any change in the speed of the ball as it approaches **K**.

(2)

- (d) **Figure 2** shows lines of force for the electric field surrounding two charged objects **L** and **M**.

Figure 2



Explain why the lines of force shown in **Figure 2** cannot represent a gravitational field.

$L \rightarrow +ve$

gravitational field is always attractive.

$M \rightarrow -ve$

(1)

- (e) State which object **L** or **M** has a charge with the greater magnitude.

object L

State which object **L** or **M** has a positive charge.

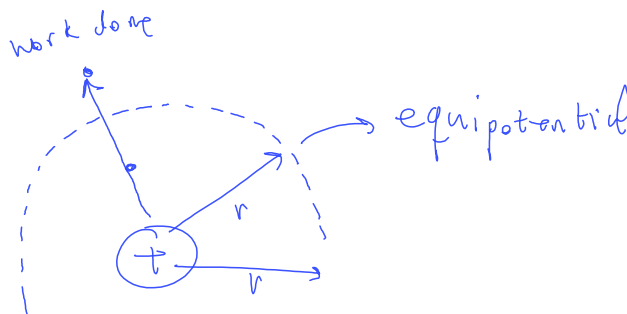
object L

(1)

- (f) Draw, on **Figure 2**, an equipotential line that passes through point **N**. Do **not** extend your line beyond the given field lines.

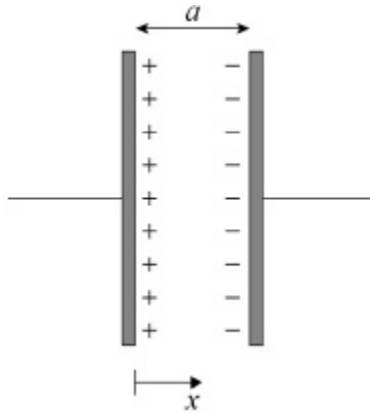
(2)

(Total 9 marks)



2.

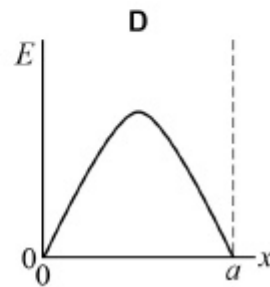
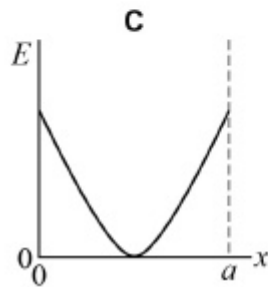
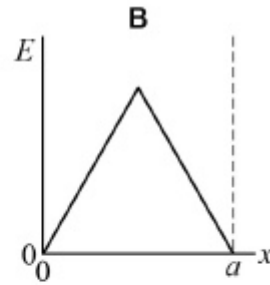
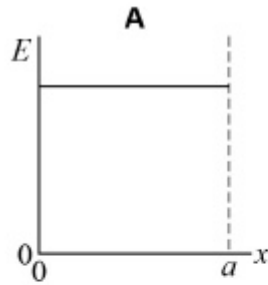
Two parallel metal plates of separation a carry equal and opposite charges.



Which graph best represents how the electric field strength E varies with the distance x in the space between the two plates?

Uniform field

$$E = \frac{V}{d}$$



A ☐

B ☐

C ☐

D ☐

(Total 1 mark)

3.

A particle of mass m and charge q is accelerated through a potential difference V over a distance d .

What is the average acceleration of the particle?

A $\frac{qV}{md}$

☐

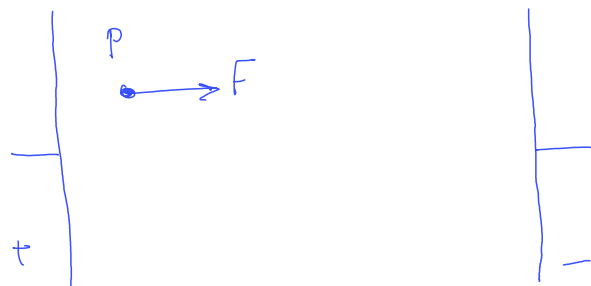
B $\frac{mV}{qd}$

☐

C $\frac{V}{mqd}$

☐

D $\frac{dV}{mq}$

☐


$$F = ma \rightarrow a = \frac{F}{m} = \frac{Vq}{dm} \rightarrow A$$

$$E = \frac{V}{d}$$

$$F = EQ = \frac{V}{d} q$$

(Total 1 mark)

4.

An electron on the surface of the Earth is placed in an electric field of strength 5000 N C^{-1} .

What is $\left(\frac{\text{electric force}}{\text{gravitational force}} \right)$ for the electron?

A 1.1×10^{-14}

☐

B 2.9×10^{-10}

☐

C 3.4×10^9

☐

D 9.0×10^{13}

☐

(Total 1 mark)

5.

An α particle makes a head-on collision with a gold nucleus containing 79 protons. The distance of closest approach of the α particle to the nucleus is $4.0 \times 10^{-14} \text{ m}$.

What electrostatic force acts on the gold nucleus when at this separation?

A $9.1 \times 10^{-11} \text{ N}$

☐

B 23 N

☐

C 290 N

☐

D $1.4 \times 10^{20} \text{ N}$

☐

$$Q_{\alpha} = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19} \text{ C}$$

$$F = \frac{1}{4\pi\epsilon_0} \frac{Q_1 Q_2}{r^2} =$$

$$F = \frac{1}{4\pi \times 8.85 \times 10^{-12}} \times \frac{2 \times 79 \times (1.6 \times 10^{-19})^2}{(4 \times 10^{-14})^2}$$

(Total 1 mark)

$$F = 22.73 \approx 23 \text{ N}$$

6.

Two fixed parallel metal plates **P** and **Q** are at constant electrical potentials of +100 V and +70 V respectively. A proton travelling from **P** to **Q** experiences a force F due to the electric field between **P** and **Q**, and a change of potential energy of ΔE_p .

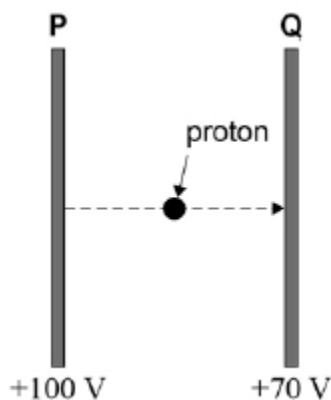
Handwritten calculations:

$$V = \frac{E}{Q}$$

$$E = VQ = 1 \times 1.6 \times 10^{-19}$$

$$E = 1.6 \times 10^{-19} \text{ J} = 1 \text{ eV}$$

Diagram showing a proton moving from plate P to plate Q. The potential difference is labeled PD = 1V. The electron symbol e is shown near the plates.



Which line, **A** to **B**, in the table gives the direction of F and the value of ΔE_p ?

	Direction of F	ΔE_p	
A	towards P	+30 eV	☐
B	towards Q	+30 eV	☐
C	towards Q	-30 eV	☒
D	towards P	-30 eV	☐

(Total 1 mark)

7.

An electron moves through a distance of 0.10 m parallel to the field lines of a uniform electric field of strength 2.0 kN C^{-1} .

What is the work done on the electron?

A zero

☐

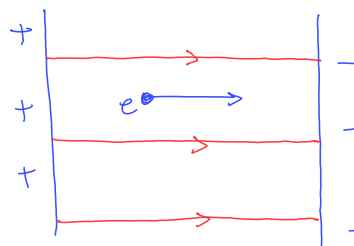
B $1.6 \times 10^{-17} \text{ J}$

☐

C $3.2 \times 10^{-17} \text{ J}$

☒

D $1.6 \times 10^{-21} \text{ J}$

☐


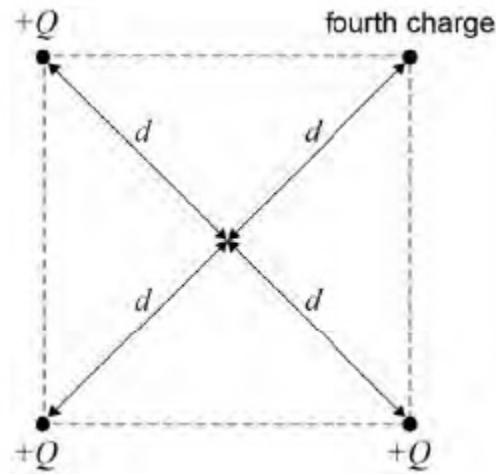
$$W = F \cdot d$$

$$F = EQ = 2 \times 10^3 \times 1.6 \times 10^{-19}$$

$$W = 2 \times 10^3 \times 1.6 \times 10^{-19} \times 0.1 = 3.2 \times 10^{-17} \text{ J} \quad \text{(Total 1 mark)}$$

8.

Four positive charges are fixed at the corners of a square as shown.



The total potential at the centre of the square, a distance d from each charge, is $\frac{5Q}{4\pi\epsilon_0 d}$

Three of the charges have a charge of $+Q$

What is the magnitude of the fourth charge?

A $-\frac{7Q}{4}$

☐

B Q

☐

C $\sqrt{2}Q$

☐

D $2Q$

☒

(Total 1 mark)

9.

A charged spherical conductor has a radius r . An electric field of strength E exists at the surface due to the charge.

What is the potential of the spherical conductor?

A $r^2 E$

☐

B $r E^2$

☐

C $\frac{E}{r}$

☐

D $r E$

☒

$$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$$

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$$

work
per
unit
charge

$$V = E r$$

force per unit charge

distance

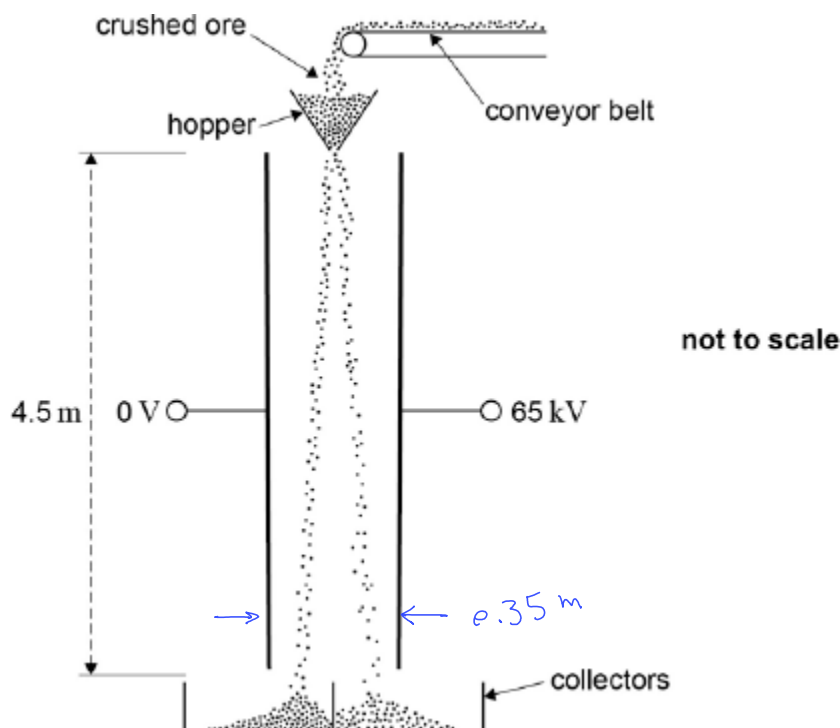
same as
 $w = Fd$

(Total 1 mark)

Formula sheet: $E = \frac{\Delta V}{\Delta r} \rightarrow \Delta V = E \Delta r \rightarrow D$

10.

The figure below shows a system that separates two minerals from the ore containing them using an electric field.



The crushed particles of the two different minerals gain opposite charges due to friction as they travel along the conveyor belt and through the hopper. When they leave the hopper they fall 4.5 metres between two parallel plates that are separated by 0.35 m.

- (a) Assume that a particle has zero velocity when it leaves the hopper and enters the region between the plates.

Calculate the time taken for this particle to fall between the plates.

$$S = 4.5 \text{ m}$$

$$u = 0$$

$$v = ?$$

$$a = 9.81 \text{ m/s}^2$$

$$t = ?$$

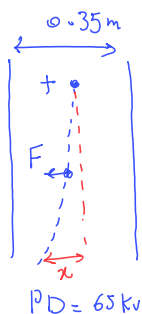
$$S = ut + \frac{1}{2}at^2 \rightarrow t = \sqrt{\frac{2s}{a}} = \sqrt{\frac{2 \times 4.5}{9.81}} = 0.96 \text{ s}$$

$$\text{time taken} = \underline{\hspace{2cm}} \text{ s}$$

(2)

- (b) A potential difference (pd) of 65 kV is applied between the plates.

Show that when a particle of specific charge $1.2 \times 10^{-6} \text{ C kg}^{-1}$ is between the plates its horizontal acceleration is about 0.2 m s^{-2} .



$$\text{specific charge} = \frac{\text{charge}}{\text{mass}} = 1.2 \times 10^{-6} \text{ C/kg} \rightarrow Q = (1.2 \times 10^{-6} \times m)$$

$$F = EQ \rightarrow F = 185714.3 \times (1.2 \times 10^{-6} \times m) = 0.222m \text{ N}$$

$$E = \frac{V}{d} = \frac{65 \times 10^3}{0.35} = 185714.3 \text{ N/C}$$

or V/m

$$a = \frac{F}{m} = \frac{0.222m}{m}$$

$$a = 0.2 \text{ m/s}^2$$

(3)

- (c) Calculate the total horizontal deflection of the particle that occurs when falling between the plates.

$x = ?$

$$a_h = 0.22 \text{ m/s}^2$$

$$s = ut$$

$$s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 0.22 \times (0.96)^2 = 0.10 \text{ m}$$

$$u = 0$$

$$v = ?$$

$$a = 0.22 \text{ m/s}^2$$

$$t = 0.96 \text{ s}$$

horizontal deflection = _____ m

(1)

- (d) Explain why the time to fall vertically between the plates is independent of the mass of a particle.

$$W = mg$$

$$F = ma$$

$$s = ut + \frac{1}{2}at^2 \rightarrow t = \sqrt{\frac{2s}{g}} \quad \text{no mass!}$$

(2)

- (e) State and explain **two** reasons, why the horizontal acceleration of a particle is different for each particle.

Mass is not constant since particle mass will vary ✓

Charge on a particle is not constant ✓

Acceleration = Eq / m or $(V / d) (q / m)$ or Vq / dm ✓

E or V / d constant but charge and mass are 'random' variables so q / m will vary (or unlikely to be the same) ✓

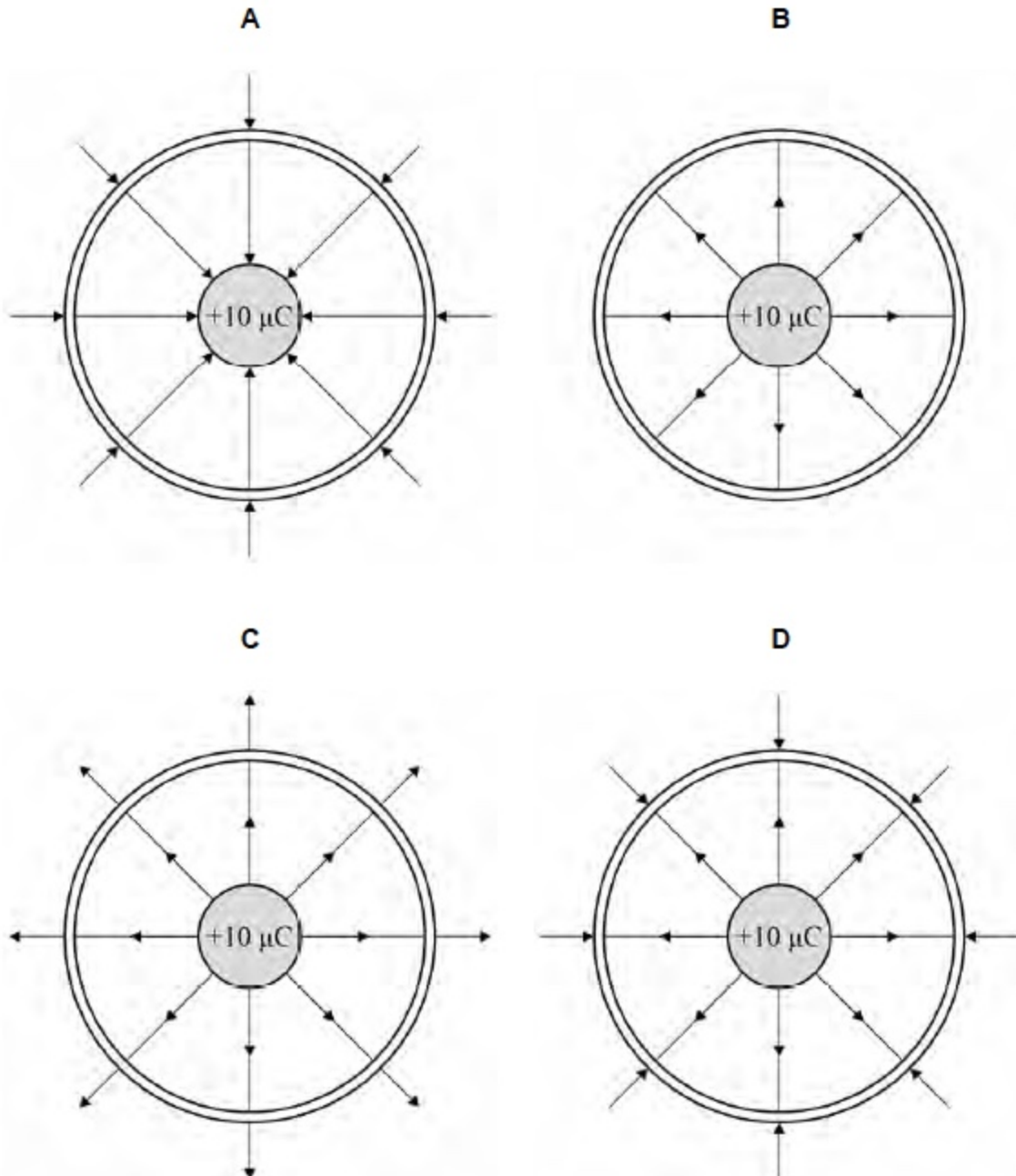
(4)

(Total 12 marks)

11.

A conducting sphere holding a charge of $+10\ \mu\text{C}$ is placed centrally inside a second uncharged conducting sphere.

Which diagram shows the electric field lines for the system?



- A ☐
- B ☐
- C ☐
- D ☐

(Total 1 mark)

12.

The ionisation potential for the atoms of a gas is V . Electrons of mass m and charge e travelling at a speed v can just cause ionisation of atoms in the gas.

What is V ?

A $\frac{eV}{2m}$

☐

B $\frac{2eV}{m}$

☐

C $\sqrt{\frac{eV}{2m}}$

☐

D $\sqrt{\frac{2eV}{m}}$

☐

(Total 1 mark)

13.

An electric field acts into the plane of the paper. An electron enters the field at 90° to the field lines.

The force on the electron is

A zero.

☐

B along the direction of the field.

☐

C at 90° to the field.

☐

D opposite to the direction of the field.

☐

(Total 1 mark)

14.

A positive charge of $2.0 \times 10^{-4} \text{ C}$ is placed in an electric field at a point where the potential is +500 V.

What is the potential energy of the system?

A $1.0 \times 10^{-1} \text{ J}$

☐

B $1.0 \times 10^{-1} \text{ J C}^{-1}$

☐

C $4.0 \times 10^{-7} \text{ J}$

☐

D $4.0 \times 10^{-7} \text{ J C}^{-1}$

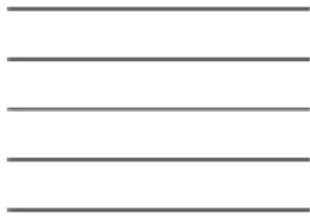
☐

(Total 1 mark)

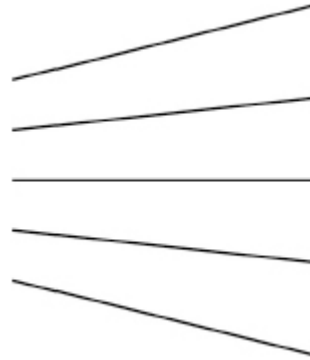
15.

Which diagram shows lines of equipotential in steps of equal potential difference near an isolated point charge?

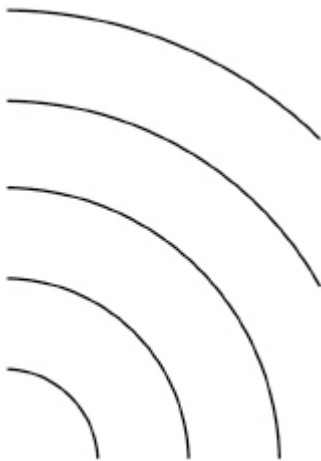
A



B



C



D



A



B



C



D



(Total 1 mark)

16.

Two fixed charges of magnitude $+Q$ and $+3Q$ repel each other with a force F . An additional charge of $-2Q$ is given to each charge.

What are the magnitude and the direction of the force between the charges?

	Magnitude of force	Direction of force	
A	$\frac{F}{3}$	repulsive	☐
B	$5F$	attractive	☐
C	$5F$	repulsive	☐
D	$\frac{F}{3}$	attractive	☐

(Total 1 mark)

17.

At a distance L from a fixed point charge, the electric field strength is E and the electric potential is V .

What are the electric field strength and the electric potential at a distance $3L$ from the charge?

	Electric field strength	Electric potential	
A	$\frac{E}{3}$	$\frac{V}{9}$	☐
B	$\frac{E}{3}$	$\frac{V}{3}$	☐
C	$\frac{E}{9}$	$\frac{V}{3}$	☐
D	$\frac{E}{9}$	$\frac{V}{9}$	☐

(Total 1 mark)

18.

- (a) Explain, in terms of binding energy, why energy can be released when two nuclei undergo nuclear fusion.

Total Mass of nuclei is more than the mass of the fusion product ✓ 1

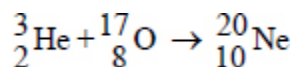
✓ 1 Alternatively the B/A of the fusion product is greater than B/A of both the starting nuclei.

Binding energy or Binding energy per nucleon increases when a nucleus is formed by fusion ✓ 2

✓ 2 In order to release energy, the total binding energy of the two nuclei must be less than the binding energy of the nuclide formed

(2)

- (b) During the collapse of a supermassive star, helium-3 and oxygen-17 fuse to release energy. The equation for this reaction is



The table below gives data for these nuclei.

Nucleus	Mass / u
${}^3_2\text{He}$	3.01603
${}^{17}_8\text{O}$	16.99913
${}^{20}_{10}\text{Ne}$	19.99244

Calculate, in J, the energy released when this reaction occurs.

mass defect Δm : mass of parent - mass of product:

$$\Delta m = (3.01603 + 16.99913) - 19.99244 = 0.02272 \text{ u}$$

$$1 \text{ u} = 1.661 \times 10^{-27} \text{ (formula sheet)} \rightarrow \Delta m = 0.02272 \times 1.661 \times 10^{-27} = 3.7738 \times 10^{-29} \text{ kg}$$

energy released = _____ J

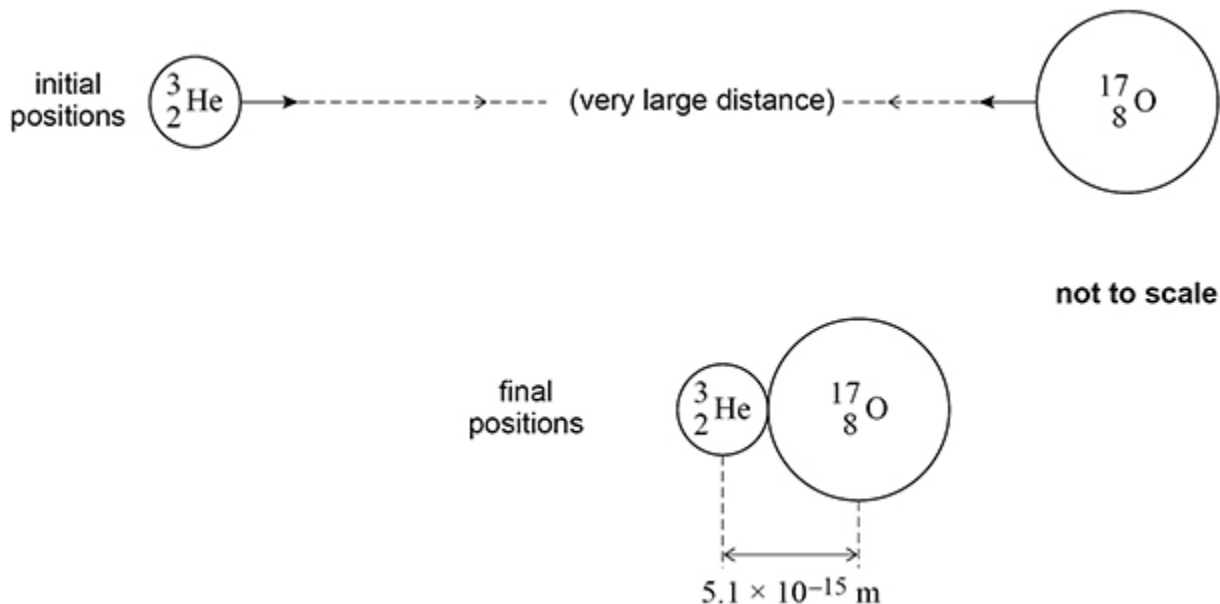
$$E = mc^2 = 3.7738 \times 10^{-29} \times (3 \times 10^8)^2 = 3.3964 \times 10^{-12} \text{ J} \approx 3.39 \times 10^{-12} \text{ J}$$

(2)

- (c) One model of nuclear fusion suggests that fusion happens when nuclei touch.

Initially the helium nucleus and oxygen nucleus are separated so that the force between them is negligible. They move towards each other until they fuse. Fusion occurs when their centres are separated by a distance of $5.1 \times 10^{-15} \text{ m}$.

The figure below shows the initial positions and final positions of the nuclei.



Calculate the total change in electrostatic potential energy between the initial positions and final positions of the nuclei.

$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r} \quad EPE = \frac{1}{4\pi\epsilon_0} \frac{Q}{r} \times q$$

$$\Delta V = V_2 - V_1 = \frac{Qq}{4\pi\epsilon_0} \left(\frac{1}{r_2} - \frac{1}{r_1} \right) = \frac{8 \times 2 \times (1.6 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12}} \left(\frac{1}{5.1 \times 10^{-15}} - \frac{1}{\infty} \right) = 7.22165 \times 10^{-13} \text{ J}$$

$Q = 8 \times 1.6 \times 10^{-19} \text{ C}$ $q = 2 \times 1.6 \times 10^{-19} \text{ C}$
 $r_1 = \infty$

$\approx 7.22 \times 10^{-13} \text{ J}$

change in electrostatic potential energy = _____ J

(2)

- (d) ${}^3_2\text{He}$ can undergo fusion reactions with either ${}^{34}_{16}\text{S}$ or ${}^{17}_8\text{O}$ at the same temperature in a star.

The nucleus has properties that depend on its proton number and its nucleon number. These properties affect the fusion reaction.

Discuss, for this star, how these properties affect the rate of fusion of ${}^{34}_{16}\text{S}$ with ${}^3_2\text{He}$ compared to the rate of fusion of ${}^{17}_8\text{O}$ with ${}^3_2\text{He}$.

Making reference to the doubling charge which increases the gain in potential energy or force needed (to bring nuclei together) ✓ 1

(So) the larger charge (of ${}^{34}_{16}\text{S}$) requires greater kinetic energy or pressure for fusion and decreases the rate of fusion ✓ 2 (ovtte)

Making reference to the larger radius/size of the sulphur nucleus compared to the oxygen nucleus

(So) the larger radius (of ${}^{34}_{16}\text{S}$) (requires smaller kinetic energy or pressure for fusion) and the separation can be larger for fusion to take place so increases the rate of fusion ✓ 3

(3)
(Total 9 marks)